INDEX

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part - 1.

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Dont be like 'ELECTRON' and Scatter mind in all directions, instead be like 'NEUTRON' and focus in one direction, irrespective of things and create maximum impact, thats what neutron do by liberation of alpha particle or recoil proton when it slows down

- Rupesh Krishna. S

Tests for Type - A

?? - 10 - 20

- water spray test
- Stacking test
- Free drop Test.
- penetration test.

What are the passing criteria for Type A transport package?

passing criteria :.

- The specimen after undergoing the test for type A package are to prevent.

i) Loss or dispersal of radioactive contents.

2) Loss of Shielding integrity which would increase in result of 20% radiation level @ surface of package. (should not be more than 20%.)

Type - A package provided with

* Sufficient amount of absorbing material to absorb twice the volume of liquid contents.

* and containment system consist of primary inner & secondary outer containment components, to ensure the retention of liquid contents, within the secondary outer containment, even if primary inner containment leaks.

Type A1 package is for special form of radio active material (Indispensible)

Type A2 package is for non special form of radio active material (dispensible)

Radionuclide	A1 (Ci)	A2 (Ci)
CO - 60	10	10
CS - 137	50	10
I - 131	80	10

2) Is TLD shows same response for equal dose at different dose rates?

* Absorbed dose to the TLD will be same irrespective of different dose rates.

* Dose rate independency is the inherent property of TLD

(Advantages:. Reusability, angular independence, Dose rate independence)

(Disadvantages:. Light sensitivity, Fading, no immediate read out.)

3) 5 R'S of Radiobiology:.

Repair, Repopulation; Redistribution, Reoxygenation, Radiosensitivity. - (Refer in detail)

4). * Describe acute whole body syndrome giving threshold volume associated syndrome?

2) prenatal defect of radiation?

1). required condition for acute radiation syndrome are:

* radiation dose must be large (> 0.7 Gy)

* The dose usually must be external.

* The radiation must be penetrating the entrie body.

* The dose must have been delivered in a short time.

The three classic. ARS syndrome are:

1) Hematopoietic or bone marrow syndrome.	Dose > 0.7 Gy.	Symptoms - anorexia fever, drop in all blood cell cour
2) Gastrointestinal Syndrome.	> 10 Gy.	dehydration, electrolyte imbalance death occur in 2 week of exposure.
3) cardiovascular syndrom	> 50 Gy.	nausea, vomitting, coma. Death occur in 3 days of expo

5) CTDI 100 (mGy) is a linear measure of dose distribution over a pencil ionization chamber.

6). RSO exam (2019)

Q) Calculate the cumulative exposure a radiation worker recieves from 15mCi (555MBq) 18F-FDG source while standing for 2hrs at a distance of 2m. Further, if the HVL of lead for 511-keV photon of F18 is 0.55cm, calculate the thickness of lead shield require to reduce the exposure by 90%. From a activit 75mCi F18-FDG dosage in a vial. (Specific gamm constant for F18 is 6.96 R/hr. cm²/mCi at 1cm.

Answer:.

hint → 15mci → FDG → 2 hr at 2m.

FDG (γ) = 6.96R/hr cm²/mci at 1cm.

$I_1 d_1^2 = I_2 d_2^2$.

$6.96 R/hr \times (1cm)^2 = I_2 \times (200cm)^2$

$$I_2 = \frac{6.96 R/hr \times (1cm)^2}{(200cm)^2}$$

$I_2 = 0.174 mR/hr$ at 2m/mci.

$I_2 \times (2hr) = 0.174 mR/hr \times 2hr$

$= 0.348 mR/mci$.

$I_2 \times 15mci = 0.348 mR/mci \times 15mci$

$$\boxed{I_2 = 5.22 mR}$$

ii). HVL for FDG = 0.55cm.

1 TVL = 3.3 × HVL

= 3.3 × 0.55cm.

= 1.82 cm.

* 1.82 cm Lead required to reduce the exposure by 90%.

7) Q). F18 - FDG dosage are shipped from a vendor 3 hr away from the customer. what should be sent in order to have a 10mci dosage for the customer?

Formula $\Rightarrow A = A_0 . e^{-\lambda t}$.

given :- $A = 10mci$ $A_0 = ?$

$F = 18, t_{1/2} = 110 mins$.

$T = 3 hr = 3 \times 60 \Rightarrow 180 mins$.

$\rightarrow 10mci = A_0 e^{-[\frac{0.693}{110 min}] \times 180 min}$

$10mci = A_0 . e^{-(1.134)}$

$10mci = A_0 . (0.32174)$

$A_0 = \frac{10}{0.3217} mci \Rightarrow \boxed{A_0 = 31 mci}$

8) Q). A primary barrier shields the public area $(T = 1/16)$ to IDR of $0.80 mSv . h^{-1}$. The linac operates at maximum dose output rate of $5.5 Gy min^{-1}$ $U = 0.25$ and $W = 600 Gy/week$. Is the shielding adequate.

Ans :- $R_W = IDR \times \frac{W \times U \times T}{(\text{output rate in time})}$

$= \frac{0.8 \times 600 \times 0.25}{60 \times 5.5} = 0.36 mSv/week$

$R_W \times 1/16 = \underline{0.023 mS/week}$ which is larger

9) Bragg peak effect is not pronounced for electrons. why?

Interactions of electron when passing through matter are quite similar to those of heavy particles.

- However, because of their relatively small mass, the electron suffer greater multiple scattering and changes in direction of motion. As a consequence, Bragg's peak is not observed for electrons. Multiple change in direction during the slowing down process smear out the bragg peak.

10) what is patient specific QA for IMRT and what is the procedure?

Refer.

11). Q) During a radiation survey, exposure levels observed near control console & patient waiting area are 60mR/hr, 30mR/hr. when the x-ray machine is operates with 125kV, 200mAS, 2sec. comment on the status of radiation worker and general public. workload 500mA-min/week.

given. W = 500 mA min/week.

125 kV, 200mAS, 2sec.

Exposure level @ console = 60 mR/hr.

@ PWA = 30 mR/hr

1) Radiation level @ console = $\frac{60 mR/hr \times 500 mA\ min/wk}{60\ mins/hr \times 200\ (sec)\ mA}$

$\Rightarrow$ 5 mR / week. < 40 mR/w

The radiation level is permissible.

2) Radiation level @ PWA = $\frac{30 mR/hr \times 500 mA\ min/wk}{60\ mins/hr \times 200\ mA}$

= 2.5 mR/week > 2 mR/w

The radiation level is not permissible.

(2) Radiation dose observed during survey hdr 19: iridium is 4 mr/hr at console activity of source is 8 ci. is it permissible or not?

IDR = 4 mR/hr

A_t = 8 ci of Ir-192.

A = 10 ci of Ir-192.

Radiation Level ⇒

R_L = IDR × Beam on time × A/A_t.

= 4 mR/hr × 4 hr/week × $\frac{10 ci}{8 ci}$

= 20 mR/week. → below 40 mR/week

∴ Radiation Level is permissible

13) what is the most common class of digital mammography detectors, and what is their defining difference from those used for general radiography?

* DM detectors is amorphous selenium in both mamography and general x-ray. difference in physical size of detector.

For mammo - 0.05 mm to 0.1 mm.

x-ray - 0.2 mm.

14. Required information for shielding thickness calculation.

$$\text{Reduction factor} = \frac{WUT}{P d^2}.$$

W → workload of machine (cGy/wk).

U → use factor T → occupancy factor.

P → permissible limit d → distance of wall from source.

Barrier thickness $T = \log_{10}(RF) \times TVT$.

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public Annual exposure (1 mSv/yr) acc to AERB.

gives 1000 µSv/year = 365 days. hence

3 µSv / day. [working time of 12 hr gives exposure level of 0.25 µSv/hr]

16. Explain ON & OFF condition of leakage LINAC

D. Mention the components contributing to the radiation dose at the entrance of 15MV Linac. write the formula for estimation of such componen

(Repeated Ques).

17. what is the half life of neutron and how its decays?

Half life of proton → 1.67×10^{34} year.

half life - 15 mins.

*. Decay of free neutron is energy feasible because the mass of neutron is greater than ~~to~~ sum of masses of proton and electron it decays into. But where a neutrino paired with a proton its decay is not energy feasible and thus such neutrons within ~~the~~ nuclei are stable.

18. What will be thickness of wall of brachytherapy woard with one patient treated with 10Ci Ir-192 HDR unit. (Distance of wall 2m, TUT is 15cm. concrete. beam on time = 3 hr. RHM = 0.45 Full occupancy.

Solution.

Ir-192 TVT = 15cm.

Activity = 10ci d = 2m.

RHM = 0.45

• workload = RHM × activity of source × duration of on time / week

$= 0.45\ Rm^2/ci\text{-}hr. \times 10ci \times 3hr/week.$

$= 13.5\ R/wk.$

$W = 13500\ mR/wk.$

Reduction Faction (RF) = $\frac{WUT}{Pd^2}$.

$= \frac{13500\ mR/wk \times 1 \times 1}{2mR/wk \times (2)^2}$ 0.002mR/wk.

$RF = 1687.5.$

Barrier thickness $= \log_{10}(RF) \times TVT.$

$= \log_{10}(1687.5) \times 15.cm.$

$= 48.4\ cm.$ ✓. ~~wrong.~~

$\simeq 0.5$ metre.

19. Why 0.6cc cylindrical ionisation chamber is not used for measuring beam profile teletherapy machin using radiation field analyser?

Ans:. * we are using 0.125cc chamber instead 0.6cc bcoz. small volume chamber has high spatial resolution than 0.6cc) high spatial resolution means high accuracy in measuring dose points.

20. What is small field dosimetry and what is msr field. (machine specific refrence field)?

* Small fields are usually in SRT/SRS technique usually from 4mm diameter to minimum of sub mm fields.

* Dosimetry for such field are performed using chambers of volume 0.015cc or less.

* refrence field size 10x10cm, where Linac tuned to deliver 1cGy/MU @ Dmax.

21. A1 value of Co-60 is 0.4TBq. which type of package will be used for transport of telecobalt sources activity 50TBq?

* Type - B package.

22. Shielding calculation - Nuclear medicine.

$$\boxed{\text{workload} = \Gamma_\delta \times A \times N \times t} \quad \mu Gy\, m^2/\text{week}$$

Γ_δ = Airkerma rate constant.

A → maximum activity in GBq.

N → no. of patients per week.

t → performance time in hrs.

(range between 30 min to 3hrs)

Transmission Factor (B):

$$B = D/D_o = \frac{d^2}{WUT \times F \times R \times 52} \times (P)$$

D → annual dose with out shielding.

Do → Annual dose with shielding.

If dose contribution from adjacent rooms.

~~Do Ct~~

1) Annual dose from radioactive material room.

$$D_o(t_U) = \frac{W \times T \times U \times R}{d^2} \times 52\ \mu Sv/year.$$

2) Dose from imaging ward.

$$D_o(t_I) = \frac{W \times T \times U \times R \times F}{d^2} \times 52\ \mu Sv/year.$$

P → yearly dose limit. d → distance.

W → work load./week. U → use factor

T → occupancy factor. F → Biological decay.

R → physical decay of radio-isotope.

problem.

Q) Activity = 300mci (11.7 GBq). distance = ~~200~~ 4m: HVL = 3mm lead.

Exposure rate constant of I-131 } = 2.17 R cm²/mci/hr at 1cm.

Air kerma rate constant } = 55 μGy m²/hr/GBq.

No. of patients per week → 3.

24. Why is Sulfur hexafluoride SF_6 used in linear accelerator (linac).

* Because of absorption of free electrons and low mobility of ions SF_6 has very excellent dielectric property. dielectric strength of SF_6 gas is about 2.5 times more than that of air. provide excellent insulating and cooling properties.

ideal quench for electrical circuit breakers and switchgear. Being such a poor conductor of electric current. it is well suited to high voltage power application. This include linac.

25. How do you describe the tomotherapy Linac System?

Tomotherapy combines a form of intensity modulated radiation therapy (IMRT) with the accuracy of computed tomography (CT) Scanning technology.

26. What is double focused MLC?

27. If your chamber is not calibrated, what will you do?

Cross calibrate with neighbouring hospital chamber and use till calibration with SSDL is done.

28. What is mayneord factor where it is used?

Mayneord factor a special application of inverse square law.

Where it is used: SSD set on a patient may be different from standard SSD. thus, PDD's for the standard SSD must be converted to those applicable to the actual treatment SSD.

29. why do we need negative pressure in high dose therapy Iodine hot lab?

* To prevent inhalation of high dose therapy radioactive materials. it is maintained in hotlab to avoid inhalation of radioisotopes.

30. Difference between x-ray & γ rays

γ-ray.	x-ray.
* produced from nucleus.	* when fast moving e^-, hits orbital, x-ray produced.
* emitted from radio active material.	* artificial production.
have discrete energy	* have spectrum of energy

31. what is cerenkov effect:.

cerenkov effect occurs when charged particle travels in medium at speed greater than speed of light in that medium. (no massive particle can travel faster than light in vaccum). under this condition, the charged particle creates an electromagnetic "shock wave". The electromagnetic "shock wave" appears as a burst of visible radiation, referred as cerenkov radiation.

32. A HDR treatment plan using Ir-192 Source, takes 281 secs to deliver. How long it will take if the same plan is delivered 7 days later?

Solution:- After 7 days, the activity of source reduced to $\frac{1}{2}^{(7/74)}$ or 6.3%.

$$\Rightarrow 281 \times 2^{7/74} = 281 \times 1.0677 = 300 \text{ secs.}$$

33. A source decays 3% in one day. what is the decrease in activity after 30 days?

= 3% × 30 day = 90% or 0.9

$DF = e^{-0.9} = 0.4065$.

40.65% (after 30 days).

Decayed activity = 59.35%.

Iridium 192 decay per day = 0.94%.

Co-60 decay per month = 1.1%

34. The tele recommended dose rate for treatment, below which clinically not relevant?

* for CO-60 telecobalt unit should not be used for clinical purpose if the output at the normal treatment distance is below 50 cGy/min

* Ir-192 not less than 12 Gy/hr delivery dose rate. otherwise it will fall under MDR cathegory.

7.2.20. paper - I

I) what are the duties and responsibilities of RSO?

1). to take, all necessary steps aimed at ensuring dose limit is not normally exceeded.

2) to instruct all radiation worker under his charge about hazards of radiation and suitable safety measures and good work practise aimed at minimizing exposure to radiation

3) to carry out leakage test for all sealed sources as per procedure.

4). to investigate and initiate prompt and suitable remedial measure in respect of any situation that could lead to potential radiation hazards

4) Quality assurance test of units, components and source and monitoring instruments are conducted periodically.

3). what is the dose limit for radiation worker.

whole body.	20mSV/year averaged over 5 consecutive years. 30mSV in a single year.
Lens of eye.	150mSV. (ICRP 60 revised as 20mSV)
skin.	500mSV in a year.
Extremities.	500mSV in a year.

4). what is radiation protection?

Radiation protection is defined by IAEA as The protection of people from harmful effects of exposure to ionizing radiation and the means for achieving this.

5). what is the principle of radiation protection?

1) Justification
2) optimization.
3) Dose limits.

7). what is the dose limit for pregnant women?

Dose to pregnant women, should be in abdomen less than 2mSV (ICRP 60), and then dose to foetus and embryo should not normally exceed 1mSV. (ICRP 103)

8). why 2mSV is set for pregnent worker and to which part of body?

embryo and foetus.

9) what is the aim of diagnostic radiology?.

Is to achieve a High quality image either on a film or imaging device possibly low radiation dose to the patient and personnel.

10) what are the QA in diagnostic x-ray machine?

1) Beam allignment and collimator accuracy.

2). Constancy of Radiation output and Linearity of mR/mAS verces KV^2.

3) Assessment of Total Beam filteration (HVL).

4). Assessment of focal spot size.

5) Accuracy of and constancy of Exposure Times.

6). Measuring of Scattered Radiation (with water phantom)

7). Leakage Radiation from x-ray tube.

11). what is field congruence test?.

* optical field used to setup the patient and the radiation field should match.

* Error in radiation and light field congruence could leads to geographical miss of the tumor.

12. what is focal spot and its significance?:

Focal spot is the small area of the target where the electron beam impinges on the target (anode) and from which x-ray are emitted.

The smaller the focal spot, better limiting the spatial resolution of x-ray system and less penumbra

16. what are the radiation protection quantities and operational quantities.

Radiation protection quantities } - [organ dose, equivalent dose, effective dose, committed dose, cumulative dose]

operational quantities :-

i) Ambient dose equivalent :- (Sv) approximate value for protection quantity used in environmental monitoring

ii). personal dose equivalent :- (Sv) Approximate value for protection quantity used in personal monitoring.

18, 19. what do you infer from the package that carries a category II yellow.

* Radiation level maximum at the external surface of package is > 0.5 to 50 mR/hr

transport index = 1.

21. what are the personnel monitoring devices?

1). Film badge. 2) TLD.

3) OSL 4) pocket dosimeter.

5) Radiophotoluminescent (RPL) dosimeter.

24. what are advantages and disadvantages of TLD?

advantages :. * Atomic number (15.1) is approximately tissue equivalent.

* energy independence.

* unaffected by visible light, moisture

* It is reusable. (about 100 times).

* More sensitive and more accurate.

* No Fading

Disadvantages :

* Does not give instantaneous result.

* Instrumentation for reading TLD badge is expensive.

* Does not provide permanent record like film badge,

22. what is composition of TLD used in india?

* $CaSO_4$: Dy :-> Dysprosium doped calcium sulphate

* LiF : Mg,Ti

* Dysprosium also has high sensitivity, Low fading

$\chi = M/H$

M → Total magnetic moment per unit

H → magnetic field intensity (applied magnetic field)

Atomic number => 66.

25. why do we use dysprosium in TLD?

Dysprosium has High magnetic susceptibility (χ) in data storage applications. It is used for high absorption cross section. And is cheap compared to other TLD compositions.

23. characteristics of TLD dosimeter?.

linearity, accuracy precision, dose or dose rate dependence, energy response, directional dependence and spatial resolution.

d). Design goal during Barrier thickness calculation?.

Area.	Annual Dose limit (mSv/yr)	ALARA factor	Design goal (mSv/wk)	Maximum hour dose rate (mSv/hr)
controlled	5	10	0.1 (10mR/wk)	—
uncontrolled	1	1	0.02 (2mR/wk)	<0.02

1. If a I-131 therapy patient is administered a therapy dose and the patient died after administration what will you do as an RSO?

* Ascertain the level of activity in the dead body is below the limits stipulated for cremation, burial, postmortem or embalming.

* Storage of the dead body in the morgue until the level come down to prescribed limits

* If Situation demands immediate release of the body, autopsy may be performed to remove vital organs containing radioactivity.

* The removed organs with radioactivity should be disposed off as per guidelines.

* Entire operation to be carried out under the supervision of RSO.

2. Define exposure with its unit ?

A quantity used to indicate amount of ionization in air produced by x-ray or γ radiation,

1 Gy = 100 Rad

$$X = \frac{dQ}{dm}.$$

unit : C/Kg (Roentgen)

∴ 1 Roentgen = 2.58×10^{-4} C/Kg

3. Define absorbed dose and its unit.

This quantity is defined for all ionizing radiation. It is the amount of energy absorbed per unit mass.

$$D = \frac{dE}{dm}.$$ unit = gray [Gy].

4. Bremsstrahlung radiation ? explain:

'Bremsstralhung or braking radiation' is any radiation produced due to deceleration of charged particle when deflected by another charged particle, typically an electron by an atomic nucleus.

7. Rationale For setting the dose limit for radiation worker and public?

* The worker dose limit was derived from the Japnese atom bomb survivor studies. It is observed that no observable effects were found below 0.5SI From this, it was surmised than 10 times lower was surely safe. So limit for worker is (0.05SV or 50mSV) in early days.

* The linear no threshold model was introduced for conservative and easily calculated risk model. The (LNT) assumption leads to no safe dose of radiation. No safe doze leads to as low as reasonably achievable as a radiation protection policy.

The limit of 1mSv/year is no longer defensible if one can claim that a lower dose is reasonable.

* Dose limit for deterministic effect of 1SV (1000mSV) and estimated working period of 50yrs

$1000/50_{yrs} = 20mSV/year.$

10. Define radiation weighting Factor? How are they setting those values?

* A radiation weighting factor is an estimate of the effectiveness per unit dose of the given radiation relative to low LET Standard. Gy(J/Kg) can be used for any type of radiation.

* LET- is the amount of energy imparted per unit path / track.

Depending on these values are set.

Photons, Electrons, β	- 1
Neutrons, thermal	- 5.
Neutrons (Fast), Alpha particle	- 20

11) What are personal monitoring devices?

personal monitoring device is a radiation sensor designed to measure, over a specified period of time, the radiation dose received by person who is occupationally exposed to radiation.

12). Define equivalent dose?

(HT) is the organ dose multiplied by radiation weighting factor. WR.

$$H_T = W_R \cdot D_{T,R}$$ (J/Kg or SV)

Define effective dose ?

Effective dose is the summation of tissue equivalent dose, each multiplied by the appropriate tissue weighting factor (W_T).

$$E = \Sigma W_T \cdot H_T \cdot (Sv)$$

weighting factor

Liver, thyroid, stomach, Esophagus, bladder. } = 0.05

Gonald = 0.2.

Skin, bone surface - 0.01.

colon, Lung = 0.12.

2) Define committed dose?

useful concept in nuclear medicine.

* Is defined as specific time integral of the dose received by the body after exposure to a specific radionuclide.

3). collective dose ? explain.

It is defined as summation of the product of the mean dose in the various groups of exposed people and the number of individual in each group.

collective dose relates to exposed group or populations.

unit : (man - Sv)

Q what are the different methods of biological dosimetry?

Accidental Dosimetry

- Physical dosimetry → Dose reconstruction, personal dosimeters
- Biological dosimetry → cytogenetic dosimetry, FISH, dicentric, micro nucleus analysis, PCC.
- clinical dosimetry. → nausea, vomittin[g], blood cell count, Skin reaction.

i) Clinical dosimetry:

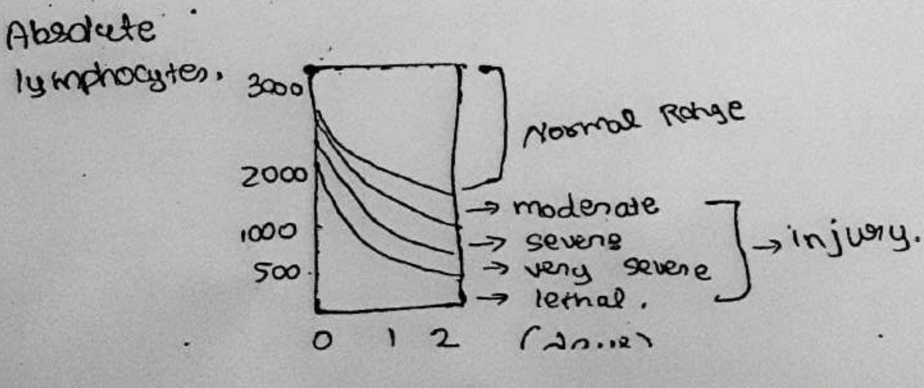
crude estimate of absorbed dose obtainable from clinical presentation.

onset:- 2h after exposure vomitting or later. } → Mild ARS (1-2Gy).

vomitting :- 1-2h after exposure → Moderate ARS } (2-4Gy).

onset :- earlier than 1 hour after exposure. } → Severe ARS (4-6Gy).

onset:- earlier than 30 mins after exposure } - very severe ARS } (6-8Gy)



* In radiation accidents, important to estimate the absorbed dose in victum to plan appropriat medical treatment.

* In most cases, physical dosimetry is not possible. even possible, it is important to confirm the estimates by other methods.

* Most commonly used method cytogenetic analysis of chromosomal aberration in peri-phenal blood lymplocytes by dicentrics, FISH, PCC, MNA assays

characterization of biological dosimetry method

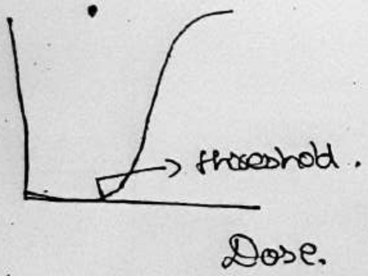
Method	cell studied	optimal test period after exposure	Exposure pattern	applicable range
Dicentric	lymphocytes	Days - weeks	Acute - whole/ partial body	0.1 - 5Gy
translocation	lymphocytes	Retrospective	Acute /chronic whole body	0.3 - 5Gy.
PCC	lymphocytes	Hours - days	Acute - whole/ partial body	0.1 - 20Gy
Micronuclei	lymphocytes	Days - weeks	Acute - whole body.	0.3 - 5Gy.
GPA.	erythrocyte	Retrospective	Acute /chronic whole body.	0.3 - 5Gy
Blood cell count	lymphocyte platelets Neutrophils	Days - week	Acute whole body.	0.5 - 10Gy

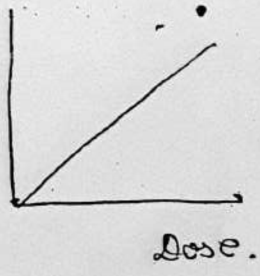
part -A. (March -2010)

1. Stochastic and deterministic effect of radiation? with eg?

Deterministic effect :- these effect depend on time of exposure, dose and type of radiation. It has threshold of dose below which the effect does not occur. (cataract, hair loss)

Stochastic effect :- there is no threshold dose. The probability of effect increases with increase in dose. even small amount of dose can cause effect. (eg. cancer, leukemia, heridity effect).





2. BED and its clinical significant?

BED - biological effective dose

* commonly used for isoeffective dose calculations.

BED is a measure of true biological dose delivered by a particular combination of dose fraction and total dose a particular tissue characterized by a specific α/β ratio.

3. Source dimension of Co-60 and also activity and dose rate normally used at time of source loading.

[Co-60 source → diameter - 1.5 cm, height - 2cm and activity - 12000ci dose rate - 200 cGy]

4. What is the cancer and genetic effect risk co-efficient for radiation worker and general public?

1. cancer risk:- For acute exposure:- 10% per SV (for general public), 8% per SV (fo radiation worker).
For chronic exposure:- 5% per SV (For general population) 4% per SV (For radiation worker).

2. Genetic risk:- 1% per SV (For general population), 0.6% per SV (For radiation workers).

5. Specify the maximum permissible table top dose and leakage levels from diagnostic x-ray machine.

* (According to AERB recommendation the exposure rate measured at the table top for the minimum focus to table distance should be as low as possible and in any case must not exceeds 5R/min.) and with AEC 10R/min.

* As per the AERB safety code on diagnostic x-ray equipment and installations, every housing

for medical diagnostic x-ray equipment shall be so constructed that leakage radiation through the protective tube housing in any directions, averaged over area not larger than $100 cm^2$ with no linear dimension greater than 20cm shall not exceeds air kerma of 1mGy. (about 114mR) in one hour at a distance of 1m from the x-ray target when the tube is operated maximum kVp and maximum current.

6). why dicentric aberration considered for biological dosimetry?

* Dicentric chromosomes are considered to be specific to radiation exposure as they are primarily generated by ionizing radiation and only a few radiomimetic drugs. Because background level of dicentric chromosomes are low in non-exposed individual, the DCA is able to assess irradiation doses as low as 0.1 Gy. Due to advantage of DCA, this assay is considered to be gold standard radiation biodosimetry.

7) If the radiation worker receives 10cGy of thyroid dose only. Does it acceptable?

10. According to ICRP recommendation an annual effective dose limit for uniform radiation of the whole body of 20 mSV, averaged over a period of 5 years. For non-uniform irradiation of the body, tissue weighting factors have been assigned to the various organ relative to the whole body as 1.

For thyroid, $W_T = 0.05$,

Implied annual dose $= \frac{20}{0.05}$ = (400 mSV) or (0.4 Gy)

But in our case, thyroid recies 0.1 Gy only. so the radiation worker did not exceed the annual dose limit.

8). What are the dose limit recommendation by ICRP-60 for radiation worker and general public? and also mention AERB recommended dose limits.

ICRP-60.

	Dose limits.	
	occupational	public.
whole body.	[20 mSV/yr, averaged over 5 yrs. with not more than 50 mSV in single year]	[1 mSV in a yr averaged over 5 yrs.]
Lens of eye skin hands & feet.	~~20~~ 150 mSV/yr. 500 mSV/yr. 500 mSV/yr.	15 mSV/yr. 50 mSV/yr. 50 mSV/yr.
(Equivalent dose in surface of	2 mSV.	

* 30mSv only as per AERB (India) directive.
* Averaged over areas of no more than any $1cm^2$ regardless of the area exposed.
* Averaged over areas of skin not exceeding about $100cm^2$.

9. What is transport index? how the packages are classified?

Transport index: It is defined as the measured radiation level at 1metre expressed in mSv/hr multiplied 100. Depends upon the transport index packages are classified as follows,

Category	Maximum radiation level at the external surface of package (mSv/hr) (mR/hr).	Transport index.
I-white.	0.005 (0.5)	0.
II-yellow.	0.5 (50) [0.5-50]	0-1
III-yellow	2 (200) [50-200]	1-10.

10. What is the basic qualification for RSO level-III?

a). A degree in science with physics as one of the subject from recognized university

b) post graduate degree / diploma in radiological physics or equivalent recognized by competent authority.

• c) approval of competent authority.

March - 2009.

1. Specify the maximum permissible table top dose and leakage level from diagnostic x-ray machine.

[Ans - March -2010]. -5.

2. What are the dose limits recommended by ICRP -60 for radiation worker and general public? And also metion AERB recommended dose limits.

[Ans - March - 2010] - 8.

3. Explain the stochastic and deterministic effect of radiation? Give any two example for each.

[Ans - March - 2010] - 1.

4. Explain Sailent features of type-B package.

* Type-B packagings must be able to survive severe accidents:

* They are used for the transportation of large quantities of radioactive material.

* A Type - B packaging may be metal drum or a huge, massive shielded transport container.

* Type-B packagings either have a certificate of compliance (CoC) by the nuclear Regulatory commission

* Type-B packages that transport radioactive materials must survive a sequence of full-scale (actual physical size) impact, puncture, fire, and immersion test designed to replicate transportation accident conditions.

5. What is the rationale set for occupational worker and public?

[March-2010 - 8].

6. List the characteristics of personal monitoring instruments.

* It should cover wide range of effective / equivalent dose. (ex. 0.1 mSv to 5 Sv)

* It should be sensitive and preferably has a linear dose response.

* It should have response independent of energy and type of radiation or ability to determine the same.

* It should be stable response (low fading) which is not affected by environmental conditions

* It should be economical & easy to use.

what are the permissible leakage level from a telecobalt source head?

Head leakage of a telecobalt unit during source OFF condition:

* Exposure rate at 5cm from the surface of source head.

[-20mR/hr when the unit is loaded with maximum RMM].

* Exposure rate at 1m from the source.

[- 2mR/hr when the unit is loaded with maximum RMM].

Head leakage of the telecobalt unit during source ON conditions:

* In patient plane in circular of radius 2m centered on isocenter.

- Max .2% and average .1% of the useful beam of $10 \times 10 cm^2$.

* other than the patient plane leakage radiation at 1m from the source.

- 0.5% of loaded RMM.

8. If the radiation worker recieves a whole body dose of 100 mSv without personal monitoring device. what method would you suggest to measure the dose?

* By the method of biological dosimetry:

(cytogenetic, FISH, discentric, micronuclie analysis, PCC).

* dicentric aberration is considered as gold standard for biological dosimetry.

9. If the radiation worker recieves 10cGy of thyroid dose only. Does it acceptable?

(March-2010 - 7)

10. Define the term LD 50/60. what is its significance in radiation protection?

LD 50/60: is the dose of radiation to the whole body that causes 50% of irradiated subjects to die within 60 days. Its significance in radiation protection helps to know the toxicity of the dose given for a particular time period.

Important viva questions.

1. why 0.1 cc to 1 cc chamber volume is limited in dosimetry?

* This size range provides sufficient 'sensitivity' and 'point dose measurement'

2. what is the range of chamber (cylindrical) volume

active volume - 0.1 and 1 cm^3.

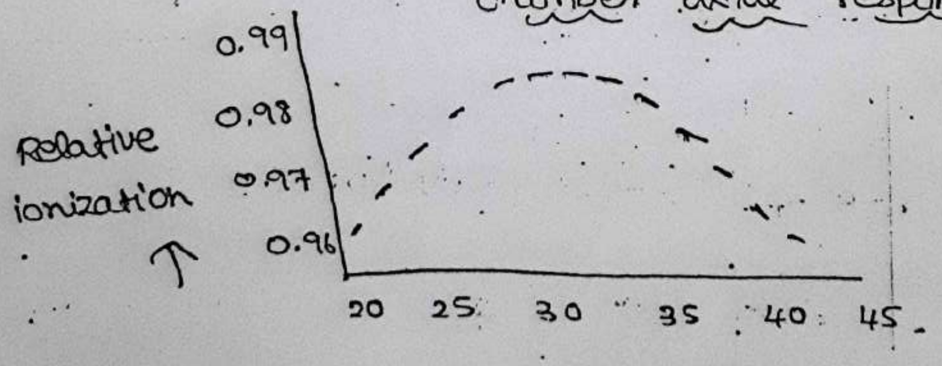
3. what type of dosimeters used in brachytherapy?

* Source used in brachytherapy are low air kerma rate sources that requires chamber of sufficient volume (about 250 cm^3) for adequate sensitivity.

* well type chambers or re-entrant chambers are ideally suited for calibration and standardization of brachytherapy sources

4. Draw well-type chamber response curve.

chamber axial response.



5. Define fluence and flux?

Flux: is the quotient of dN/dt, where dN is the increment of particle number in time interval 'dt'.

unit : s^{-1}.

Fluence :. is the quotient of dN/da, where 'dN' is the number of particles incident on the cross sectional area 'da'.

unit :. m^{-2}.

6. Is neutron radiation effective than photon.

yes. neutron radiation is more effective than photon because it have high LET and high RBE compared with photons. hence it appears to be more effective in destroying very dense tumors.

7. Define LED.

LED - 'Light emitting diode' is an electronic device that emits light when an electrical current is passed through it. (semiconductor - gallium arsenide).

8. Above which LET level we could call it as high LET radiation?

LET in the range of 50 - 200 keV/μm

9. what is the activity level for releasing delay tank system?

Maximum limit on total discharge per day 3.7 MBq. average monthly concentration of radioactivity for discharge of I-131 is 22.2 MBq/m^3.

10. What is dose limit for radiation worker and general public?

[Ans. March -2010] - 5.

11. What do you mean by stochastic and deterministic effect with example

[Ans - March - 2010] - 1.

12. If the radiation level at 1m from a source is 100 mR/hr, then what will be radiation level at 50 cm?

$I \propto 1/r^2$ $\qquad \frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$.

~~100cm/50~~ ~~100cm/I2~~ =

$$\frac{100mR}{I_2} = \frac{(50cm)^2}{(100cm)^2}$$

$$\frac{100mR}{0.25} = \boxed{I_2 = 400mR}$$

13). Define TVT and how it is related HVT?

HVT - defined as thickness of the attenuating material required to reduce beam intensity to half of its initial value. $HVT = 0.693/\mu$ → ①

TVT is defined as thickness of the attenuating material required to reduce beam intensity to 1/10 of its initial value. $TVT = \frac{2.302}{\mu}$ → ②

compare ① & ②,

$$\frac{2.303}{TVT} = \frac{0.693}{HVT}$$

$$\boxed{TVT = 3.32\ HVT}$$

14): Give some shielding materials for fast and slow neutrons?

(Fast neutrons - hydrogenous material (Ex. paraffin, water, boron)

(Slow neutrons - boron or cadmium, concrete)

15) what are the isotope used in PET?

carbon-11, Nitrogen-13, oxygen-15, Fluorine-18.

16). what is the unit of work load for therapy and diagnostic x-ray machine?

workload for therapy - (Gy/week)

For x-ray machine - (mA - min)/week.

17). Derive the relation between the ALI and DAC?

$$\therefore DAC = \frac{ALI}{2.4 \times 10^3}\ Bq.$$

where 2.4×10^3 is the volume of intake of air (m^3) of a standard man during working hours throughout the year.

8. If a person got more than 100mSv. what test you will prefer in the absence of personal monitoring devices?

- Biological dosimetry - dicentric aberration, FISH, micronucleus. etc.

19. what is the half-life of I-131?

8 days. energy - γ - 364Kev. β - 606Kev.

3mm (HVL)

20. Basic Difference between the external beam radiotherapy and nuclear medicine?

* In external beam radiotherapy, cancer cells are treated with γ-rays or high energy x-rays generated from linac or cobalt machine kept at specific distance and treated outside from the patient.

* In nuclear medicine, is a targeted therapy in which, Radioactive solution is injected or inhaled by the person, and it is attracted by those specific organ and the cancer cells are treated. Its a Internal therapy.

21. Define ALI.

It is the amount of radioisotope Intake which will result in annual maximum permissible effective (whole body) dose in the next fifty years

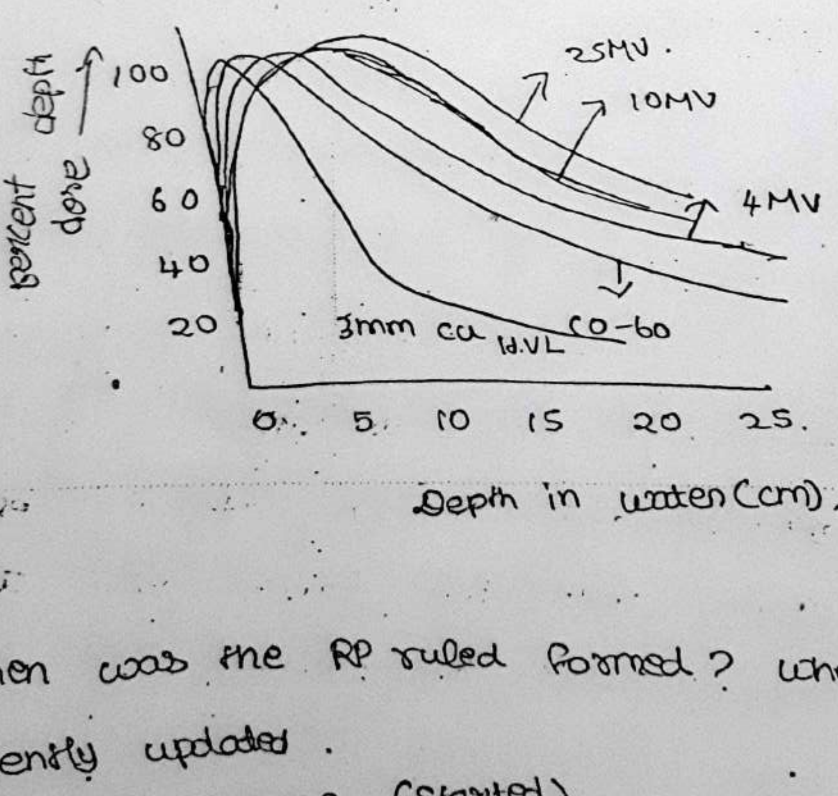
22. What is apparent activity?

The activity of a unfiltered point source of the same radionuclide which will give the same exposure rate in air at the same distance.

- can be determined by dividing measured air kerma with air kerma rate constant.

$$A_{eff} = \frac{r^2 \cdot K_a(P)}{\Gamma_{Ka}}$$

23. Draw the PDD curve for CO-60 and 4 MV X-ray beam.



24. When was the RP ruled formed? When was it recently updated.

ICRP – 1928. (Started).

AERB. Act – 1962

Last upadated in 2004.

22. who is the competent authority in india.
under the environmental protectection act, 1986,
has notified AERB (atomic energy regulatory board)
as the authority to enforce direction and procedures
with radioactive substances.

23. Explain the TRS-398 formalism with suitable formulae?

IAEA - TRS-398 - Absorbed dose determination in external beam radiotherapy : An international code of practice for dosimetry based on standards of absorbed dose to water.

Formula :.
The general formalism for determination of absorbed dose to water at the reference depth Z_{ref} in water, in a photon beam of quality 'Q' and in the absence of the chamber, is given by,

$$D_{W,Q} = M_Q N_{D,W,Q_0} K_{Q,Q_0}$$

* M_Q is the reading of the dosimeter with the refrence point of the chamber positioned at Z_{ref} in accordance with refrence condition corrected for the influence quantities temp, pressure, electrometer calibration, polarity effect, ion recombination.

N_{D,W,Q_0} → is the calibration factor in terms of absorbed dose to water for the dosimeter at the refrence quality Q_0 and K_{Q,Q_0}.

K_{Q,Q_0} → is a chamber - specific factor which corrects for difference between the refrence beam quality Q_0 and the actual quality being used Q.

24. Is there any non-ionization radiation in LA?

Yes. There are some non-ionizing radiation in LA. The sources of possible exposure are; radiofrequency driver, klystron, waveguide, gun, modulator, magnetron, power supply, and control panel with its video display units. Such sources can radiate a wide range of radiation: 50Hz and harmonics, radiofrequency radiation (very low and low frequencies) upto 100KHz by short pulses. and microwaves with frequency 3000MHz.

25. What is the threshold energy for pair production?

* minimum photon energy required for the effect to happen, of $2m_ec^2 = 1.02MeV$.

For triplet production = $4m_eC^2$

26. What is the difference between the x-rays and γ-rays?

x-ray	γ-ray
* when fast moving electron hits orbital, x-ray produced.	* produced from the unstable nucleus
* artificial production.	* emitted from radioactive material
* Have spectrum of energy.	* have discrete energy.

27. what is absorbed dose and derive the relation between exposure and kerma?

Absorbed dose is an non-stochastic quantity applicable to both directly and indirectly ionizing radiations. It is defined as the mean energy $\bar{\varepsilon}$ imparted by ionizing radiation to matter of mass 'm' in a finite volume V by,

$$D = \frac{d\bar{\varepsilon}}{dm}$$

Relation between exposure and kerma:

$\left(X = \frac{dQ}{dm}\right)$ exposure.

$$X = (K_{col})_{air} \left(e/W_{air}\right)$$

$$K_{col} = K(1-\bar{g})$$

$$X = K_{air}(1-\bar{g}) \cdot \left(e/W_{air}\right)$$

$$K_{air} = X \cdot \left(\frac{W_{air}}{e}\right) \cdot \frac{1}{(1-\bar{g})}$$

28. what is mammography and its KVp range?

Mammography is the process of using low energy X-ray (usually aroung 30kVp) to examine the human breast for diagnosis and screening.

- The goal of mammography, is early detection of breast cancer, typical through detection of characteristic masses or microcalcification.

[Range - 30 or 32 kVp with screen film.]

At 28kVp is more typical for imaging average breast, HVL should not exceed 0.37mm Al.

29. what type of target material used in mammography and why?

Amorphous selenium is used as target material and it is direct conversion using flat panel technology.

30. classify neutrons according to their energy.

thermal neutrons	~ 0.025 eV.
Slow neutrons	0.01 Mev and 0.1 Mev.
fast neutrons	0.1 Mev and 20 Mev.
Relativistic	> 20Mev.

31. leakage level radiation in co-60 during ON & OFF condition?

(March - 2009) - 7.

Q. who and why RPR rules provided?

Radiation protection rules are provided by AERB. The mission of the board is to ensure that the use of ionizing radiation and nuclear energy in india does not cause undue risk to health and environment.

33. Explain about beta shield method and material.

Beta particles can penetrate into the body and deposit dose to internal structure near the surface. Therfore greater shielding than in case of alpha radiation. Materials with low atomic number (Z) are appropriate as beta particle shield. eg. (aluminium, plastic, Lead, perspex).

34. List the emergency situation likely to be occured in LA.

* Software failure in Linac (electron to x-ray mode switch over).
* Treatment with accelerator operated in service mode
* collision between machine and patient.
* Incorrect use of treatment parameter (beam profile, PDD, tray factor given as input in TPS).
* Holder for port film left in beam during treatment.

35). what type of target used in diagnostic x-ray and LA?

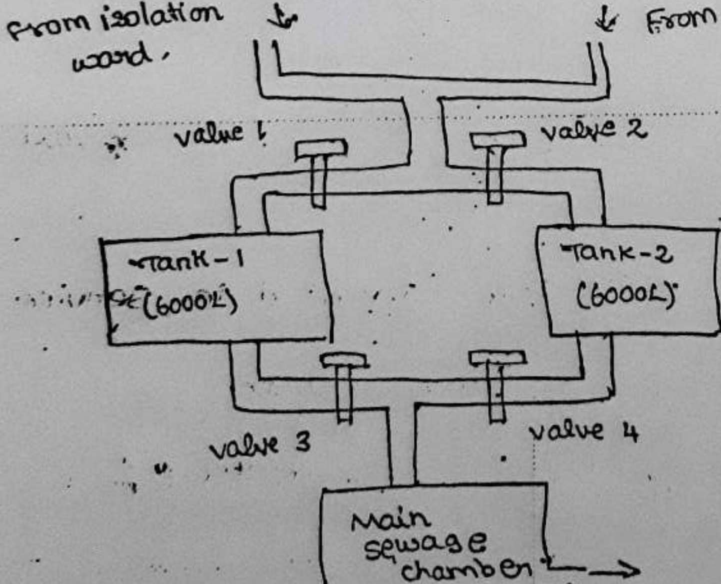
* Tungsten is used as standard target material due to its high proton number. in both diagnostic x-ray and LA.

36). Define LD 50/60.

(2009 - March - 10)

37). Explain about dual delay tank system?

Liquid waste generated from I-131 admistrations are collected in the delay tank. This dual delay tank system consist of volume of capacity 12,000 litre 6,000 L for each person. The maximum limit for discharge is 3.7 MBq/day. and average monthy concentration of 22.2 MBq/m3 for I-131.



The waste is stored in delay tank till the activity becomes low as possible.

38. Why do not we use GM type survey meter in LA?

G-M counter is very sensitive to radiation and is used to detect very low level of radiation. In LA, due to varying energy, the G-M counter will becomes insensitive to radiation if there is sudden increase in radiation level. And the counter is insensitive for particular period of time called dead time and the radiation is not noted during this time.

39. List some QA for diagnostic X-rays.

* congruence of radiation and optical field.
* central beam alignment and collimator accuracy.
* constancy of radiation output and linearity of mR/mAS versus kV?
* Assessment of Total beam Filteration.
* Assessment of focal spot time.
* Accuracy and constancy of exposure timer.
* Measurement of scattered radiation.
* Leakage radiation from x-ray time.

40. List some QA for LA.

QA parameters.

Electrical - interlocks, control switches etc.

Mechanical - gantry, collimator, couch.

Dosimetry - output, flatness, Symmetry, etc.

Radiation safety - Leakage radiation.

QA tests:

* congruence between optical and radiation beam.
* radiation beam flatness and symmetry
* Emergency off switches.
* collimator and gantry rotation angle.
* field size and distance indicators.
* photon and electron beam energies.
* output constancy of each beam energy.

Q. Explain field congruence test in detail.

* optical field used to setup patient and and radiation field should match. Error in radiation and light field congruence could lead to geographical miss of the tumor.

procedure:

* position the x-ray tube 100cm from the cassette on the table top.
* place the test tool and lead wires on the cassette. Align the central ray with the middle of the test tool.
* pre-exposure the entire cassette using 50KV and 1 mAS with test tool in place.
* Adjust the collimator, take another exposure and evaluate the results.

42. Define transport index?

Transport index marked on the exterior of a package. It is the number expressing the maximum radiation level in millirem per hour at 1 meter distance from the external surface of the package.

43. What is penumbra?

Is defined as the region, at the edge of a radiation beam, where the dose rate changes rapidly as a function of distance from the beam axis.

Types :- Geometric., Transmission, physical.

44. Define isocentre?

It is defined as a imaginary point in space where the axis of gantry, axis of collimator and axis of couch meets.

45. Explain about dead time?

For detection system that record radiation, the dead time is the after after each event during which the system is not able to record another event. The counter becomes insensitive for a particular period of time.

46. Which detector is having long dead time and what is its consequence?

G-M counter have long dead time of

100 and 300 μsec. As the result, during the next particle event taking place is not recorded and the gr counter will be insensitive for the period of time. hence G-M counter cannot be used in high level of radiation.

47. what are the three methods of radiation protection and what are three principles of radiation protection?

Three methods:

* Time, Distance, Shielding.

Three principle:

* Justification, optimization, Dose limits.

48. what is the table top dose in diagnostic x-rays?

Table top exposure rate maximum acceptable criteria is less than 5R/min.

49. what is the purpose of electron applicator in electron mode?

* The applicator plays an important role during the electron beam therapy because they flattening the electron beam around the of treatment field size, and without applicator the beam profile get a cone shape.

50). why do not we use γ-zone monitor in LA?

γ-zone monitor is used in Radioactive sources like Co-60 machine, because, it continuously emit small amount of radiation during treatment OFF condition. where as in 'LA', high energy x-rays are used and are operated and produced by power supply and no x-ray are generated during 'OFF' condition. Hence, no need of γ-zone monitor in 'LA'.

51) characteristics of brachytherapy source?

* Acceptable half life.
* preferable solid.
* High specific activity.
* optimum gamma ray emission.
* Source strength
* Inverse square fall-off dose with distance.

52). How will you arrive 8mR/dy is the permissible limit?

According to ICRP, annual dose limit = $\frac{20mSv}{year}$

$= 2000 mR / year.$

$= \frac{2000mR}{50 \text{ weeks}} = \frac{40mR}{week}.$

working days of (5) $= \frac{40mR}{5 \text{ day/week}} = \boxed{\frac{8mR}{dy}}$

1. TPR 20,10.

* It is the ratio of the absorbed dose at depth of 20 cm and 10 cm in a water phantom, measured with a constant source - chamber distance of 100 cm and a field size of 10 cm x 10 cm at the plane of the chamber.

* The most important characteristic of beam quality index TPR 20,10 is its independence of the electron contamination in the incident beam.

2. Bremstralung - explain.

The process of bremstralung (braking radiation) is the result of radiative 'collision' between a high speed electron and a nucleus. The electron while passing near a nucleus, may be deflected from its path by the columb force of attraction and loss energy as bremssfralung. Thus deceleration of charged particle by another charged particle, typically an electron by an atomic nucleus.

3. Neutron intractions

Like x-rays, γ-rays, neutrons are indirectly ionizing. their mode of interaction with matter is of two process. a) recoiling proton from hydrogen and recoiling heavy nuclei from other elements, and b) nuclear disintegration. The first process may be likened to billard-ball collision in which the energy is redistributed after the collision between the colliding particles. On the other hand, the neutron loses very little energy when colliding with a heavier nucleus.

4. Elastic and Inelastic scattering.

* In elastic scattering, the total energy is same before and after the collision. It is the type of collision in which kinetic conserved.

* Inelastic scattering is a type of scattering collision, where kinetic energy is not conserved. The total kinetic energy was greater before the collision than after,

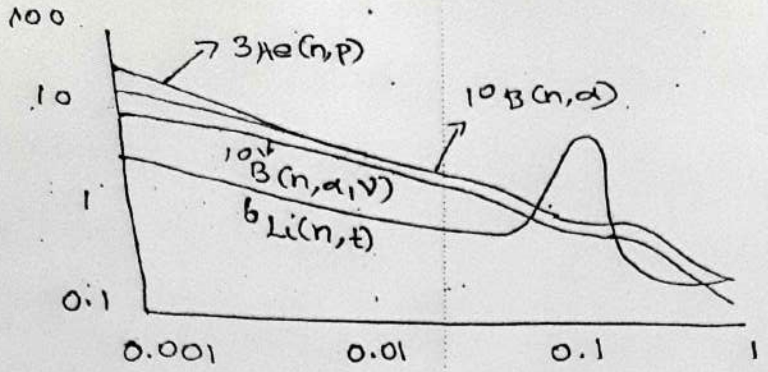
5. What are the different neutron monitoring instrument for thermal neutrons?

Gas-filled thermal-neutrons detectors are either BF_3 or He-3. In the case of BF_3; the gas is enriched in ^{10}B. Helium-3 is only about 1ppm of natural helium.

6. Types of radiation used in treatment of cancer.

External & Internal } proton, electron, neutron, x-ray, γ-rays. & charged particles.

7. what is shape of neutron cross section graph.



8. what is principle of neutron detection in CR-39.

· CR-39 is a solid state nuclear track detector (SSNTD). The principle of measurement is based on counting of number tracks etched into the surface of CR-39 detector after irradiation. These tracks are caused by either recoil proton produced by the interaction of neutron with hydrogen atoms contained in a polyethylene radiator or α-particle produced from $^{10}B(n,\alpha)^{7}Li$ reaction in boron loaded radiator.

CR-39 is a polycarbonate plastic.

* Following irradiation, the material is etched in bath of NaOH, approx. 15 hours at 70°C, to enlarge the proton recoil or alpha tracks. The dose is then evaluated by counting the number of tracks.

9. what are the physical factors modyfying biological effect?

* Type of radiation. (LET, RBE).
* Dose.
* Dose rate.
* Dose fractionation.

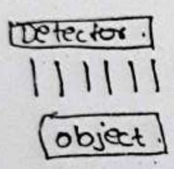
10. chemical factors modifying biological effect.

oxygen, chemical sensitizers, repair inhibitors.

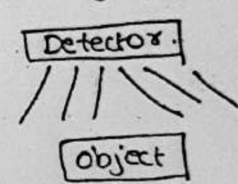
Temperature.

11. what are the different types of collimator used in NM.

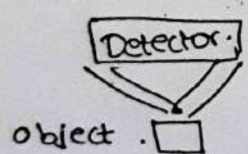
* parallel hole.



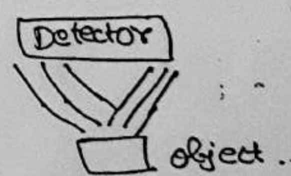
* Diverging hole.



* pinhole



* converging hole.



12. what are the neutron monitoring instrument:

1. Gas proportional detector.
   * He^3 gas-filled proportional detector.
   * BF_3 gas-filled proportional detectors.
   * Boron lined proportional detector.
2. Scintillation neutron detector.
3. Semiconductor neutron detector.
4. Neutron activation detector.
5. Fast neutron detector.

13. Specific gamma ray constant?

Is Defined as the exposure rate per unit activity at 1 cm distance from a source.

unit: $R\,hr^{-1}\,mCi^{-1}$ at 1 cm.

14. why do we go for biological dosimetry?

Biological dosimetry allow to read an accidental dose of radiation. by analysing the level of chromosomal damage (aberration) in peripheral blood lymphocytes of an exposed person. usually it is used when physical dosimetry fails, or irradiation needs to be confirmed.

15. what is the dose limit of dicentric and translocation dosimetry. (minimum dose limit)?

* As per ICRP, cytogenetic analysis, stated that the lower limit of dose detection by dicentric for low LET radiation is around 0.1 - 0.2 Gy. Lower limit of dose estimation by frequency of translocations is 0.2 - 0.25 Gy

16. what happens when radiation is incident on a cell?

when ionizing radiation incident on a cell it weakens and breaks up DNA, either damaging cells enough to kill them or causing them to mutate in ways that may eventually lead to cancer.

17. What are the Sources used in brachytherapy.

Iridium-192, Iodine-125, ceasium-137.

18. Heavy ion therapy?

It is a form of external beam radiotherapy using beams of energetic protons, neutrons, or positive ions for cancer therapy. In this, dose increases while the particle penetrates the tissue, up to maximum. that occur near the end of particle range. The advantage is less energy is deposited into the healthy tissue surrounding the target tissue.

* [Heavy ion therapy is the use of particle more massive than proton or neutron, such as carbon ions.

* They are produced in ion sources and accelerated up to 50% of the speed of light in order to reach the necessary depth in the patient.

* A typical therapy beam consist of 1 million to 10 millions carbon ion per second]

19. what is A1 and A2.

A1 (Special form) radionuclide are usually encapsulated source which would only pose an external radiation hazard, not a contamination hazard, if the package was ruptured.

A2 (normal form) radionuclide are usually not securely encapsualated and could yield significant contamination if the package was ruptured. These materials could pose an internal hazard to people at the scene of an accident. Normal form materials are typically liquids and powders.

20. which value is high? (A1 or A2).

'A' values provide the limit for the amount in package, 'A2' value cannot be greator than 'A1' values, since A2 values represents material in normal form, which makes it more 'hazardous'. However, for some nudides, the hazard may be the same in either form so that A1 can be equal to A2. In any case, neither A1 nor A2 can be greator than 1000 curies.

21. what are the isotopes used in nuclear medicine?

Technetium-99m, I-123, I-131, F-18, C-11 Semarium-153, Luthitum-177, phosphorous-32.

22. why Tc-99m is used for diagnosis why not I-131.

Tc-99m have half life of 6 hours and γ-energy of 140keV, which is used for diagnosis of disease, compared to I-131, which has half life of 8 days and ~~even~~ energy of 364 KeV γ-rays and 606 KeV, β-energy which is useful in the treatment of cancer.

23. What is RBE and LET ?

* RBE is the ratio of biological effectiveness of one type of ionizing radiation relative to another, given the same amount of absorbed energy.

$$RBE = \frac{D_{x\text{-ray}}}{D_{particle}}.$$

* LET is the energy transferred per unit length of the track.

unit :- (KeV / μm) of unit density material.

24. If 6Gy is the x-ray dose required to produce a biological effect and 3Gy is the neutron dose to produce the same biological effect then what is RBE ?

$$RBE = \frac{D_{x\text{-ray}}}{D_{particle}}.$$

$D_{x\text{-ray}}$, if LD_{50} is 6 Gy.

$D_{neutrons}$ if LD_{50} is 3 Gy.

$$RBE = \frac{6}{3} = 2 \text{//}.$$

25. what is the crystal used in gamma camera?

* SODIUM IODIDE with THALLIUM NaI(Tl)

* The main function of crystal is convert gamma ray to photon of visible light process called scintillation. Amount of light proportional to deposited energy.

26. what is the threshold dose for cataract? what is its latent period?

* Threshold eye dose of about 200 rads (2Gy) of beta or gamma radiation.

* Threshold may be as low as 60 rads for neutron radiation

* Long latent period, depending upon,

1) Total dose of radiation received.

2) Faster the dose rate, shorter the latent period

* The latency is about 8 years after exposure to a dose in range of (2.5 to 6.5 Gy).

27. what is bragg- Gray cavity theory?

It was the first cavity theory provide a relation between the absorbed dose in a dosimeter and the absorbed dose in the medium containing the dosimeter.

The conditions for application of bragg - Gray cavity theory are:

(b) The cavity must be small when compared with the range of charged particle incident on it.

28. what is stopping power? what is difference between stopping power and LET?

* stopping power has units of MeV/cm, - the amount of energy deposited per centimeter of material as a charged particle traverses the material.

* It is the sum of energy deposited for both hard and soft collisions.

$$S = \left(\frac{dE}{dx}\right)_{tot} = \left(\frac{dE_s}{dx}\right) + \left(\frac{dE_h}{dx}\right)$$

* stopping power is closely related to LET expect that LET does not include radiative losses of energy (which is ~~not~~ lost to the medium and so not absorbed).

29. Mass stopping power and its unit?

Mass stopping power for a material of a charge particle of given type and energy is the quotient (dE/dl) where 'dE' is the mean energy lost by the charged particle in traversing a distance 'dl' in the material of density 'ρ'.

$$\boxed{S/\rho = 1/\rho \cdot dE/dl}$$ units. $MeVcm^2/g$

30. Define exposure and Roentgen?.

Exposure:- A quantity used to indicate the amount of ionization in air produced by x or γ-ray radiation.

$x = dQ/dm$. unit:- C/Kg (Roentgen).

Roentgen is defined as: the quantity of radiation which liberates by ionization one esu of electricity per cm^3 of air under standard temp and pressure.

1 Roentgen = 2.58×10^{-4} C/kg.

31. Is positron stable in space?.

positron is a positively charged subatomic particle having the same mass and magnitude of charge as the electron and constituting the antiparticle of negative electron. stable in a vaccum (free space), positron quickly react with the electron of ordinary matter by annihilation to produce γ-radiation.

32- what is basic principle of TLD?

A thermoluminescent dosimeter, is a passive radiation dosimeter, that measures ionizing radiation exposure by measuring the intensity of visible light emitted from a sensitive crystal in the detector when the crystal is heated.

33. The radiation level at 50cm is 400mR/hr and what is radiation level at 1m.

$$\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$$

$$I_1/I_2 = (100)^2/50^2 = \frac{10,000}{2500} = 4.$$

$$I_2 = \frac{400}{4} = 100 mR/hr.$$

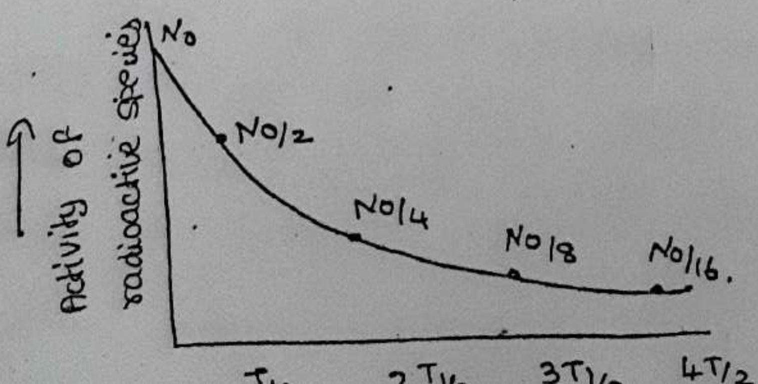
34. what is transient equilibrium. Give example?

If the half-life of the parent is not much longer than that of the daughter, then the type of equilibrium established is called transient equilibrium.

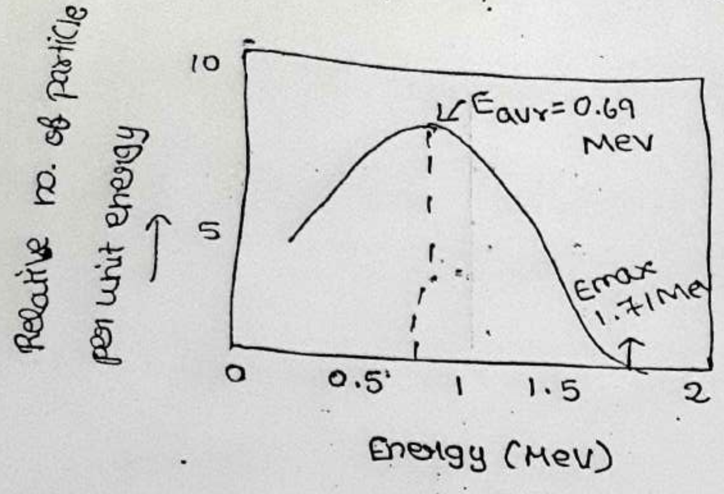
$$\frac{A_2}{A_1} = \frac{\lambda_2}{\lambda_2 - \lambda_1}.$$

example : ^{99}Mo generator producing ^{99m}Tc for diagnosing procedure.

35. Draw the activity time graph?



36. Draw the β - spectrum of. P-32.



37. why β-Spectrum is continuous for P-32?

observed Spectrum in the β-decay is continuous which suggests that 'there is more than one particle emitted in this process'.

38. Are neutrino charged?

The neutrino has no charge and practically no mass.

39. why do we use fractionation in dose? Explain.

Fractionation also refers to a method of treating cancer with radiation therapy.

If a radiation dose is delivered in a series of equal fractions, separated by sufficient time for repair of sublethal damage to occur between doses, the effective dose - survival curve becomes an exponential function of dose.

2. If the dose rate is sufficiently low, repair may be able to take place during radiotherapy treatment

3. cells at the center of tumor are hypoxic & are resistant to low LET radiation. hypoxic cells get reoxygenated occur during a fractionated course of treatment, making them more radiosensitive to subsequent dose of radiation.

40. which phase of the cell cycle is more radio resistant and which is more radiosensitive?

* most radiosensitive - G_1, G_2 and M phase.
* most radioresistant - S phase.

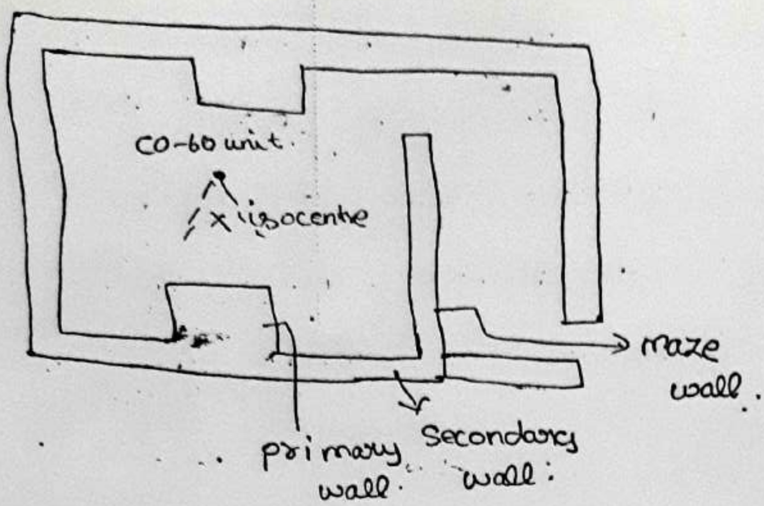
41. what is reoxygenation?

Reoxygenation is the process whereby cell in a tumor that are hypoxic after a dose of radiation become oxygenated again as the tumor shrinks or as the demand for oxygen is reduced.

42. are all tumor hypoxic?

No. cells at the center of tumor are hypoxic & are resistant to low LET radiation. hypoxic cells get reoxygenated occur during a fractionated course of treatment, making them more ~~resistant~~ radiosensitive to subsequent dose of radiation.

43. Draw the layout for a tele cobalt installation.



44. what are the different walls?

* primary wall.
* secondary wall.
* Maze wall.

45. why maze wall is used?

The maze is typically designed to prevent scattered photons from exiting the bunker directly - they must interact with a wall before they reach the door. This reduces the amount of radiation that escapes from the bunker by a significant amount.

46: write the formula used for calculating the shielding thickness.

$$t = TVL_1 + (n-1)\,TVL_e$$

$n = \log(1/B)$

B = transmission factor.

$$B_{pri} = \frac{Pd^2}{WUT}.$$

P → permissible radiation level. 2×10^{-5} SV./wk

W = workload of machine

U = use factor.

T = occupancy factor.

47. How to calculate workload?

$$W = \left[\frac{\text{Dose (cGy)}}{\text{patient}} \times \frac{\text{patient}}{\text{day}} \times \frac{\text{no. of days}}{\text{week}}\right]$$

48. what is carrier-free radionuclide?

A preparation of a ~~radionucl~~ radioactive isotope which is 'free' from stable isotope of the element. More precisely, a preparation of a radioactive isotope of 'high specific activity' to which no isotopic carrier was intentionally added and which was not produced by irradiation of stable isotope of the same element.

No tracer is need for carrier free radionuclide.

49. what is the half life of 'Tc-99m' and MO-99?

Tc-99m - 6 hours.

MO-99 - 66 hours

50. what are Tc-99m generator and its process?

Tc-99m generator is a device used to extract the metastable isotope Tc-99m of technetium from decaying sample of Mo-99.

• The eluted Tc-99m is collected in the vial and used for various diagnostic purpose by adding suitable tracer along with it.

51. what will you do in brachy manual afterload?

In afterloading technique, hollow applicator are first inserted into the lesion of interest (tumor) sources are introduced afterwards manually using a safe device.

52. what is densitometer?

* A densitometer is a device that measures the degree of darkness (the optical density) of a photographic or semitransparent material or reflecting surface. It determines the density of a sample placed between the light source and photoelectric cell from difference in reading.

* an instrument for measuring the photographic density of an image on a film.

53. what are the daily test in cobalt unit?

* Door interlocks.	Functional.	tolerance.
* Radiation room monitor.	Functional.	
* Audio-visual monitor.	Functional.	
* Lasers.	1.5mm.	
* distance indicator (ODI)	1.5mm.	

54. what is the effect of 1Gy?

The effect of 1Gy due to ionising radiation causes radiation sickness. It causes erythema (Skin gets red), nausea, vomitting etc.

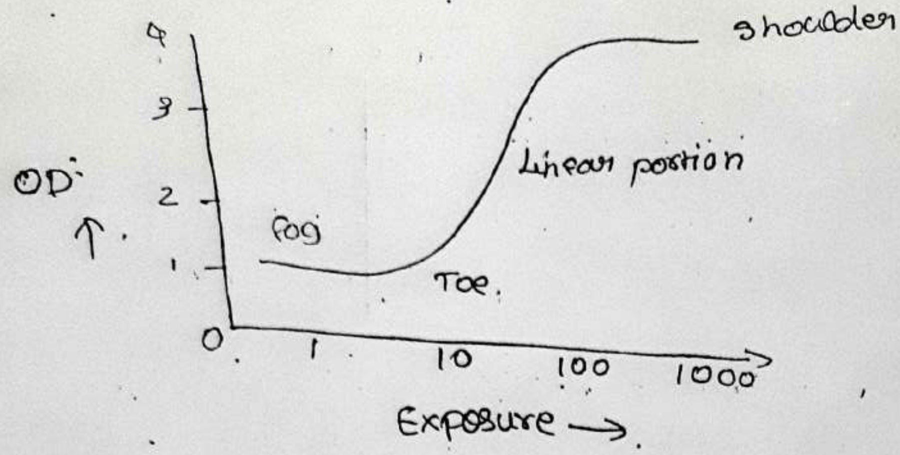
55. what type of gamma zone monitor can be used in manual brachy? (reset or automatic).

Gamma zone monitor for Telecobalt and remote after loading brachytherapy unit should be auto-reset type. whereas, for manual brachy therapy must have manual-reset button.

56. what are the protective barrier in diagnostic x-ray.

* lead lined doors of 1-2mm.
* ceiling suspended glass, lateral shield couch hanging flaps
* lead apron for personal

57. Draw densitometer curve?



58. What are radiation quantities?

* photon fluence, energy fluence, exposure, dose, dose equivalent, flux, fluence rate.

59. Radiation weighing factor for alpha, electron and proton, neutron and its value.

alpha - 20. electron - 1

neutron <10KeV - 5.

neutron 10 - 100keV - 10

neutron >100keV - 20

proton - 5.

60. What is the use factor for primary beam for Linac and HDR.

* for Linac - 1/4.

* For HDR, it is isotropic direction, hence - 1

1mGy of absorbed dose at thyroid due to alpha radiation find out the equivalent dose and effective dose.

- equivalent dose = organ dose × radiation weighing factor.

= 1mSv × 20 (for α).

= 20mSv.

effective dose = tissue equivalent dose × tissue weighing factor.

= 20mSv × 0.05 (for thyroid)

= 1mSv.

62. what is the permissible leakage and contamination level brachy therapy HDR unit?

permissible level for leakage & contamination level in HDR is < 185Bq.

63. Ir-192 source is transported under which package.

Sources used in Brachytherapy (high dose rate therapy) of Ir-192 is transported under Type-A package.

64. what is meant by normal conditions in type-A package?

These packages are designed to withstand minor accidents. These are subject to test of normal conditions, such as exposure to rain, rough handling, and slight mishaps.

65. What are types of penumbra.

* Geometrical penumbra.
* Transmission penumbra
* physical penumbra.

66. Define dosimetric penumbra?

dosimetric or physical penumbra is the lateral distance between the specified isodose curve at a specific depth (80% & 20%, or 90% & 10%) at Dmax. This particular penumbra takes scattered radiation in the region into account.

67. what is the activity level in controlled area, supervised area, restricted area?

Supervised area - less than 0.75 mR/hr.

controlled area - more than 0.75 mR/hr.

Restricted area - 2.5 mR/hr.

68. why filters are used in x-ray
units?

* At x-ray energies, filters consist of material placed in the useful beam to absorb, radiation based on energy level, or to modify the spatial distribution of the beam. Filteration is required to absorb the lower-energy x-ray photons emitted by the tube before they reach the target.

69. Monthly limit of TLD dose?

Monthly limit of TLD should be no greator than 0.5 mSv. (10 mSv overexposure)

70. Men infertility dose?

Dose as low as 600 cGy (6 Gy) cause irreversible damage to the sperm forming cells. Dose less than this may cause a temporary drop in the number and quality of sperm produced. [Tempeory - 0.15 Gy. (permanent - 3.5 - 6 Gy)

71. what does Hp(0.07) indicates?

Hp(10) and Hp(0.07) are personal dose equivalent, which represents the probability of stochastic health effect from radiation.

Hp(0.07) is the shallow dose equivalent, also refered to skin dose equivalent. It is equivalent dose at 0.07 mm below the surface of body.

72. What is the quality index of electron beam?

* For electron beam the beam quality index is the half-value depth in water R_{50}. This is the depth in water (in gcm^{-2}) at which the absorbed dose is 50% of its value at the absorbed-dose maximum, measured with a SSD of 100cm and a field size at phantom surface of at least 15cm × 15cm. For all energies.

$$R_{50} = \frac{\text{Energy}}{2.33}.$$

73. What is the activity with which the F-18 FDG must be transported to a centre 3h away to get a final activity of 10ci?

$A = A_0 \cdot e^{-\lambda t}$.

Final activity $A = 10ci$. $T_{1/2} = 108$ mins (1.8hr)

$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{1.8}$

$\lambda = 0.385$

$10ci = A_0 \cdot e^{-0.385 \times 3h}$

$10ci = A_0 \cdot e^{-1.155}$

$10ci = A_0 \times (0.3150)$

$A_0 = \frac{10ci}{0.3150} = 31.7\,ci$.

$A_0 = 31.7ci$ of initial activity is needed to transport F-18, 3h away from centre.

Radiation Detection and measurement.

1. what type of probe is required for detection of emission from iodine-125 / iodine 131 radionuclides?

* use a survey meter and a NaI scintillation probe to obtain highest sensitivity and counting efficiency.

* however, a G-M survey probe is adequate and most cost effective for I-131.

2. what type of radiation is emitted by Tritium (3H) carbon-14? How do you detect it?

* Tritium and carbon-14 are pure beta emitters. It is detected with the help of scintillation type of detector.

3. Name a couple of beta emitters?

strontium-90, tritium, carbon-14., P-32.

4. is both I-125 / I-131 radionuclide emit the same type of radiation?

* I-125 emits soft gamma radiation and x-ray with a maximum energy of about 35 keV.

* I-131 - decays mostly by beta - emission (606keV 90%). it also emits high energy γ-radiation (364 keV ; 10%)

5. What are common type of radiation survey instrument used in radiation oncology / diagnostic Radialogy / Nuclear medicine Department.

Radiation oncology } - Ionisation survey meter.
Diagnostic } G-M survey meters.

Nuclear medicine - proportional counter, Dose Calibrator, ionisation survey meter, G-M counter.

6. Why G-M type dosimeter are not used for absolute dose measurement?

G-M type dosimeter are very sensitive to radiation and it is used to detect small level of radiation. when used in high level radiation, it becomes insensitive and continuous discharge takes place. and it cant further detect radiation, in absolute dosimeter, dose is determined without reference to another dosimeter.

7. How often should the radiation measuring instrument be calibrated?

portable radiation survey meter must be calibrated at least annually to an accuracy of ±20 percent, for the γ- energy of source in use.

8. what do you understand by SSDL / PSDL? what is the role.

SSDL/ PSDL are secondary standard dosimeter laboratory and primary standard dosimeter Laboratory. The reading obtained from PSDL are used to absolute dosimetry and SSDL readings are compared with it.

9. why ionization instrument is not recommended for use in nuclear medicine to detect contamination:

Ionization chamber survey meter requires a higher radiation flux than do G-M counter to produce a precise reading. They are therefore applicable to situation such as monitoring radiation level of patient recieving radionuclide or radioactive implants for therapy. but not appropriate for detecting contamination radiation,

10. Exposure rate 150mR/hr. time spending is 5min. what is the exposure?,

$$\frac{150\,mR}{60\,mins} = 2.5\,mR/min.$$

$$2.5 \times 5\,min = \boxed{12.5\,mR / 5\,mins}$$

Radiation quantities and units.

1. what is the deposition of charge if a radiation field of one roentgen passing through in one Kilogram of dry air?

one roentgen deposits = 2.58×10^{-4} C / Kg.

2. what are the limitation in using the unit of Roentgen?

Roentgen has the disadvantage that it is only a measure of air ionisation, and not a direct measure of radiation absorption in other materials, such as different forms of human tissue.

3. Name three radiation quantities that have same unit. (J / Kg).

* Absorbed dose
* equivalent dose
* effective dose.

4. Term : ambient dose equivalent?

Is the operational quantity for area monitoring. The ambient dose equivalent is given symbol - $H^*(10)$. For strong penetrating radiation the depth d = 10mm is used.

Interaction of Radiation with matter:

1). Define LET? stopping power? specific ionisation?

LET is the energy transferred per unit length of the track. unit :- (KeV/μm) of density material.

specific ionisation is the number of ion pair produced per unit track length.

stopping power is defined as expectation value of rate of energy loss per unit path length (dE/dx) of the charged particle. (MeV/cm).

2). what is the average amount of energy needed to create an ion pair in air? (IAEA - 60) page.

* The current estimate for average amount of energy needed to create ion pair in air (Wair) is 33.97 eV / ion pair.

3). Two major mechanism of energy transfer of α particle radiation.

* Ionisation
* Excitation.

4) Three major mechanism of energy transfer of β - particle radiation.

* Ionisation
* Excitation.
* Bremsstrahlung interaction.

5. Three major mechanism of which γ-photon radiation interacts with matter?

* photoelectric effect.
* compton effect. (scattering)
* pair production,

6. when the probabily of photoelectric effect is maximum?

* The probability of effect increases as the atomic no. increases.

Note: photoelectric effect $\propto (Z)^3$.

* incident photon energy > binding energy of electron.

7. examples for directly ionising radiation and indirectly ionizing radiation?

Directly ionizing Radiation:.

* electron.
* heavy ions.
* proton.
* α-particle.

Indirectly ionizing Radiation:.

* x-ray.
* neutron.
* γ-rays.

Short answers.

1. Define exposure.

A quantity used to indicate the amount of ionization in air produced by x or γ-ray radiation.

$$X = dQ/dm.$$

unit : C/Kg (Roentgen).

2. Define Roentgen.

Roentgen is defined as the quantity of radiation which liberates by ionization one esu of electricity per cm^3 of air under standard temp and pressure.

$$1 \text{ Roentgen} = 2.58 \times 10^{-4} \text{ C/Kg}.$$

3. Define Absorbed dose.

It is the quantity of radiation energy deposited per unit mass of an absorber material.

$$D = dE/dm.$$

unit : J/Kg.

4. Define gray.

It is the SI unit of radiation dose, expressed as absorbed energy per unit mass of the tissue. 1Gy = 1 Joule/kilogram.

5. Define KERMA.

Kerma is defined as the mean energy transferred from the indirectly ionizing radiation to charged particles. (electrons) in the medium $d\bar{E}_{tr}$ per unit mass dm.

$$K = \frac{d\bar{E}_{tr}}{dm.}$$ unit :. J/kg.

6. What is Grenz-ray therapy?

* Has a very soft beam (<20KV).
* absorbed within the first 2mm of skin, does not penetrate beneath the dermis.
* used clinically for skin lesions like Atopic dermatitis, Lichen planus.
* Typically 200cGy per session at weekly intervals for a total of 800 cGy to 1000 cGy.

7. Write the equation for pressure and temperature correction for cobalt -60 output calibration.

$$K_{TP} = \frac{(273.2 + T). P_0}{(273.2 + T_0) P}$$

pressure in kPa. temp in °C.

8. Define linear attenuation coefficient? (or)

It produces the measure of the fractional attenuation per unit length of material traversed. unit :- cm^{-1}.

9. Define Mass attenuation co-efficent?

It ~~prod~~ provides a measure of the fractional attenuation per unit mass of material encountered.

$\Rightarrow (\mu/\rho)$. unit : cm^2/g

10. Define electronic attenuation co-efficient?

* Is given as the mass attenuation coefficient divided by the electron density. Because all materials have approximately the same electron density, the electronic attenuation co-efficient will be approximately proportional to mass attenuation co-efficient. $(\mu/\rho)(1/N_0)$ $N_0 \rightarrow$ number of e^- per gram.

unit :- $(cm^2/electron)$

11. Define half life.

half life ($T_{1/2}$) of a radioactive sustance is defined as the time required for either the activity or the number of radioactive atoms to decay to half the initial value.

$$T_{1/2} = 0.693/\lambda$$

12. Define mean life :-

It is the average lifetime of a radioactive atom before it decays. It is the sum of lifetime of all the individual nuclei divided by total no. of nuclei involved.

$$\tau = 1.44 \times T_{1/2}$$

13. Define photoelectric effect?

The phenomenon of emission of electron from a metallic surface when photon interacts with a tightly bound orbital electron of an attenuator is called photoelectric effect.

14. What is compton scattering?.

Compton scattering represents a photon interaction with an essentially free and stationary orbital electron. The incident photon energy $h\nu$ is much larger than the binding energy of orbital electron.

15. Define pair production?

The conversion of a photon into an electron-positron pair on its interaction with the strong electric field surrounding a nucleus, is called pair production.

16. Define annihilation?

The converse of pair production in which an electron and positron combine to produce two photons is known as annihilation of matter.

17. In a deep x-ray treatment bone would receive higher dose than tissue, why?

In deep x-ray treatment, photoelectric effect takes place, which is depend on the cube of the atomic number. bone is high density material compared to soft tissue. hence bone recieve higher dose.

18. write the three ways of electron interact with matter.

* elastic collision.
* Inelastic collision.
* ~~radiation~~ radiative collision. (bremsstrahlung).

19. How does neutron Intract with matter.

* Elastic scattering.
* inelastic scattering.
* Neutron capture.
* Spallation reaction.

20. Define stopping power.

The linear stopping power 'S' for charged particle in a given absorber is simply defined as the differential energy loss for that particle within the material divided by the corresponding differential path length.

$$S = -dE/dx.$$

21. Define mass stopping power?

Mass stopping power for a material for a charged particle of given type and energy is the quotient (dE/dl) multiplied by $(1/\rho)$.

where 'dE' is the mean energy lost by the charged particle in traversing a distance 'dl' in the material of density 'ρ'.

$$(S/\rho) = 1/\rho \cdot dE/dl.$$

22. what is the main difference between bragg-Gray formulation and spencer-attix-ionization chamber theory?

* Bragg-Gragg cavity theory does not take into account the creation of secondary electrons generated as result of hard collision in slowing down the primary electron in the sensitive volume of dosimeter.

* spencer-attix theory, accounts the creation of these electron that have sufficient energy to produce further ionization on their own.

23. calculate the number of atoms present in a cobalt-60 isotope after 13 yrs. if initial no. of atoms is 10^8.

$T_{1/2} = 5.26$ yrs.

$A = A_0 \cdot e^{-\lambda t}$.

$\lambda = \frac{0.693}{5.26} = 0.1317$

∴ $A_0 = 10^8$.

$A = 10^8 \times e^{-0.1317 \times 13 \text{ yrs}}$

$= 10^8 \times e^{-1.71} \Rightarrow 10^8 \times 0.180$

$= 1.804 \times 10^7$ no. of atoms

24. The half life of I-125 is 59.4 days. calculate mean life and decay constant.

$$T_{1/2} = \frac{0.693}{\lambda} \Rightarrow \lambda = \frac{0.693}{59.4} = 0.0116.$$

$$\text{mean life} = 1.44 \times T_{1/2} = 85.53.$$

25. The source in cobalt 60 unit is 2cm in diameter, the SSD is 80cm and SDD is 50cm. what is the size of penumbra at the surface of patient.

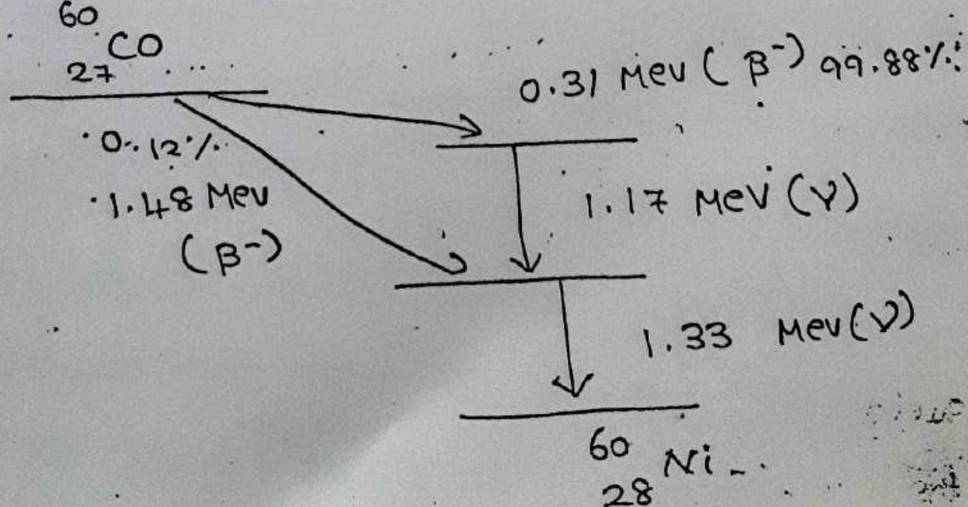
$$W = D\left(\frac{SSD - SDD}{SDD}\right)$$

$$= 2 \times \frac{(80 - 50)}{50} = \frac{60}{50} = 1.2\,cm$$

26. write the equation for production of coblalt 60.

$$^{59}_{27}Co + ^{1}_{0}n \longrightarrow ^{60}_{27}Co.$$

27. Decay scheme of ^{60}Co.



28. Exposure rate constant?

exposure rate constant is defined for unshielded point source. is defined as exposure rate per unit activity at 1cm distance from a source. unit :- R hr^{-1} mCi^{-1} at 1 cm !

29. Difference between specific γ-ray constant and Exposure rate constant?

* The D.B between two that is the specific γ-ray constant include exposure contribution due to only the primary gamma emission whereas exposure rate constant includes, apart from primary gamma emission, the contribution due to characteristic x-rays.

30. What is anode heel effect?

The heel effect is due to a portion of x-ray beam being absorbed by the anode. This results in an x-ray beam that is less intense on the anode side and more intense on the cathode side. The heel effect is more pronounced with steeper anode angle.

31. Define anode angle?

It is defined as the angle of target surface with respect to the central ray in the x-ray field. * angle range [6° - 20°]

What is internal conversion?

In this process, the excited nucleus, passes its excess energy to one of the orbital electrons, which is then ejected from the atom. The resulting K shell vacancy is filled with higher level orbital electron and the transition energy is emitted in the form of characteristic photons or auger electrons.

eg. decay of excited ^{125}Te, which results from electron capture decay of ^{125}I, into stable ^{125}Te through emission of 35 keV. γ rays (7%) and internal conversion electrons (93%)

33. What is the principle of electron acceleration in Betatron?

In a betatron, the changing magnetic field from the primary coil accelerates electrons injected into the vaccum torus, causing them to circle around the torus in the same manner as current is induced in the secondary coil of a transformer (Faraday's law)

34. What is the principle of electron acceleration in microtron?

In a microtron accelerator, the electrons revolve in a uniform magnetic field and accelerate each time they pass through the electric field of the accelerator cavity. once the accelerated electrons reach a predified energy level, they are expelled as a beam via an exit pipe to an external device.

35. where does cyclotron find use in Radiotherapy?

* It is used as a source of high energy proton beam therapy.

* Also can be used as neutron beam.

36. what is D-T generator?

D-T neutron generators are small accelerators that utilize the large fusion cross section (5 barns) of the deuterium (D) and tritium (T) ions in the following reaction to produce 14.2MeV neutrons.

$$D + T \rightarrow n + {}^{4}He$$

37. How is standing wave setup in linac wave guide?

In Linear accelerator, electric fields are ~~step~~ set up as standing waves, within a cylindrical metal 'resonant cavity' with drift tubes suspended along the central axis.

38. Name two issues in using a scattering foil to obtain useful electron beam.

* Beam attenuation.
* Generation of bremsstrahlung radiation.

39. why is scattering foil used in linear accelerator?

In the electron mode of linac operation, narrow pencil electron beam, about 3mm in diameter, instead of striking the target, is made to strike an electron scattering foil to spread the beam as well as get a uniform electron fluence across the treatment field. (made of thin high Z metallic foil) (lead, tantalum).

40. what is flattening filter?

* In conventional linear accelerator, delivering photon beams are equipped with a flattening filter (FF) in order to allow delivery of homogenous dose distribution with broad beams.

✓ Flattening Filter contribute to scattered, reduce dose rate, leakage from the treatment head, beam hardening and also neutron fluence for high energ x-ray used in linac.

41. Types of waves guide used in linac?

* Standing wave guide.
* Travelling wave guide.

42. What are the types of bending magnet used in medical linac accelerator?

* 90° bending magnet.
* 270° bending (achromatic).
* 112.5° (slalom) bending magnet.

43. What are characteristic x-rays?

* Characteristic x-ray result from coulumb interactions between the incident electron and atmomic orbital electron of the target material. The orbital electron is ejected from its shell and an electron from a higher level shell fills the orbital vacancy.
* The difference in energy between two shell is emitted as characteristic x-ray or auger electrons.

44. Name the types of source ON/OFF mechanism in cobalt units?

Currently, two methods are used for moving the teletherapy source from 'Beam OFF' into the 'Beam ON' position and back.

* Sliding drawer.
* Rotating cylinder.

45. What is continuous x-rays?

Ans. Bremsstrahlung (continuous) x-ray result from Coulumb interactions between the incident electron and the nuclei of the target material.

* During the interactions electron is accelerated and loses part of its kinetic energy in the form of bremsstrahlung photons.

46. What are the frequency range of microwaves of L, X and S band?

Band	Frequency range	wavelength range
L	1 to 2 GHz	15cm to 30cm.
S	2 to 4 GHz	7.5 to 15 cm.
C	4 to 8 GHz	3.75 to 7.5cm
X	8 to 12 GHz	25 mm to 37.5cm.

47. What Radiofrequency is used in Medical linac and in what RF ~~belo~~ band it belongs to?

* Frequency of '3GHz' was chosen because a radar-type magnetron was used as RF power source on first prototype. It belongs to RF 'S band'

48. Where 'x band' Linacs are used?

The X-band accelerator technology ~~is~~ has been used in high-energy as well as industrial applications. In radiation therapy field, it is already implemented in some machines like mobetron, an intra-operative Radiation therapy instrument. another

• eg. SRS machine, the cyberknife. The compactness of these machine, required the use of an x-band accelerator.

49. what are the two types of electron gun used in linear accelerator?

Two types of electron gun used as sources of electron in medical linacs are.

* Diode type.
* Triode type.

50. What is the length of waveguide for 4MeV and 25MeV linac accelerator?

The length of accelerating waveguide depends on the final electron kinetic energy, and ranges from ~30cm at 4MeV to ~150cm at 25MeV

51. what are the types of RF power sources used in linear accelerator?

* Klystron,
* Magnetron.

52. Write the difference between klystron and magnetron?

Klystron	Magnetron.
It can be used both as amplifier and oscillator.	It can only be used as oscillator.
Application:. It is used in TV transmitter, radar and particle accelerators. used as high power, narrowband stable amplifier.	It is used in microwave ovens, operating at 2.45 GHz. It is also used for RF heating when operating at 900 MHz or 2.45 GHz.

53. What is the pulsed modulator in linac?

The pulsed modulator is the part of linac located in treatment room. The primary function of modulator is to supply high voltage pulses to the cathode of the microwave generator valve and electron gun. And its contains the emergency off button that shuts the power of linac. [(high voltage (~100kV), high current (~100A) short duration (~1s)]

54. What is the function of steering coils and where is it located in linear accelerator?

Steering and focusing solenoid coils are used to control the direction and position of stream within the guide. It is located below & above the accelerating waveguide.

55. Name any six components seen in the head of 5th generation linear accelerator:

1) Injection system.	4). Beam transport system.
2). RF power generation system.	5). Beam collimating and monitoring system.
3) Accelerating wave guide	6) Auxiliary system.

56. what are the types of target used in medical linear accelerator?

Types of targets:. Thin, intermediate and thick.

Material:. high z target. (eg. Pb and tungsten).

57. what should be consideration when designing the thickness of x-ray target?.

Target material is based on three characteristics

* Atomic number must be high, so that it results in high efficiency in x-ray production.
* thermal conductivity:- must be able to conduct heat away from the target.
* high melting point:. must be able to withstand high temperature.

58. what material is preferred as the flattening filter?

copper. or brass.

59. What is dose monitoring system in linear accelerator:

Dual ionization chamber :- The dose delivered to the patient is measured and controlled by the monitoring system. i.e ionization chamber.

* The chamber are usually transmission type. we are using flat parallel plate type. ionization chamber.
* Here the first chamber is the primary dosimeter, it measures and stops the radiation when the required dose is delivered.
* The other chamber is the backup chamber, one it stops the radiation when primary chamber fails.

60. What is effective atomic number? write the equation to determine the same.

EAN, the number that represent the total no. of electrons surrounding the nucleus of a metal atom in a metal complex. It is composed of the metal atom's electrons and the bonding electrons from the surrounding electron-donating atoms and molecule.

$$EAN = Z - X + Y$$

Z = atomic no.

X = no. of electron lost during formation of metal ion from its atom.

Y = no. of electrons donated by ligand.

eg. $[Fe(CN)_6]^{-4}$ oxidation = +2 & Z = 26.

$= 26 - 2 + 6(2) = 36.$

61. How is high energy beam quality described as per IAEA protocol?

For high-energy photons produced by clinical accelerators the beam quality 'Q' is specified by the tissue-phantom ratio, $TPR_{20,10}$. This is the ratio of absorbed dose at depth of 20cm and 10cm in a water phantom, measured with constant source-chamber distance of 100cm and a field size of 10cm x 10cm at plane of chamber.

62. Define percentage depth dose?

The ratio of dose absorbed at a predefined depth (D_d) to Dmax (dose maximum) for a predified SSD and field size is termed as PDD.

$$PDD = \frac{D_d}{D_{max}} \times 100.$$

63. what are the parameter that influence depth of dose distribution?

* The depth of maximum ionization increases as the energy of beam increases.
* Factors such as field size, and distance may also influence the depth.

64. Define Tissue maximum ratio. (~~TPR~~) (TMR)

* TMR is a special case of TPR.

* It may be defined as the ratio of dose at a given point in phantom to the dose at the same point at the refrence depth of maximum dose.

65. Define. Tissue phantom ratio (TPR).

The absorbed dose at a given depth in phantom to the absorbed dose at the same point at a refrence depth in phantom.

66. What are the parameters that influence the PDD.

* energy of beam.
* field size.
* depth effect.
* SSD.

67. How is field size defined in clinical x-ray beam?

The projection that, on a plane perpendicular to the beam axis of the light field, corresponds to the area being treated by radiation.

68. What are the parameters used to quantify field uniformity?

* Flatness.
* Symmetry

69. Define Radiological penumbra.

* Radiological penumbra is defined as the 80 - 20% width of the dose profile.

* Geometric penumbra + Scatter - Radiological penumbra

70. write the equation used to determine field flatness..

The radiation field flatness of the beam is defined by the following formula:.

$$\text{Flatness } (\%) = \frac{D_{max}}{D_{min}} \times 100\%.$$

D_{max} and D_{min} are the maximum and minimum dose.

71. write the equation used to determine the field symmetry of beam.

Radiation field symmetry is outlined as the quantitative relation of doses at two symmetrical points relative to the central axis of the field.

$$\text{symmetry } (\%) = \frac{[D,(x,y)]}{D,[(-x,-y)]} \times 100\%$$

72. what are beam modifier of clinical photon beam?

Beam modifiers are devices used to modify the spatial distribution of radiation within the patient by insertion of any material in the beam path. Types of beam modifiers - Shielding, compensation, wedge filteration, flattening.

73. Define wedge angle.

According to ICRU, the wedge angle is defined as the angle at which an isodose curve is tilted at the central axis of the beam at a specified depth. (usually 10cm).

$$\theta = 90^\circ - \phi/2$$

θ = wedge angle.
φ = hinge angle.

74. Define hinge angle.

It is the angle between central axes of two beams passing through the wedge.

75. what is wedge Factor.

It is the radio of doses with and without the wedge, in a phantom at a suitable depth beyond the depth of maximum dose.

76. what is Dynamic wedge?

Linac are available with options allowing independent movement of the collimator jaws. This option may be used to create wedged shaped dose distribution by moving one of the independent collimator jaws while the opposite jaw remain stationary during irradiation. This is

77. What is virtual wedge?

virtual wedge is a Siemens treatment modality which generates wedge-shaped dose distributions by moving a collimator jaw from closed to open at a constant speed while varying the dose rate in every 2mm jaw position.

78- What is universal wedge?

* Universal wedge are designed so that the same wedge can be used with all field sizes
wedge angle used are :- 60°, 45°, 30°, 15°.
Not suitable for cobalt beam because of excessive reduction of beam output with smaller fields.

79. What are beam shaping devices used to shape clinical photon beam?

* compensators.
* Breast cone.
* Beam spoilers.
* Beam flattening filters.
* Bolus.
* Shielding blocks.
* asymmetrical jaws.
* custom blocks.
* MLC.

80. Name the beam Directional devices used.

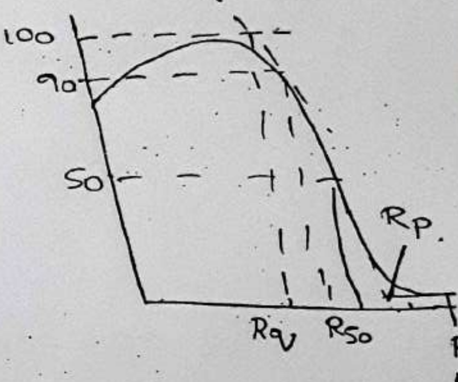
* collimators.
* Front pointer / SSD indicator.
* Back pointer.
* pin and arc.
* Lasers.
* Isocentric mounting,

81. Define relative dose factor or output factors.

In radiation therapy, the output factor, is defined as the ratio of measured dose between a certain field and a refrerence field in a slab phantom of ($10 \times 10 cm^2$) perpendicular to the beam axis.

82. What are the parameters used to describe the depth dose of a clinical electron beam?

* Maximum range (Rmax).
* practical range (Rp).
* Therapeutic range R90.
* Depth R50.
* Depth R9.



83. Define practical range of electron beam? what is the practical range of 12MeV electron beam.

* Rp is defined as the depth at which the tangent plotted through the steepest section of the electron depth dose curve intersects with the extrapolation line of the bremsstrahlung tail.

$$R_p = E/2 \text{ (cm or g/cm}^2) \Rightarrow \frac{12 \text{ MeV}}{2}$$

$$R_p = 6 \text{ cm}.$$

84. Define therapeutic range of clinical electron beam. what will be approximate therapeutic range for 9 Mev beam.

The depth of the 90% dose level (R_{90}) is defined as the therapeutic range for electron beam therapy. This depth is approximately given by E/4 in cm of water, where 'E' is the nominal energy in Mev of the electron beam.

* Therapeutic range for 9 Mev beam. $\Rightarrow R_{90} = \frac{9}{4}$

R_{90} for 9 Mev = 2.25 cm

85. write the equation to determine the most probable electron energy Ep of a clinical electron beam and explain the parameters.

* most probable energy $E_{p,0}$ is given by

$(E_p)_0 = C_1 + C_2 R_p + C_3 R_p^3.$

For water, $C_1 = 0.22$ Mev $C_2 = 1.98$ Mev cm^{-1}

$C_3 = 0.0025$ Mev cm^{-2}

$$E_{p,0} = 0.22 + 1.09 R_p + 0.0025 R_p^2$$

R_p = practical range.

86. Determine the Ep of clinical electron beam with Rp of 6cm.

$$E_p = 0.22 + 1.09\,(6cm) + 0.0025\,(6)^2.$$

$$= 0.22 + 6.54 + 0.09.$$

$$\boxed{E_p \doteq 6.85.}$$

87. Write the equation to determine the mean energy of clinical electron beam.

* The mean electron energy $\bar{E}_0$ at the phantom surface is related to half-value depth R_{50} as follows,

$$\boxed{\bar{E}_0 = CR_{50}.}$$

C = 2.33 MeV/cm for water.

* For depth 'z' in water phantom, mean energy $\bar{E}_z$ is

$$\boxed{\bar{E}_z = \bar{E}_0 (1 - z/R_p)}$$

88. Determine the mean energy of clinical electron beam that R_{50} = 5.2cm.

$$\bar{E}_0 = CR_{50}.$$

$$\bar{E}_0 = 2.33\ MeV/cm \times 5.2\ cm.$$

$$\boxed{\bar{E}_0 = 12.116\ MeV}$$

89. calculate the practical range and R50 of 12 MeV beam.

$$R_p = E/2 = \frac{12}{2} = 6 \text{ cm}.$$

$$R_{50} = \frac{E}{2.33} = 5.15 \text{ cm}.$$

90. what is bremstrahlung tail in clinical electron Beam?

Typically the electron beam central axis depth dose curve exhibit a high surface dose, and the dose then builds up to a maximum at a certain depth refered as zmax. Beyond zmax, the dose drops off rapidly and levels off at a small low level dose component referred to as 'bremsstrahlung tail'.

91. what contribute to the bremstrahlung tail in clinical electron beam?

* Bremsstrahlung produced in the head of the accelerator, in the air between the accelerator window and the patient, and in the irradiated medium is responsible for the tail in the depth dose curve.

92. Bremsstralung. contamination of clinical electron beam.

The bremsstralung contamination depends on electron beam energy and is typically less than 1% for 4 MeV and less than 4% for 20 MeV electron beam for an accelerator with dual scattering foils.

93. Name four different types of electronic protal imaging detector?

* Mirror based video system.
* Fiberoptic video system.
* Liquid ionization chamber system.
* scanning ionization chamber system.

94. what is meant by detector quantum efficiency.

The detective quantum efficiency is a measure of the combined effects of the signal and noise performance of an imaging system, generally expressed as a function of spatial frequency. This value is used primarily to describe imaging detectors in optical imaging and radiographs.

$$DQE = \frac{SNR^2 \text{ at detector output}}{SNR^2 \text{ at detector input}}$$

SNR → Signal to noise ratio.

DQE → Detector quantum efficiency.

95. write two issues in using film dosimetry?

* Darkroom and processing facilities requires
* Energy dependence problems, cannot be used for beam calibration.

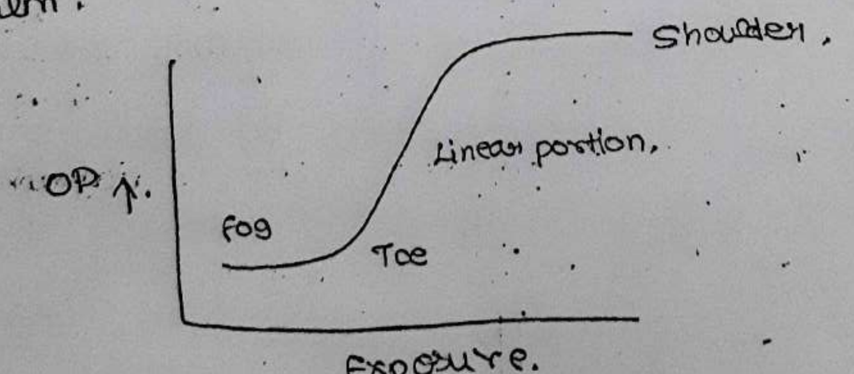
96. Define optical density.

OD is defined as $OD = \log_{10}(I_0/I)$ and is function of dose. 'I_0' is the initial light intensity and 'I' is the intensity transmitted through the film.

OD density has a pre size numeric value that can be calculated if the level of light incident on a processed film and the level of light transmitted are measure.

97. what is gamma of a film characteristic curve.

* The slope of the straight line portion of the H & D curve is called the gamma of the film.



98. write two methods which could be used for absolute dosimetry and explain why?

1) The total absorption method based on 'chemical dosimetry' - in this dose is determined by measuring the chemical change produced in the medium, using a suitable measuring system.

2). 'calorimetry' - is the most fundamental method of realizing the primary standard for absorbed dose, since temperature rise is the most direct consequence of energy absorption in a medium.

3). 'ionometric' method.

99. What does the term 'glow curve' mean?

The energy absorbed from electromagnetic radiation or other ionizing radiation in TLD material is re-emitted as light upon heating of the material. "The amount of light emitted relative to the temperature is called the glow curve"

100. what is thermoluminescence?

Thermoluminescence is thermally activated phosphorescence, The property of some material which have accumulated energy over a long period of becoming luminescent when pretreated and subjected to high temperature. It is the process in which mineral emit light while

101. what are the two branches of gel dosimetry?

* Frickle gels based on well established 'Frickle dosimetry'
* 'polymer gels.'

102. what are the methods of reading dose in gel matrix?

* upon radiation exposure, monomers undergo polymerization reaction, resulting in a 3-D polymer gel matrix that is function of absorbed dose that can be evaluated using 'Nuclear magnetic Resonance (NMR), x-ray computed tomography (CT) optical tomography, vibrational spectroscopy or ultrasound.

103. Explain absolute and Relative Dosimetry.

Absolute	Relative
* Absolute dosimeter produces a signal from which the dose in its sensitive volume can be determined without requiring calibration. in a known radiation field.	* Relative dosimeter requires calibration of its signal in a known radiation field.

* Here the dose is determined without reference to another dosimeter.	* These dosimeters requires calibration against primary standards.
eg. Free air ionization chamber, calorimeter, Frickle dosimeter.	eg. thimble chamber, plane parallel ion chamber, TLD'S, Diode and films.

104. Why calorimetry is not practical in a clinical setup?

Direct calorimetry is not practical in most setting. It requires an expensive apparatus and it is logistically impractical to leave a patient unattended for the extended period of time. And also they are impractical for routine clinical use because of the extremely small temperature rises that occur when clinical radiation doses of order 1Gy are used to irradiate the calorimeter.

105 What is an isocentric treatment?

The axis of rotation of three structures, gantry, collimator, couch coinides at a point is called 'isocenter'. An isocentric technique is where all beams used in radiation treatment have an common focus point. It require less patient can be delivered with gantry and collimator movement, reducing treatment times.

106. what is an SSD treatment?

* This approches positions a fixed treatment distance of 80 or 100 cm on the patient's skin for each field.

107. what is SAD treament?.

It is also a isocentric technique, it provides tumor localization in three dimensions, using a isocenter placed within the target volume.

108. Define gross tumor volume (GTV). (IAEA - 220 refer)

* Gross demonstrable extent and location of the malignant growth. (visible tumor.

It consist of primary tumor, metastatic lymphadenopathy and other metastasis.

* If the tumor is removed prior to radiotherapy then no GTV can be defined.

109. Define clinical target volume (CTV).

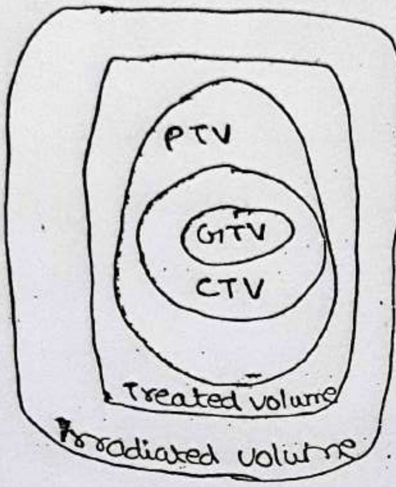
CTV, is defined as GTV + subclinical/invisible invasion. A volume to account for uncertanities in microscopic tumor spread, that is CTV.

110. Define planning target volume?

PTV is defined as ITV + SM. (setup margin erro

L> CTV + IM (internal margin for organ motion

* a volume to account for geometric and other uncertainties that is PTV.



111. what is an isodose curve?

Isodose curves are the lines joining the points of equal percentage depth dose (PDD). The curves are usually drawn at regular intervals of absorbed dose and expressed as a percentage of the dose at a reference point.

112. what is an isodose charts.

* It consist of family of isodose curves.

The depth dose value of curves are normalized:

1) At the point of maximum dose on central axis (Dmax).

2). At a fixed distance along the central axis in the irradiated medium (SAD.

113. write the equation to select wedge angle from hinge angle?

$$\text{wedge angle } (\theta) = 90^\circ - \frac{\phi}{2}$$

* ϕ = hingle angle

114. write the equation to determine the CT number (HU) and mention the CT number for air, bone and tissue in x-ray CT.

$$\text{CT number} = \frac{\mu_{tissue} - \mu_{water}}{\mu_{water}} \times 1000 \text{ (in hounsfield unit)}$$

Air = − 1000   water = 0.

Bone = 1000.   soft tissue = +40 → +80

115. what is Bolus?

* In radiotherapy therapy; bolus is a material which has properties equivalent to tissue when irradiated. It is widely used in practice to reduce or alter dosing for targeted radiation therapy.

* Tissue equivalent material used to reduce the depth of maximum dose. (Dmax). (made of rubber material 'Super Flab')

116. What is an isocenter of external beam treatment unit?

* The axis of rotation of three structures; gantry, collimator, couch coincide at a point is known as isocenter of external beam treatment unit.

117. what is dose volume histogram (DVH)?

Is a histogram relating radiation dose to tissue volume in radiation therapy planning. A 3-D treatment plan consist of dose distribution information over a 3-D matrix of point over the patient's anatomy. DVH's are most commonly used as a plan evaluation tool and to compare doses from different plans or to structures.

118. what are the types of DVH?

Two types of DVH are,

* Direct (differential) DVH.
* cumulative (integral) DVH.

119. What is mean by dicom format?

Digital imaging and communication in medicine (DICOM) is the standard for the communication and management of medical imaging information and related data. The standard include a file format definition and networ communication protocal that uses

TCP/IP to communicate between systems.

120. what are the requirements to deliver IMRT?

The clinical implementation of IMRT requires at least two systems:.

- (a) a treatment-planning computer system that can calculate non-uniform fluence map for multiple beams directed from different directions to maximize dose to the target volume while minimizing dose to the critical structure.

(b). a system of delivering the non-uniform fluence as planned. Each of these systems must be approximately tested and commissioned before actual clinical use.

121. what are the methods of delivering IMRT?

Methods to deliver an IMRT treatment are

- compensator based IMRT.
- Multileaf collimator (MLC) based
  - * Step & shoot mode.
  - * Dynamic mode.
- Intensity modulated arc therapy.
- Tomo therapy.

122. what is multi-leaf collimator?

MLC is a collimator (or) beam

limiting device that is made of individual 'leaves' of a high atomic numbered material, usually tungsten, that can move independently in and out of the path of radiotherapy beam in order to shape it and vary its intensity.

123. Name three advantages of MLC over conformal blocks:

* The MLC has several advantage compared with conventional field shaping:

1) Time for shaping and inserting of MLC is not required, reshaping and modulation of beam intensity in IMRT is an automatic process. The patient anatomy can be followed easily during the treatment planning.

2). patient setup time may also decrease.

3) Variants of conformal therapy have been considered that required each field be compensated or modulated. ~~The motion of the~~

124. How is helical tomotherapy differen from tomotherapy?

The major difference between the Tomotherapy and helical tomotherapy is that, in the former case the patient counch is stationary while the gantry rotates to treat each slice pair at a time and in the latter case the patient is translated continuously in helical manner along with the gantry rotation.

125. What is step and shoot IMRT?

* In this IMRT delivery technique, in which radiation dose is delivered in the form of small multiple segmented field called subfields, where the each subfield of uniform intensity implying that the beam is only turned-on when the MLC leaves are stationary in each of the prescribed subfield positions. There is no MLC motion while the beam is turned on.

126. What are difference between SRS and SRT.

SRS	SRT
* SRS is a 'single fraction' radiation therapy procedure for treating intracranial lesions. narrow multiple beams delivered through noncoplanar isocentric arcs	* The same procedure as SRS, where 'multiple dose fractions' are used.

* A high degree of dose in the target volumes 'conformity' is a hallmark of SRS.	* Accuracy of beam delivery is hallmark of SRS (or) SRT.

127. What are the methods of delivering 'SRS'?

* X-ray knife.
* γ - knife.

128. How many CO-60 Sources are used in γ-knife unit and what is the total activity of the CO-60 sources?

* The γ-knife contains '192-201' cobalt-60 sources of approximately 30 curies each, placed in circular array in heavily shielded unit.
* The total activity of CO-60 source of γ-knife machine is '6000 ci'.

129. What the methods of delivering TBI?

* Bilateral technique.
* AP/PA technique.

130. what are the disease treated with TBI ?

TBI with megavoltage photon beams is most commonly used a part of conditioning reigmen for bone marrow transplanatation, which is used in the treatment of a variety of disease such as leukemia, aplastic anemia, lymphoma, multiple myeloma, autoimmune diseases.

131. what is the purpose of beam spoiler used in certain ~~main~~ method of TBI delivery?

* Beam spoilers is always used in TBI treatment for the purpose of increasing lower energy components in the beam to avoid skin sparing, which is not desirable in TBI protocal.
* Skin/surface dose in megavoltage beam is less than Dmax.
* Beam spoiler has to be positioned close to the patient, for build up the surface dose up to at least 90% of the prescribed dose.

132. what is the dosimetric aim of TBI delivery?

An agrement of ±5% between the calculated and measured doses is considered reasonably good. An overall dose uniformity of ±10% is considered acceptable for most protocals.

133. what is TSET and why is that used?

* TSET - Total skin electron therapy., is an effective form of radiation - based treatment for treatment of mycosis fungoides.

* Entire surface of the skin is treated with radiation; however only low-energy electrons are used to destroy cancer cells.

135. what are the methods of delivering TSET?

* Translational Technique.
* Large electron field Technique.
* Rotational Technique.

136. what is Intra-operative radiation therapy (IORT)?

* IORT is a special radiotherapeutic technique that delivers in a single session a radiation dose of the order of 10-20Gy to a surgically exposed internal organ, tumor or tumor bed.

* Thus IORT combines two conventional modalities of cancer treatment, surgery and radiotherapy.

~~but; despite its long~~

137. what sources of radiation are used for IORT?

* Orthovoltage x-rays.
* Megavoltage electron beam.
* High dose rate Ir-192 brachy sources.

138. What are the advantages of heavy charged particles over x or γ - rays?

* The major advantage of heavy charged particles is their characteristic distribution of dose with depth.
* Small entry & exit point.
* Does not depend on tissue.
* Maximum dose is depth related - Bragg peak.

139. How is bragg peak formed by heavy charged particle?

* When a fast charged particle moves through matter, it ionizes atoms of the material and deposite a dose along its path.
* Due to their charge and increased mass, heavy charged particle deposit most of their energy at the end of their range, producing what is known as 'bragg peak'

140. Why Bragg peak not observed in electron Beam?

There is no Bragg peak observed in electron, because there is a large amount of electron scattering while passing through a medium.

* Even through individual electrons have similar total range along their tracks. it is not so along the depth due to electron straggling.

141. What is depth profiling or range modulation in proton beams?

* The range modulation technique is used that changes in SOBP plateau flatness, range and effective dose at the distal edge.

* Range shifter (rotating wheel with different thickness) is used to irradiate at different penetration depth (SOBP).

142. What are the corrections applied for excess tissue or lack of tissue due to surface irregularity?

* In certain treatment situations, the surface irregularity gives rise to unacceptable non-uniformity of dose within target volume. The problem can be overcomed by, including the use of wedged field or multiple field and the addition of 'bolus' material or 'compensators'.

* Bolus is tissue equivalent material used for orthovoltage radiation, but for higher-energy results in skin-sparing advantage.

* For higher energy radiation, tissue compensators should be used.

143. what is mg Ra equivalent?

* In historical days, brachytherapy sources is expressed in terms of 'equivalent mass of Radium'. The exposure rate is expressed in terms of effective equivalent mass of radium.

* The conversion is simply made by dividing the exposure rate at 1m by the exposure ~~mass~~ ~~of~~ rate constant of radium (point source filtered by Pt 0.5mm) at 1metre.

144. calculate the mg Ra equivalent of 10mci of Ir-192?

$$\text{Effective mg-Ra eq} = 10\text{mci} \times \frac{0.495}{0.825}$$

$$= 10 \times 0.6 \text{ mg}$$

$$\Rightarrow 6\text{mg}$$

0.495 → Exposure rate const of Ir-192.

0.825 → Exposure rate const of Radium-226.

($0.825\ mR\text{-}m^2/h\text{-}mg$)

145. Define air-Kerma strength?

Air Kerma strength is defined as the product of air Kerma rate in 'free space' and the square of distance of the calibration point from the source center along the perpendicular bisector.

unit :: $\mu Gy\, m^2/hr$.

$$S_K = \dot{K}_\ell \cdot \ell^2$$

$\dot{K}_\ell$ → air kerma rate at a specified distance 'ℓ'.

146. what is dose rate constant?

* The dose rate constant 'Λ' is defined as the dose rate to water at a distance of 1cm on the transverse axis per unit air kerma strength source in water.

$$\Lambda = \frac{D(r_0, \theta_0)}{S_K}$$

$$\text{unit} = \frac{cGy\, h^{-1}}{cGy\, cm^2 h^{-1}} \Rightarrow cGy \cdot h^{-1} U^{-1}$$

147. (a) Define geometric function $(G(r,\theta))$?

Geometric function $G(r,\theta)$ accounts for the variation of the relative dose due to spatial distribution of activity within the source. $G(r,\theta)$ reduces to $1/r^2$ for point source approximation and to $\beta/(Lr\sin\theta)$ for a line source approximatio with β and L defined.

148. Define radial dose function?

Radial dose function g(r) accounts for the effects of attenuation and scatter in water on the transverse plane of source ($\theta = \pi/2$), excluding fall off, which is included by the geometry function $G(r, \theta)$. It may also be influenced by filtration of photons by the encapsulation and source material.

149. What is anisotropy function $F(r, \theta)$?

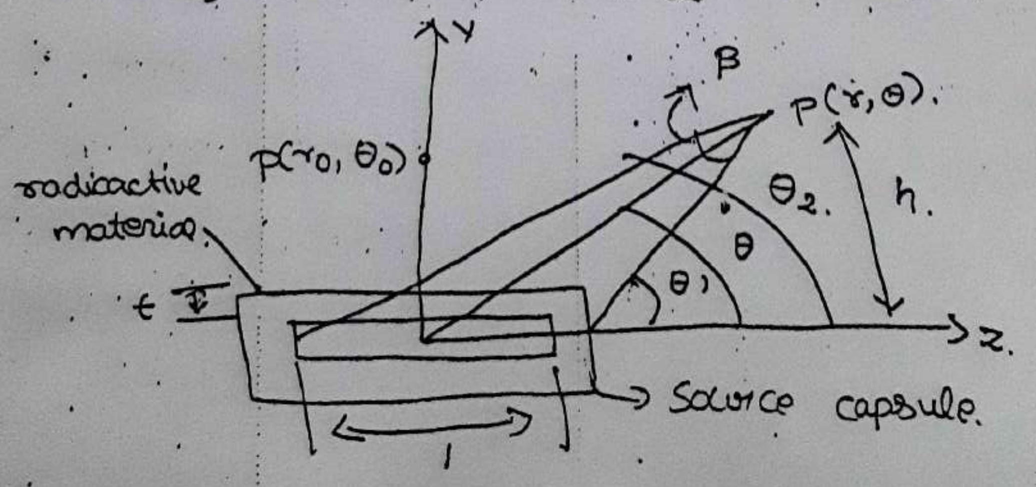
It accounts for the anisotropy of dose distribution around the source, including the effects of absorption and scatter in water. $F(r,\theta)$ is defined as unity on the ~~transfer~~ plane; however its value off the transfer plane decreses:-

i) as r decreases.

ii) θ approaches 0° or 180°.

iii) as source encapsulation thickness increases

iv) as photon energy decreases.



150. How is I-125 produced? write the equation.

I-125 is a reactor produced radionuclide and is available in large quantities. It production follows in two reactions.

$^{124}Xe\ (n;\gamma) \longrightarrow {}^{125m}Xe\ (57s) \rightarrow {}^{125}I\ (59.4d)$

$^{124}Xe\ (n,\gamma) \longrightarrow {}^{125g}Xe\ (19.9h) \longrightarrow {}^{125}I\ (59.4d)$

151. what are the diserable characteristics of ideal brachytherapy sources for temporary implant?

* It should be pure gamma emitter with an energy suitable for the intended treatment site.
* acceptable half life.
* high specific activity.
* physically small.
* cheap and easily produced.

152. what are the diserable characteristic of ideal brachytherapy sources for permanent implant?

* The sources of short lived radionuclide is used.
* emittion of low energy.
* emission of characteristic x-ray in range ~20keV photon advantage in permanent implant

153. Name three sources used for permanent implants.

* Gold (Au-198) - 2.8 days
* Iodine (I-125) - 60 days.
* paladium (Pd-103) - 17 days.

154. What is TRUS?

Transrectal ultrasonography or TRUS in short, is a method of creating an image of organs in the pelvis, most commonly used to perform ultrasound guided needle biopsy evaluation of the prostate gland in men with elevated prostate specific antigen or prostatic nodules on digital rectal exam.

155. Define LDR and HDR brachytherapy?

LDR	HDR
* LDR uses multiple sources, together with inactive spacers, to achieve a treatment dose rate of about 0.4 - 2 Gy/hr.	* HDR system use a single source of Ir-192 with typical ~~activity~~ dose rate >12 Gy/hr.
* Low specific activity.	* high specific activity.
* various forms: wires, needles, Tubes.	* Single form: Tubular source.

156. which isotope is used in ophtalmic applicators and?

* Intraocular melanoma is the most common eye tumor. An eye plaque, loaded with I-125 seeds.

* 'seeds' or 'grains' consisting of radioactive isotope of (gold - Au 198) have been used in past for interstitial implants.

* A less common approach to the treatment of lesions in the eye is based on β emitting sources. Sr-90 / Y-90.

157. what isotopes are considered as radium substitute & why?

Radium substitutes :-

cobalt-60, gold-198, cesium-137, Iridium-192

* Radium is not used, because itz daughter product is RADON, 'alpha emitter', it is gas which is soluble in tissue.

* Not easily detected by visual check, can escape through hairline crack in radium capsule.

* protection of these sources requires large thickness of lead.

* using very heavy protecting screens around the patient

158. Define 'point A' in gynecological brachytherapy?

'point A' was originally defined as 2cm superior to the lateral vaginal fornix and 2cm lateral to the cervical canal.

* Later, it was redefined to be 2cm superior to the external cervical os (or cervical end of tandem) and 2cm lateral to the cervical canal.

159. Define point 'B'?

* point 'B' defined to be 3cm lateral to 'point A'.

160. Give the typical manchester loading in gynecological brachytherapy.

First step:- Define treatment in terms of dose to a point ~~respect~~ representative of the target. i.e uterus, more or less reproducible from patient to patient.

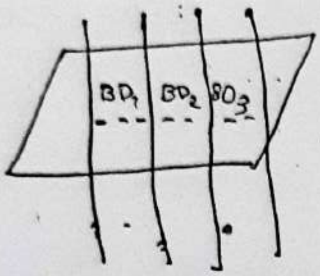
Second step:- Design applicators and their loading to enable the same-dose rate to this point A regardless of which combination of applicator used.

Third step:- Define a set of rules dictating the relationship, position, and activity of radium sources in the uterine and vaginal applicator [illegible] rates.

161. Define basal dose ?

The arithemetic mean of minimum dose rate, which is located half-way between the sources in the well-defined patterns.

162. what is basal dose in single plane implant.



$$BD = \frac{BD_1 + BD_2 + BD_3}{3}$$

BD ↓ basal dose

Single plane implant.

163 what is the refrence isodose in paries technique?

In the paris system, the dose specification is based on isodose surface, called refrence isodose. the value of reference isodose is fixed at '85% of the basal dose', which is defined as the average of minimum dose between sources

164. what are the methods of source localization in Brachy therapy using simulator?

* Fluoroscopy (simultors or C-arm).
* Core Beam CT (Acuity Simulator)
* CT: Diagnostic and CT simulator.

* plain Radiographs (Film) or Amorphosilicon imaging.

* other non-Radiographic method:. EM tracking

165. which neutron source is used in brachytherapy? Mention its half life.

* californium - 252, neutron emitting source is used in ca cervix, with combination of EBRT.

* half - life - 2.64 years.

* Mean energy - 2.3 MeV.

166. what isotops are used in HDR brachytherapy? and mention the initial activity of sources when loaded on HDR unit in each case.

* sources - cobalt-60, iridium-192
  - cobalt-60 ↓ 5.26 yrs
  - iridium-192 ↓ 74 days

* initial activity } - 2 ci   10 ci

167. what is PDR in brachytherapy?

PDR involves short pulses of radiation, typically once an hour, to stimulate the overall rate and effectiveness of LDR treatment.

Advantage of PDR:

* Full radiation protection. * no source inventory.
* no source preparation.
* optimization of dose rate distribution.
* only one source to be replaced every three months.

168. What is hyperthermia?

Hyperthermia is a form of therapy where heat is used to enhance effectiveness of radiation to destroy tumor. Hyperthermia (also called as thermal therapy or thermotherapy) is a type of cancer treatment in which body tissue is exposed to high temperature (up to 113°F)

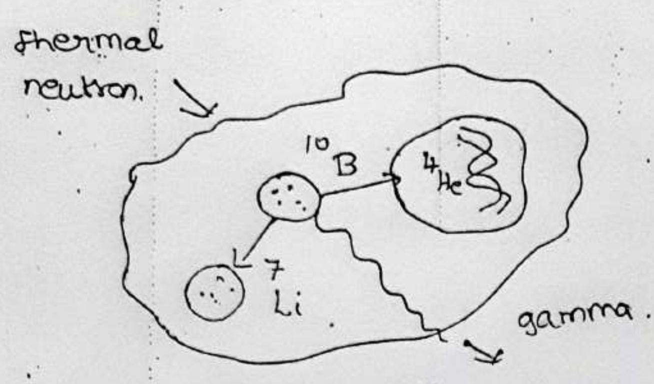
169. Give the reaction used in Boron neutron capture therapy (BNCT)?

* Boron neutron capture therapy is a high linear energy transfer (LET) radiotherapy exploitable for cancer treatment, based on neutron capture and fission reaction that occurs when ^{10}B is irradiated with thermal neutrons to produce α particle (^4He) and ^7Li nucleus.

$^{10}B + n$ (thermal neutron $\rightarrow$ $^{11}B^* \rightarrow \alpha + {}^{7}Li + 2.31$ Me[V]

$\downarrow$

^{4}He



cancer cell.

170. what is photodynamic therapy (PDT)?

* photodynamic therapy (PDT) is a treatment that uses a drug, called 'photosensitizer or photo sensitizing agent' and a particular type of light.

* when photosentizer are exposed to a specific wavelength of light, photoactivation causes the formation of singlet oxygen, ~~lober~~ which produces peroxidative reactions that can cause cell damage and death.

171. Mention two advantage of carbon ion therapy over proton therapy?

* Ion radiation in relation to photon is biologically more effective and thus, can improve chances of recovery.

* Ion beams can reach tumors lying deep in the body.

* Destructive effects are particularly strong with heavy ions.

proton beam therapy.	carbon ion therapy
* Lower cost.	* higher cost (2-3x proton
* Able to be delivered via gantry, allowing multiple beam angles	* usualy delivered via fixed beam, not permitting multiple angles
* more narrow range of RBE (1-1.1).	* There are uncertainties in RBE (1.5-3.4)

172. what is hardon therapy.

* particle therapy is also referred to more technically as hardon therapy. hardon therapy is a form of external beam radiotherapy using beams of energetic neutrons, protons or other heavier positive ions for cancer therapy.

eg:- proton therapy, carbon ion therapy.

173. what is half life and energy of Iridium - 192 source?

Half life - 74 days.

energy - 0.38 MeV.

174. In HDR unit, source is struck what will u do as RSO?

1). press the interrupt button on control console panel

2) press the emergency button on the wall.

3) open the treatment room door to allow the control console panel to indicate 'Door open'.

4) Enter the treatment room and press the red emergency button on the HDR unit.

5) Turn the emergency hand crack in the direction of the arrow.

6) If radiation survey shows the source is still in patient, immediately summon attending physician to begin surgical or other removal procedure.

7) Remove the applicator from patient and insert the applicator containing the stuck or broken source into emergency container. Do not cut the cable or guide tube.

8). Remove the patient from treatment room and re-survey the patient. Seal the treatment room door with radioactivity warning symbol and notify, RSO, physician, State regulatory agency.

175. you tried all interlocks and emergency button, but u can't not take back the source to the safe (OFF) position. what will yo do?

* Answer included in 174.

176. 1mR = how much μSv?

*. 1mR = 10 μSv.

177. what is meant by nuclear medicine?

Nuclear medicine is a specialized area of radiology that uses small amounts of radioactive materials, or radiopharmaceutical to examine organ functions and structures. It is called as internal treatment. It is also used in therapy procedures such as treating thyroid cancer with I-131.

178. what Radionuclide is used frequently and why?

Technitium-99m nuclear isotope is used for medical imaging in 90% of cases all over the world due to its near ideal nuclear characteristics of 6h halflife and γ-ray emission energy of 140 KeV.

179. what is the half life, energy and exposure constant of TC-99m?

Half life - 6 hours. energy = 140Kev.

exposure constant - 0.78 R/hr-mci at 1 cm.

(HVL = 0.028 cm Pb)

180. In PET what radionuclide is used nowdays.

position emission tomography (PET) is an imaging technique that uses radioactive substances to visualize and measure metabolic process in the body.

*. Different tracers are used for various imaging purpose, depending on target process within body.

→ 511Kev.] EC = 6R/hr/mci at 1cm.
→ 4 mm Pb]

eg. (F-18) FDG is commonly used to detect cancer. (F-18) NaF is widely used to detecting bone formation and (O-15) H_2O is used to measure blood flow.

181. what is the half-life of FDG? What is the use of using FDG?

Fluorine-18 decays by position, (β^+) emission and has half-life of 109 minutes.

The photon useful for diagnostic imaging are 511 Kev gamma photons.

182. What is the difference between FDG & Tc-99m.

Tc-99m	FDG
* Tc-99m is generator produced and are easily available in hospitals.	* F-18 are reactor produced. (cyclotron)
* It is transported all over the world.	* It is transported within cities due to low - half life.
* Tc-99m is low cost and used for diagnosize most the disease. * energy - 140 keV half life - 6 hours	* F-18 cost is high compared to Tc-99m, but image quality is superior to Tc-99m. * energy - 511 keV, half life - 108 mins.

183. This year recieved dose in 30 mSv ? in the next four years, is can get 20 mSv in every year why?.

No. according to AERB, the effective dose is 20 mSv/yr, averaged over 5 consecutive years. In single year, we can get 30 mSv. But averaged over 5 years should not exceed

184. what is the dose limit to fetus and why?

Dose limit to fetus of pregnant women is 1 mSv. It is because, ICRP consider that exposure of pregnant worker are considered and regulated as occupational exposure whereas exposure of embryo and fetus of pregnant workers as public exposure.

185. 1 Ci of Co-60, at one metre how much exposure will be there?

Exposure rate constant of Co-60 at one metre is - $1.30\ R\,m^2\,Ci^{-1}\,h^{-1}$

186. what are the types of photon interaction with matter?

* photoelectric effect.
* coherent (Rayleigh) scattering.
* compton effect. (incoherent scattering)
* pair production.

187. what are the type of electron interaction with matter?

1) Inelastic collision with atomic electrons. (ionization & excitation).

2) inelastic collision with atomic nuclei.
(bremsstrahlung)

3). elastic collision with atomic electrons.
(electron - electron scattering)

4). elastic collision with atomic nuclei
(nuclear scattering.

188. Example of radiative losses of electron?

when phosphours - 32, having 1.71 Mev of beta particle, striking the nucleus of Pb in lead - glass shield, bremsstrahlung production is significant.

* A good example Y-90, a tarcer widely used for radiotherapy, bremsstralung scintigraphy allows imaging of the specific localization of tracer to get tumor cites.

189. For the 6 Mev electron dosimetry which chamber will you use? why?

* According to reference dosimetry protocols, recomment that use of plane - parallel camber for energies below 10 MeV electron. and cylindrical chamber for energies equal or above 10 Mev electron beam

Reasons:

* It is useful for depth dose and surface dose measurement in build up region of mega voltage photon beams.

* A well-guarded plane-parallel chamber is thought to minimize effects from in-scattered electrons and therefore the chamber samples the electron fluence incident only through the front window.

190. How to measure neutron dose?

There are various tools for the measurement of neutron dose, such as TLD's, solid state nuclear track detectors, bubble detectors, activation foils.

191. What detector will you use for fast neutron & slow neutrons?

Fast neutron.	Slow neutron.
* He-3 proportional counter.	* Lithium-containing slow neutron detector.
* Diamond detector.	* He-3 detector
* Scintillators.	* B-10 lined proportional counters.
* Proton Recoil Telescope.	* BF_3 detector.

192. In which region, neutron detector working?

* In the proportional region, neutron detector are working. The amount of charge collected from each interaction is proportional to the amount of energy deposited in the gas of counter by interaction.

193. The BF3 detector will be surrounded by what material?

* It is essentially, BF3 chamber surrounded with paraffin or another moderator. (The thickness of moderator (eg. polyethylene) might range from 1 to 6 inches depending on neutron energy spectrum.

194. Why those are working in proportional regions

* Neutron detectors are 'proportional' counters because the total amount of charge created remains proportional to the amount of charge liberated in the original neutron detection event.

195. What are the advantages of Linear accelerator over cobalt -60.

Telecobalt	Linear accelerator.
* 1.25 MeV gamma photons.	* 4 to 21 MeV photon beam.
* Maximum dose at depth of 5mm.	* Maximum dose at higher depth with energy
* Source to be charged 2 to 3 half lives.	* No radioactive source.
* Leakage radiation present even while the beam is off.	* Radiation only when the source is switched is 'ON'.
* Larger penumbra.	* Smaller penumbra.
* Relatively uniform dose absorption.	* uniform dose absorption
* higher penetration deep seated tumor.	* higher energy than cobalt possible. also possible to select higher energy depending on patient thickness.
* gamma photons only.	* Electron beam of various energies possible

advantages of Linac:

* Accuracy more than CO-60.
* conformational and modulated beam treatment
* Sharp beam ho least penumbra possible.
* No source disposal.

advantage of CO-60.

* cheaper.
* Less expertise needed.
* May treat day and night continuous.
* used most for palliative treatment.

196. what are the isotopes used in nuclear medicine.

Technitium - 99m	- 140 Kev	- 6 hours
Iodine - 123	- ~~~~ 159 Kev	- 13.2 hr.
P - 32	- 1.7 Mev.	- 4.3 days.
Sr - 85.	- 514 Kev.	- 65 days
F - 18.	- 511 Kev	- 108 mins

197. whom the 'RSO' must advice regarding employme of pregnant women?

* RSO must advice 'scientific committee' That each hosipital have, and change the working condition of pregnant women.

198. where is CO-60 used?

* It is used in cancer therapy most in palliative cancers. It is also used in place of x-ray in ~~inception~~ inspection of materials to several internal structures flames or foreign objects.

199. what will you do if source gets struck?

* First conform whether the source is really struck or not.

1). check the rod position in the co-60 head in visual device outside the room.

2). open the door of treatment room and use survey meter to check radiation level or see the γ- zone monitor.

After conforming the source stuck → Remove the patient out of primary beam

↓

Attempt to return the source using the manual pushing device. (Avoid primary beam) T- Rod

↙ ↘

If succeful try to measure the dose recieved by the patient due to accident - call the radiation safety officer and service / maintaince to investigate the fault and rectify it.

* If not successful seal the room and door - call the radiation safety officer and service / maintainance to investigate the fault and rectify it.

* No further treatment shall be performed until the fault has been investigated and rectified. The checks performed in this process need to be documented.

200. What are the instrument used in general necessities for brachytherapy installations?

* planning system.
* Remote afterloaders.
* survey meters.
* Imaging devices.
* Body - site specific applicator.

201. Why do we go in for Ir-192 in spite of its half - life?

* Low gamma energy and high specific activity.
* Rapid dose fall off: (so no normal tissue exposed).
* Lesser room shielding required due to low energy.
* production and cost is minimum. and easily disposable.

202. Is the dose from Co-60 is β or γ?

The dose used from Co-60 treatment unit is γ- radiation 1.25 MeV average energy. Co-60 emits 'β' too. but it is stopped within

103. What are the QA test in brachytherapy.

According to TG-40, QA test for brachytherapy is weekly, source change or quartely, annually.

Each treatment day.	Room safety door interlocks, light, and alarms, console functions, switches, visual inspection of source guide	Functional.
	verify accuracy of ribbon preparation. (Auto radiograph)	
weekly.	Accuracy of source and dummy loading.	1mm.
	source positioning	1mm
Source change or quartely.	calibration.	3%.
	Timer function.	1%.
	accuracy of source guides and connectors	1mm.
	Mechanical integrity of applicators.	Functional.
Annual.	Dose calculation algorithm (at least one standard source configuration for each isotope)	3% 1mm
	simulate emergency conditions	
	verify source inventory.	

204. what is the energy in linac beyond which neutron monitoring is necessary ? why?

* In high energy Linac (above 10MV.) Installations, neutrons are produced by x-ray neutron (x, n) and electron - neutron (e, n) reactions.

* Thus neutron contamination is produced by high energy photons and electrons incident on target, primary collimator, beam flattening filter, collimator jaws, beam accessories, patient.

* The reason for neutron monitoring is neutron can activate other elements, which remain radioactive and will contribute to the radiation exposure of radiotherapy staff entering the treatment room after high energy photon beam treatment.

eg. reactions such as O^{15} (2 mins), N-13 (10 mins).

205. what is mecanism taking place between cadminium and thermal neutrons? what is γ energy emitted

$$^{113}Cd_{48} + {}^{1}n_{0} \longrightarrow {}^{114}Cd_{48} + \gamma \text{ (5 MeV)}.$$

reaction of Boron with thermal neutron.

$$^{10}B_{5} + {}^{1}n_{0} \longrightarrow {}^{7}Li_{3} + {}^{4}He_{2}$$

(α-particle).

206. why it is advantages to use boron instead of cadmium for shielding thermal neutrons?

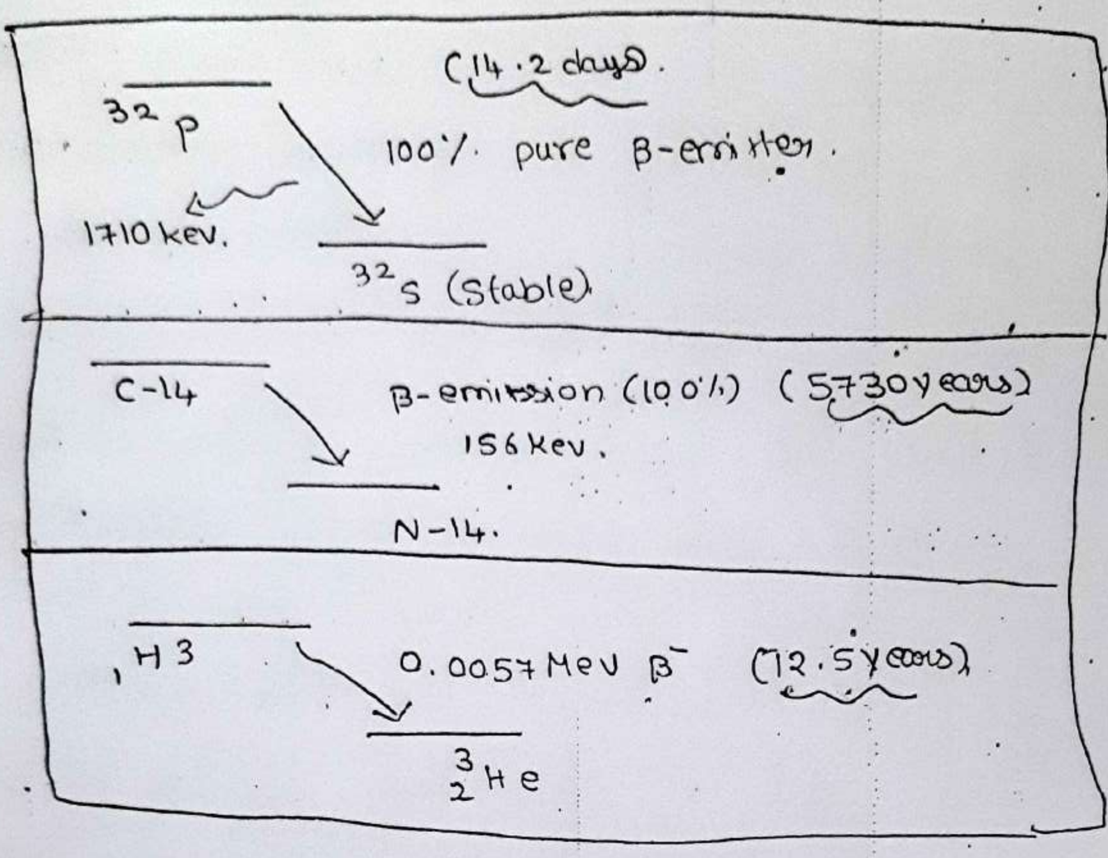
* The thermal neutrons are absorbed by materials such as boron or cadmium

* However boron have distinct advantage over cadmium in absorbing thermal neutron. This absorption of neutron by boron results in liberation of α particle that is easily stopped. In case of cadmium, this neutron capture is accompanied by emission of γ - which in turn must be shielded.

207. At door, is it enough if we shield using hydrogenous material for neutron shielding?

A maze entranceway can be designed to reduce greatly the quantity and energy of neutron reaching door. In most cases, few inches of hydrogenous material such as polyethylene in the door are sufficient to ~~reat~~ reduce the neutron dose equivalent to acceptable level outside the treatment room. and neutron are absorbed by (n, γ) reactions in the door, gamma rays are released with few MeV of energies. These γ-rays are attenuated by lead in the door & dose rate outside room is

208. what is the decay scheme of P32, H3, C14.



209. If a survey does not show any readings, what are you interpretation?

* Batteries are most frequently the cause of problems with survey meter. They should be changed whenever they are weak.

* connection cable ; The cable connecting the probe to the electronics package is an element that should be checked frequently. with prolonged use this cable may become defective, either no reading or false high reading.

210. what is the unit of calibration factor?

The calibration factor is ~~normally~~ (N) is dimensionless when the indicated value already has same units as the measurand, a perfectly accurate instrument should have calibration factor of one.

211. Explain the light gamma congruence check.

* optical field used to setup patient and the radiation field should match.

* Error in radiation and light field congruence could lead to geographical miss of the tumor.

* A simple quality assurance test tool for visual verification of light and radiation congruent using EPID and computed radiography is used.

* The test is normally performed at a gantry angle of 0°. but possible movement of light source as ganry is rotated could be detected if the congruence of radiation and light field is checked at other angle. At least two field sizes. ($10 \times 10 cm^2$ and $20 \times 20 cm^2$) and four different gantry angles (0°, 90°, 180°, 270°) should be tested.

212. what are steps to be taken incase of misadministration of isotope?

* Immediately use all available means to minimize any adverse effects.

* Inform responsible nuclear medicine physician.

* Inform patient and referring physician.

* calculate dose.

* Indicate corrective measures and implement it.

* Submit report to the head of department, to radiation protection comittee, it required to the regulatory authority.

213. what phosphor is used in TLD?

* Among thermoluminescence phosphor, dysprosium doped calcium sulphate ($CaSO_4$: Dy) phosphor, is one of the most efficient phosphor, for use in dosimetry. other phosphors such as LiF : Ti, Mg, and CaF_2 : Mn are also used.

214. what are radiation emergencies in nuclear medicine?

* Spillage of radio pharmaceuticals.

* Misadministration of radiopharmaceuticals to patient.

* Loss of sources in the department of in transit.

* vomiting of radiopharmaceutical by the patient,

* Death of patient with administered radiopharmaceutical in the body.

215. If source is spilled, how will you know the identify of source?

* use a G-M survey meter, for isotopes that are detectable by GM survey, the identity of which source is found out by depending on the radiation level it emits, and the spillage is identified by surveying or check the area around with G-M survey meters,

216. Enumerate the output procedure for CO-60.

1) * The calibrated thimble chamber is placed at refrence depth of 10cm in $30 \times 30 \times 20 cm^3$ water phantom. For SSD measurement the surface of water is kept at 80cm, such the source to chamber distance is 90cm.

* Then five readings are taken each for '1 minute', for refrence field size taken as $10 \times 10 cm^2$.

* For SAD measurement water surface is kept at 70 cm, so that source to chamber distance is 80 cm.

2), The absorbed dose rate to water at refrence depth is obtained by using the following formula.

$$\text{output (Dose rate in water)} = \begin{pmatrix}\text{Meter} \\ \text{reading}\end{pmatrix} \times (K_{pol}) \times (K_S) \times (K_Q) \times (N_{D,W}) \times (K_{TP})$$

K_Q → correction factor for energy and for Co-60 is 1.

3.) since, the chamber has been ~~keep~~ kept at depth 10 cm, the output obtained from above eqn is 10 cm depth. In order to obtain at output dmax. as a function of field size the formula is divided by 'depth dose' (PDD)

4.) Then comparing the output obtained by two methods (actual dosimetry and decay method), the percentage error for every month and there after, every year has been calculated.

217. What is advantages of G/M counter?

* They are cheap detector with a large variety of sizes and applications.

*. G/M Survey are widely used for low radiation levels.

*. very sensitive even for production of single ion pair.

* They can detect all type of radiation (α, β, γ).

* pulse height is independent of nature and energy of incident particle or radiation.

218.. Difference between G/M counter & ion chamber.

G/M counter.	Ion chamber.
*. The detector operates in pulse mode only.	* Ion chamber can be operated in 'current' or 'pulse mode'
* used to detect very low level of radiation (applicable for leak testing & contamination)	* Ionization chamber operating in current mode are more suitable for higher dose rate measurement.
* G/M detectors suffer very long dead time.	* There is no dead time in ion chamber.
* high amplification	* No amplification.
Range : 0-50mR/hr, 0-500mR/hr 0-5000mR/hr	

219. Tolerance limit for Kidney?

* Doses less than 5Gy would not materially affect the Kidney, whereas doses greater than 10 Gy would cause rapid gastrointestinal death. (8-10Gy).

* parallel organ (Kidney) at least 200CC should receive a dose of 16 Gy or lower (Dose to ≥ 20.0CC ≤ 16 Gy).

220. why do we use polythene radiator in fast neutron monitoring?

* The detection efficiency for neutron was increased by a factor of 6.5 to 10, without and with a polyethylene radiator.

* The minimum detectable fast neutron dose could be lowered from 30 mR to 5 mR by attaching a polyethylene radiator to the CR-39 foil.

221. Define. Two source rule?

If the thickness of the required barrier is about the same for each secondary component, 1 HVL is added to the larger of the two barrier thickness. If the two thickness differ by a TVL or more, the larger barrier is used.

222. 12000 RHM source at 1 metre, and with 4 TVT, what is the radiation level,

one TVL = 1200 RHM. Two TVL = 120 RHM.

three TVL = 12 RHM. Four TVL = 1.2 RHM.

223. whether 10 mrem/day is permissible in diagnostic laboratory console.

* The maximum permissible radiation level in controlled area (control console) is 40 m rem/week. (working of 5 days),

* one day is about 8 m rem/day.

hence it is not acceptable.

224. what type of survey meter is used in diagnostic laboratory?

* In diagnostic laboratory, ionization based survey meter are used. The use of survey meter (such as G-M counter or proportional counter is not recommended for diagnostic radiology. such devices are typically designed to detect isotope emissions. (eg: NM, CO-60, brachy).

225. why 400 Gy is taken for shielding calculation of Co-60 source?

For a Co-60 treatment facility, the workload is 40 patients /day is a reasonable assumption. If the dose delivered ~~by~~ per patient at a isocentre is 3 Gy and the facility is used for Five days per week, then

$$\text{workload} = \frac{40\,\text{patient}}{\text{day}} \times \frac{3\,\text{Gy}}{\text{patient}} \times \frac{5\,\text{days}}{\text{week}}$$

$$= 600\ \text{Gy/week at isocenter (80 cm)}$$

$$= (600 \times 0.8^2) = \boxed{\frac{384\,\text{Gy}}{\text{week}}\ \text{at}\ 1\,\text{m}}$$

∼ approx = 400 Gy taken.

226. How do you arrive 40 mR/week as permissible dose limit to occupational worker?

The annual ~~eq~~ effective dose limit prescribed by ICRP 60 is $\frac{20\,\text{mSv}}{\text{yr.}} = 2000\,\text{mR}$.

weekly permitted dose for 1 year, average of 50 weeks $= \frac{2000\,\text{mR}}{50\,\text{weeks}} = \boxed{\frac{40\,\text{mR}}{\text{week}}}$

227. what is the range of measurement of radiatio by CR-39?

* CR-39: a widely used neutron dose detector, and insensitive to x, γ, β particles. Neutron dosage can be determine by reading track length of CR-39 under microscope.

Energy response:. 100KeV ~ 40MeV.

Dose range:. 0.2mSV ~ 50mSV.

228. Difference between TRS-277 & TRS-398.

TRS-277. (1987).	TRS-398. (2000).
* Determination of absorbed dose to water in radiotherapy beam based on application of several co-efficients, perturbation and correction factors.	* Absorbed dose determination in EBRT.
* Assumes used has a calibration factor for exposure N_x or air Kerma N_k for the ion chamber/ electrometer.	* Recommending procedures to obtain the absorbed dose in water from measurement made with ionization chamber in EBRT.

229. what is the refrence depth for photon measurement using TRS - 398 protocol.

The refrence depth for high energy photon beams according to TRS-398 is $20 g\ cm^{-2}$ and $10 g\ cm^{-2}$.

230. A telecobalt unit having leakage radiation in off condition at the treatment head is 16 mR/hr at 5cm from the surface, is it permissible level?

* permissible leakage radiation, of telecobalt, Exposure rate at 5cm from surface; head is 20 mR/hr when the unit is loaded with maximum RMM. Hence it is acceptable

231. what are type approved machine?

* Type approval or certificate of conformity is granted to a machine or products that meets a minimum set of regulatory, technical and safety requirements by the authority.

232. How will you start radiotherapy set up as RSO?

1) programe design and Implementation. (assessment of insitute clinical needs, and ... minimum equipment specification, staff training)

2) Radiotherapy Facility design.

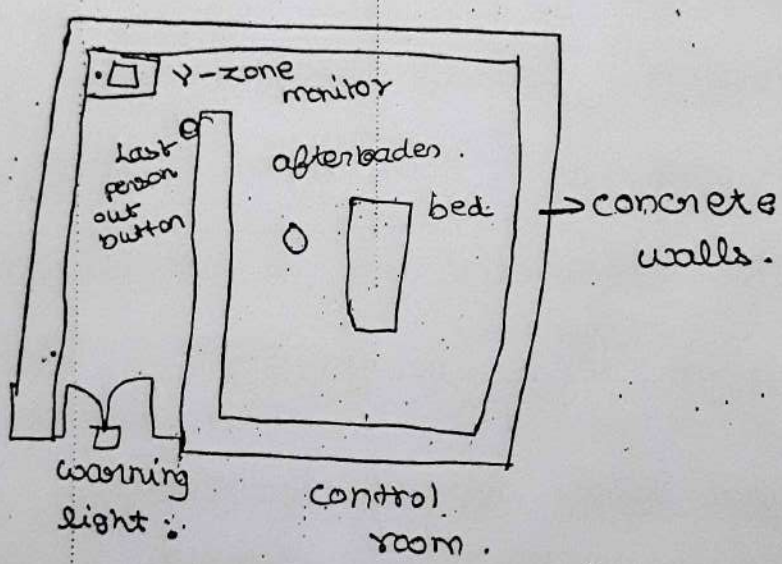
(EBRT, LDR, HDR brachy etc).

3). staff requirement for a radiation therapy program. (patient assessement, Radiation safety).

4). Equipment. (Type of equipment, QA of equipment, maintaince)..

5). Radiation protection and safety

233. Layout of manual brachytherapy. (afterloaders).



234. purpose of using gamma zone monitor in brachy therapy?

* γ-zone monitor primarily meant to serve as a gamma zone monitor to indicate dose rate and alarm status (visual and aural), once the dose rate exceeds the preset level fixed by the user.

One word answers.

1). Dose limit of 20mSv/year to radiation worker refers to a) equivalent dose b) effective dose c) Exposure d) commited dose

2). Mass collision stopping power of charged-particle is expressed in unit of a) $MeVs^{-1}$ b) $MeVcm^{-1}$ c) $MeVcm^{-2}g^{-1}$ d) $MeVgm^{-1}$

unit of linear stopping power - $MeVcm^{-1}$.

3). The leakage radiation level at 1m from xray tube is a) 1mGy in one hour b) 1mGy/hour c) 0.1mGy in one hour d) 0.1mGy/hour.

4). which of the following modality uses low kV x-rays. a) computed tomography b) Interventional Radiology c) Bone mineral densitometry d) Mamography

5). what is the UN classification for radioactive materials? a) 7 b) 6 c) 4 d) 1

6). what is the discharge limit of radiation level at 1meter for a patient administered I131

a) 50 µSv/hr b) 25 µSv/hr. c) 1Sv/hr.

d) 10 Sv/hr

7). The specific γ-ray constant of I131 is ($Rm^2/h\cdot ci$) a) 2.2 b) 0.22 c) 0.32 d) 0.06

8). As per ICRP-103 the minimum value of radiation weighting factor for neutron is

a) 2.5 b) 5 c) 2 d) 1

9). Specific activity is expressed in unit of

a) Bq/gm b) Bq/cm c) Bq/sec d) Bq/litre

10). Mass collission stopping power of charged particle for given medium with atomic no. Z and atomic wt A is proportials to a) Z/A

b) Z c) A d) None of these

11. The earliest radiation effect, which appears exposure to large acute doses is a) Skin burns

b) cataract c) Temporary sterlity d) Radiation Sickness

12. Bremsstrahlung produced by a charged particle is

a) Inversely proportional to square mean of charged particle

b) proportional to square mean of charged particle.

c) Directly proportional to mean of charged particle.

d) Independent of mean of charge the particle

13. contamination shall mean presence of radioactive substance on a surface in excess of 0.4 Bq/cm^2 for beta & γ emitters and 0.04 Bq/cm^2 for α-particles

14. The purpose of using screen along with film in radiography is a) to improve resolution b) to decrease patient dose c) to provide support to film. d) all the above.

15. Transmitted intensity of photon in narrow beam geometry is expressed by a) $I = I_0 e^{-\mu x}$ b) $I = B \cdot I_0 e^{-\mu x}$ c) $I = I_0 e^{-\mu x}/B$ d) $\frac{I}{B} = I_0 e^{-\mu x}$

16. Bragg gray cavity theory is applicable to a) electrons b) photons c) heavy charged particle. d) all these radiation.

17. unit of particle flux a) s^{-1} b) $cm^{-2}s^{-1}$ c) cm^2 d) $MeVs^{-1}$

18. The predominant interaction by photons from I-125 titanium material is a) Rayleigh scattering b) photoelectric effect c) compton scattering d) pair production.

9D. The A_1 value of CO-60 is 0.4TBq. Its A_2 value is 0.4TBq. A teletherapy source of CO-60 of activity 444TBq is to be transported, the type of package that will be used for carriage of such material is a) type A b) Type B(U/M) c) Excepted package d) Industrial package Type (I).

20. When the maximum external radiation level on the source is 600 μSv/hr & Transport index 0.8 the package belongs to a) I white b) II yellow. c) III yellow d) III yellow exclusive use.

235. Effects of stochastic and deterministic effect at cellular level?.

Deterministic effect.	stochastic effect.
* Lethal DNA damage.	* Sub-lethal DNA. damage.
* cell death.	* Gene mutation.
* ↓ Tissue and organ function.	* Replication of mutated cells.
eg. cataract, xerostomia	eg. Leukemia, Thyroid cancer

236. Dose level for CA test of a radiation worker

* Requirement of CA test can be decided based on committee review (or) inspection.

* priority review by present. > ~~50mSv~~ 100mSv committee.

237. Radioactive waste management in nuclear medicine.

procedure of Radioactive management:

* waste collection, waste segregation & transfer. waste treatment, waste storage, waste disposal.

238. Methods of segregation of waste.

* Delay & Decay.
* Dilute & Disperse.
* concentrate & contain.
* Incineration.

239 - Activity limit of waste for disposal.

Activity limit for discharge of radioactive liquid waste is 3.7 MBq/day or an average monthly concentration of 22.2 MBq/m^3 for I-131.

240. Radiation level outside the diagnostic is 2mR on which basis whether the level is acceptable or not?

* According to AERB, the weekly recommended dose for uncontrolled area is 2mR/week.

241. Energy of Fast and thermal neutron?

Fast neutron → 1-20 MeV.

thermal neutron - 0.025eV.

242. what will be changed if SSD is increased?

* As the SSD is increased, the PDD increases because of the change in the inverse square law with a change in distance.

* As the result of these changes, special consideration must be used to calculate treatment time and MUs at extended distance treatment with use of PDD.

243. what is difference between legislation and regulation.

legislation	regulation.
* Laws made by the competent authority of the enabling act in one of their responsibity.	* These are rules made by the authority to follow the laws made.

244. what are the types of system used in HDR brachy

* Interstitial.
* Intracavity.
* Intraluminal.
* Intravascular.
* Surface mould.

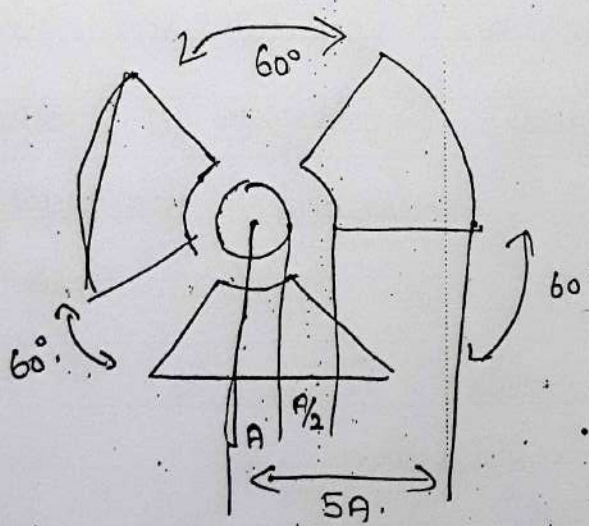
245. How neutron deposits its dose in tissue?

* The type of interaction and amount of dose deposited is dependent on neutron energy and absorbing material.

* Neutron are Indirectly ionizing radiation, and gives rise to densely ionizing particle; recoil proton, α-particles, and heavier nuclear fragments.

* These particle deposit dose in tissue.

246. Draw the trifoil radiation symbol?



247. Threshold level for eye lens?

* Threshold dose to induce non cancer tissue reactions in eye lens

- 0.5 Gy

248. CR-39 chemical formula.

$(C_{12}H_{18}O_7)_n$ is a polymer family poly allyl

249. For thyroid cancer, what type of isotope should be used?

* For thyroid cancer, Iodine-131 isotope is used, because thyroid organ takes iodine from the body.

250. At what level you can maintain TLD?

* TLD is maintained at chest level. and if we wear apron, it should be placed inside of it, touching the body. and one outside the apron at neck or eye level.

251. In which condition you can use wrist badge?

* Some special procedures in radiology such as angiography, fluorescopy, the same amount of radioactive dye is injected into the patient body while exposure to x-ray. In such cases wrist badge is used.

252. Suppose the patient administered to I-131, but patient vomiting immediately. what will you do as RSO?

* To prevent air borne contamination using Sodium Thiosulphate.

253. What is $T_{1/2}$ of neutron?

10 to 15 minutes.

INDEX

NAME: RUPESH KRISHNA STD.: M.Sc SEC.: RSO ROLL NO.: AU SUB.: Medical physics.

S. No.	Date	Title	Page No.	Teacher's Sign / Remarks
		PART - II.		
		THINK LIKE A PROTON +		
		AND STAY POSITIVE		
		— ALWAYS —		

254. If 200mci I-131 is given to patient for uptake but after 2hours patient died; you are RSO what you will do?

* If patient died after, injecting or inhaled I-131 radio isotope. the dead body should be stored in the morgue until the level comes down to prescribed limits.

* If situation demands immediate release of the body, autopy may be performed to remove vital organ containing radioactivity.

255. what is the radiation level to release patient dead body, containing I-131.

* Maximum activity of Radionuclide for disposal of corpses without special precautions containing I-131 is 400 MBq

256. How many days you will keep the body for attain permissible level?

* of 200mci, only 20-30% uptake is taken in thyroid organ, others are excreted whereas in dead patient, the patient body should be stored minimum of 2 days.

257. why meter reading increases while approaching the source?

* Since, the radioisotope emitts radiation in all direction (isotropic). The intensity of radiation is inversely proportional to the square of distance.

* So meter reading increases as approaching the source, more ionization occurs in chamber.

258. At 1m distance radiation level is 2mR/hr, at 3m distance what is radiation level.

$I_1 = 2mR/hr \quad I_2 = ? \quad r_1 = 1 \quad r_2 = 3.$

$I_1/I_2 = r_2^2/r_1^2 \Rightarrow \frac{2}{I_2} = \frac{(3)^2}{1^2}$

$I_2 = 2/9 = \boxed{0.22 mR/hr.}$

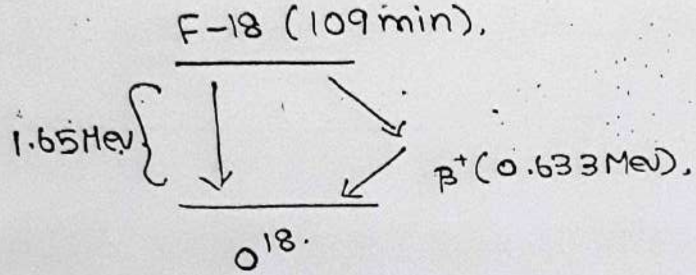
259. In output measurement, how will you measure polarity correction factor?

when a chamber is used in beam that produces a measurable polarity effect, the true reading is taken to be the mean of absolute values of reading taken at both polarities.

$$K_{pol} = \frac{|M+| + |M-|}{2M}.$$

M+ and M- are the electrometer reading obtained at positive and negative polarity, and M is the reading obtained with polarity routinely (+ or -).

260. Decay Scheme of F-18



261. what are different types of misadministration in nuclear medicine?

* Administration of radiopharmaceutical (rp) to worng patient (10%)
* Administration of wrong activity (2%).
* administration of wrong rp (80%).
* Administration through wrong route eg. oral, injection, intravenous or musculor.
* Administration of rp in pregnant patient.

262. Acceptable limit of misadministration of dose?

* 10% for prescribed in therapeutic dose.
* 50% for prescribed diagnostic dose.

263. Define speed of the medical radiographic film?

The speed of a film is determined by giving the exposure required to produce an optical density (OD) of 1 greator than the OD of fog.

264. Define latitude of radiographic film?

The latitude is defined as the range of exposure over which the OD's will lie in the linear region.

265. How leakage radiation measured from diaphram?

* close the x-ray tube diaphragm and place the tube down on the x-ray table.
* surround the x-ray tube with at least 6 big x-ray cassettes with film, forming a close volume around the x-ray tube housing.
* perform a heavy exposure. for eg 120KV/200mA/s
* Develop the film and identify the dark places on the film.
* place a large volume ionisation chamber at the places, where the films are most dark, 10cm from tube housing and repeat the heavy exposure.

* Repeat the measurement at other places where around the tube housing and record values.
* calculate the dose rate of measured leakage radiation and compare it with recommended limit of 1mGy/hr @ 1 metre. (26 μGy/1sec @ 10cm)

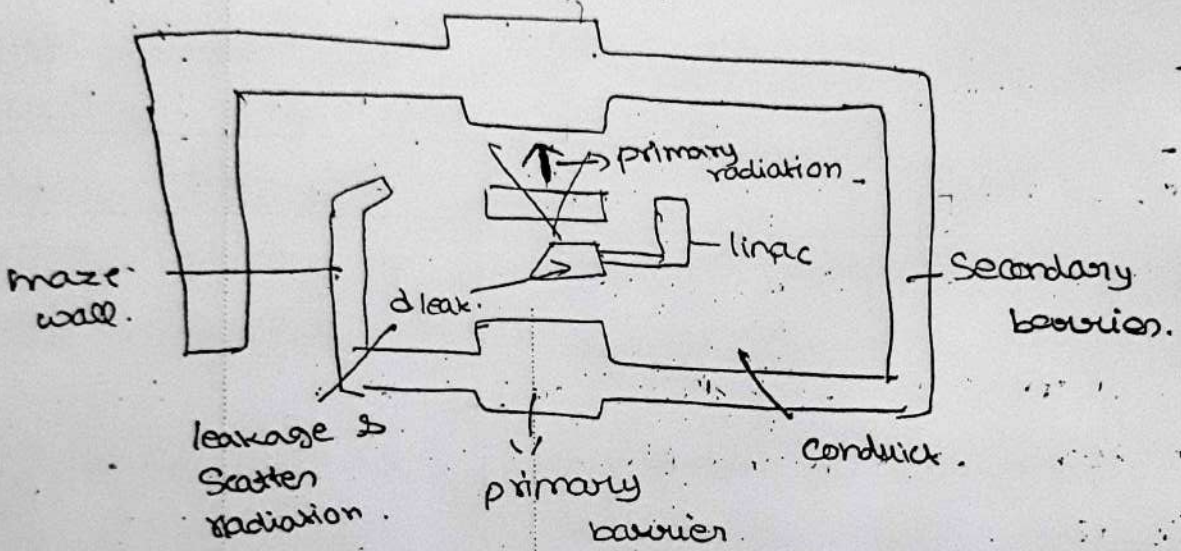
266. compare TLD, film badge for personal monitoring

TLD.	Film badge.
* Does not provide permanent record like film badge.	* provide permanent record of radiation.
* unaffected by visible light, moisture and mechanical vibration.	* Its film fade at high temperature and humidity.
* Limited shelf time (one month),	* Reusable. can be used for about 100 times. (300 months).
* can be read in anywhere	* complete dark room procedure.
* Instrument for reading TLD badge is expensive.	* Least expensive..
* It is more sensitive and accurate than film badge.	* Film gets affected to high sensitive of light, pressure

287. what parameters of β-Source, determine Shielding?

Low atomic number. (Bremsstrahlung radiation occurs). materials like Aluminium, plastic used.

288. Draw model of 10MV linac room?



289. why we put MV for X-rays and MeV for cobalt-60.

1) The photons emitted by high energy X-ray machine like linac has a spectrum of energy from 0 up to energy of the electron creating bremsstrahlung. This it have heterogeneous energy spectrum because of bremmstrahlung effects.

* photons emitted from radioactive decay would be properly be labelled MeV because they are mono-energetic (homogenous).

280. Difference between Teletherapy and Brachytherapy.

Teletherapy.	Brachytherapy.
* Treatment in which radiation source is kept at a distance from patient.	* Treatment in which sealed source is placed inside or next to the area required treatment.
* External radiotherapy.	* Internal therapy.
* Beam is directly in one direction.	* dose delivery in isotropic view.
* More shielding required for room and transport of sources.	* Less shielding compared to teletherapy.

281. How to measure telecobalt leakage check?

* Instantaneous dose rate for leakage radiation was measured at 5cm from source heady using survey meter and measuring tape during OFF condition. (and also ~~tem~~) 1 metre distance)

* And also in patient plance of radium 2m centered on isocentre during on condition. other than patient plane leakage radiation at 1metre from source is also measured.

282. what are the reference condition for output measurement in electron beam.

Influence quantity.	Reference characteristics
* phantom material.	For $R_{50} \geq 4 g cm^{-2}$ water. For $R_{50} < 4 g cm^{-2}$, water or plastic
* chamber type	For $R_{50} \geq 4 g cm^{-2}$ plane-parallel or cylindrical. For $R_{50} < 4 g cm^{-2}$, plane parallel.
* Refrence point on chamber.	For plane parallel, on the inner surface of the window at its centre. For cylindrical, on the central axis at the centre of the cavity volume.
* position of refrence point on chamber.	For plane parallel, at point of chamber. For cylindrical, 0.5 raje deeper than point of interest.
* SSD.	100 cm.
* Field size at phantom surface.	For $R_{50} \leq 7 g cm^{-2}$ 10 cm x 10 cm. For $R_{50} > 7 g cm^{-2}$ 20 cm x 20 cm

283. What are the refrence condition for output measurement in Co-60 beam?

Influence quantity.	Refrence characteristics.
* phantom material	water.
* chamber type.	cylindrical or plane-parallel
* Measurement depth.	$5 g cm^{-2}$ (or $10 g cm^{-2}$)
* Refrence point of chamber.	For cylindrical, on the central axis at centre of cavity volume. For plane parallel, on the inner surface of window at it centre.
* position of refrence point of chamber	For cylindrical and plane parallel, at measurement depth Z_{ref}.
* SSD or SCD.	80cm or 100cm.
* Field size.	10cm x 10cm.

284. How will neutron decay?

Decay of neutron.

$$n \rightarrow p + e^- + \bar{\nu}$$

p ↓ proton

$\bar{\nu}$ ↓ anti neutrino.

285. when you are received transport container, what will you do as an RSO?

1). package will be monitored for Surface contamination and external radiation level within 3hours after receipt if recieved during working hours or within 18 hours if recieved after working hours.

2). All shipment of liquids greater than exempt quantities will be tested for leakage.

3). put on gloves to prevent hand contamination.

4). visually inspect package for any sign of damage (wetness, crushed) if damage is not, stop opening procedure.

5). Measure the radiation level from 1metre

286. what is minimum contamination level for brachytherapy?

Minimum leakage and contamination level limit < 185 Bq.

287. what the characteristics of nuclear medicine ~~therapy~~ diagnostic sources?

* Diagnostic range of 100 - 300 keV.
* No charged particle emission.

* Easily localized in the area of interest and eliminated from other parts & body.
* Should not alter any biological behaviour of organ.
* Suitable half life.
* Should be elimated from body after scanning procedure.

388. what ICRP recommendation genetic risk for workers and public,

ICRP-60.

Radiation Risk.	Fatal cancer	non-fatal	Genetic effects.
workers.	$4\times10^{-2} Sv^{-1}$	$0.8\times10^{-2} Sv^{-1}$	$0.8\times10^{-2} Sv^{-1}$
public.	$5\times10^{-2} Sv^{-1}$	$1\times10^{-2} Sv^{-1}$	$1.3\times10^{-2} Sv^{-1}$.

389. Define DDREF (Dose & Dose rate effectiveness Factor)

* The DDREF is defined as the factor by which radiation cancer risk observed from large acute dose should be reduced when the radiation is delivered at low dose rate or in series of small dose fractions.

ICRP recomends,

DDREF = 2 { For doses below 200mSv at any dose rate & For ~~dose~~ higher dose if the dose rate is < 100 mSv/hr.

290. what reading will 10000 RHM source produce in case of shielding is done with 4 TVT at a distance of 5 metre? what dose is recived by a person if he is exposed for 10 min?

10000 RHM → shielding 4 TVT gives

⇒ 1 RHM (Roentgen per curie per hr at 1 metre distance).

$\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$; $I_1 = 1$ $I_2 = ?$

$r_1 = 1$ metre $r_2 = 5$ metre.

$\frac{1}{I_2} = \frac{5^2}{1^2}$ ⇒ $I_2 = \frac{1}{25}$.

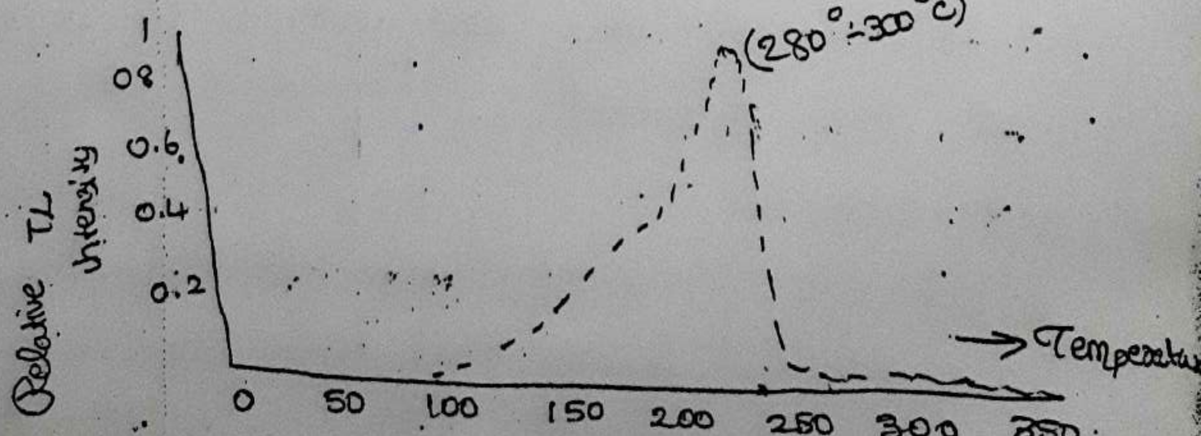
$I_2 = 0.04$ Roetgen at 5 metre.

$I_2 = 0.04 \times 0.1666$ (10 mins).

$\boxed{I_2 = 0.00666}$ Roetgen at 5 metre

if he is exposed for 10 mins

291. Draw TLD dose response curve.



what is dose level at peak ?

The peak in the glow curve may be correlated with trap depths responsible for thermoluminescence emission.

292. Disc. dimesion of TLD cards.

1st Disc - 1mm Al and 0.9mm cu.
(For x & γ)

2nd Disc - 1.5mm plastic. (cut of soft beta, and gives x, γ and hard beta)

3rd Disc - no filter. (record all radiation.

* Each disc having, a diameter of 13.3mm and thickness 0.8mm & weight ~~250mg~~ 250mg.

293. Dose range and threshold of TLD?

wide range of doses from 0.1mSv to 10Sv.

Detection threshold - 50μSv.

294. KVp, mA and timer setting in diagnostic x-ray.

(timer setting) mAs. ← A special type of timer monitor the product of mA and terminates the exposure when the desired mAs has been attained. (equal to no. of electrons flowing from cathode to anode per unit sec) ⇒ (mA) tube current

KVp (peak kilo voltage) is the maximum voltage applied on x-ray tube, it determines the kinetic energy accelerated in the x-ray tube and the peak energy of x-ray spectrum.

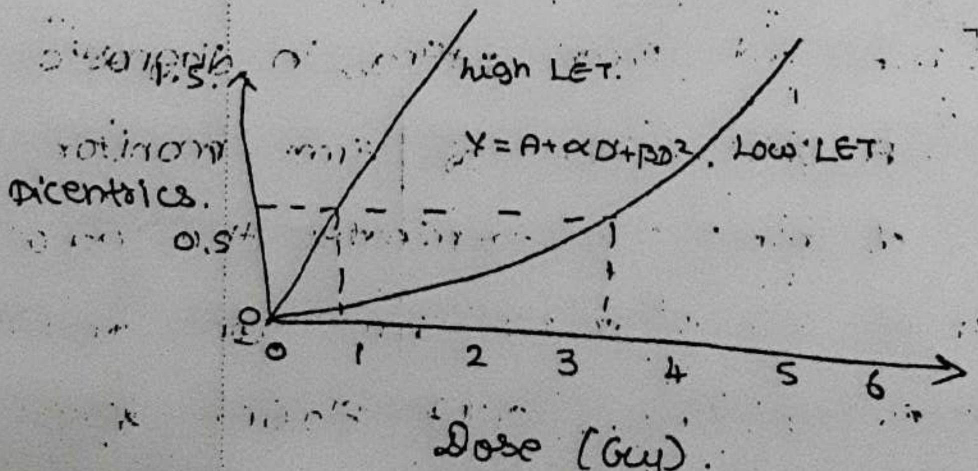
* KVp ↑, increase efficience of x-ray productio

295. Treatment time calculation for Co-60.

$$\text{Treatment time} = \frac{\text{prescribed dose}}{\text{PDD} \times \text{output Factor (Co-60)}} \times 100.$$

296. Dose response of high LET radiation and its calibration graph?

As higher the radiation dose as more likely some effects will occur. As higher the LET and/or the RBE as more likely damage may occur. The effect is described by dose response curve.



297. what are the regulatory requirement and guidelines for new Radiotherapy facility?

1) clearance of unit by AERB (Type Approval or NOC)
2). Registration of institute in eLORA.
3) Approval of Room Layout plan of Radiotherapy installation
4) Appointment of RT staff.
5) procurement of personnel monitor Badges.
6) Nomination of RSO.
7) Measuring and Monitoring instruments.
8) other associated equipment / Accessories.
9) Equipment and source procurement permission.
10) Loading and source Tranfer report.
11) commissiong, survey Report and Licience of operation.
(12). Annual Report status of RT safety and QA / Dose reports.
(13). Disposal and Transport of Disused radioactive Sources.

298. During Ca. Thyroid ~~their~~ treatment, what are the organ at risk? What are the precautions taken to reduce the risk?

[organ at risk - Salivary glands, kidney, bladder and gonalds].

Precautions taken to reduce the risk:.

*. During the first two days of therapy, patients should be asked to chew a lemon or any agent that increases salivation. Excessive salivation results in accelerated clearence of I-131 from salivary tissue, thus minimizing the radiation dose to tissue.

*. Radioiodine is primarily excreted through urine and therefore the kidney, bladder and ~~gonads~~ gonads are likely to get considerable radiation dose. The patient should be asked to drink plenty of fluids and void as frequently as possible. Frequent hydration and voiding will definitely minimize the radiation dose to kidney, bladder and gonads.

299. How do you calculate disintegration per second (dps) if counts per second (cps) and efficiency of detector for specific

$$\text{Detector efficiency} = \frac{\text{count rate}}{\text{disintegration rate}} \times 100\%$$

$$\text{disintegration rate} = \frac{\text{count rate}}{\text{Detector efficiency}} \times 100\%$$

300. 1mci of Co-57 has a count rate of 2.4×10^7 c/s what is detector efficiency.

$$\text{Detector efficiency} = \frac{2.4 \times 10^7 \text{ c/s}}{3.7 \times 10^7 \text{ d/s}} \times 100\%$$

$\Rightarrow 64.86\%$.

ICRP -60 & 103

301. ~~There~~ 1 person recieve one gray of alpha radition, 2nd person recieve once gray of Beta radiation. and other person recieve one gray of γ. who will recieve least damage?

* Alpha particle produce greater harm than do beta and γ - rays.

alpha > beta > gamma.

* ionisation power is more for alpha and least for gamma compared to other two.
* The person recieves least damage to γ - radiation compared to other two radiation.

302. what are the three basic principle of system of dose limitation adopted by ICRP?

* Justification.
* optimization.
* Dose limits.

303. what are the two classified area definitions and working condition defined by ICRP-60?

* controlled area - 10mR/wk. (0.1 mSv)
* uncontrolled area - 2mR/wk. (0.02 mSv).

304. Is there any limit set on RADON exposure if detected at the place of residence?

If Radon exposure detected at the place of residence, the limit is at average indoor level is 1.3 picocurie per litre. and limit of maximum level should be within 4 pci/Litre.

305. what are the three exposure situations as as advocated by ICRP-103?

The ICRP publications 103 divide all possible situations, where radiological exposures can occur into three types.

* planned exposure situation. (in radiology)
* emergency exposure situation.
* existing exposure situation.

* The use of radiation in radiology is a planned exposure, it must be under regulatory control.

306. could you please state a couple of situation in which dose limits don't apply?

* Dose limits do not apply to medical exposures. If they did, the effectiveness of diagnosis or treatment might be reduced, doing more harm than good for patient. The emphasis is on justification of medical procedures and optimisation of protection.

* Dose limits do not apply in ~~exp~~ emergency exposure situations where an informed, exposed individual is engaged in volunteered life-saving action or is attempting to prevent a catastrophic situation.

307. what are the major changes recommended in ICRP-103 compared to ICRP-60 recommendation?

ICRP-60	ICRP-103
* practice	→ planned exposure situation.
* Intervention. { in existing exposure Situation.	→ Existing exposure Situation.
in emergency exposure situation	→ Emergency exposure situation.
* radiation weighing factor	* radiation weighing factor

308. what are the three exposure categories?

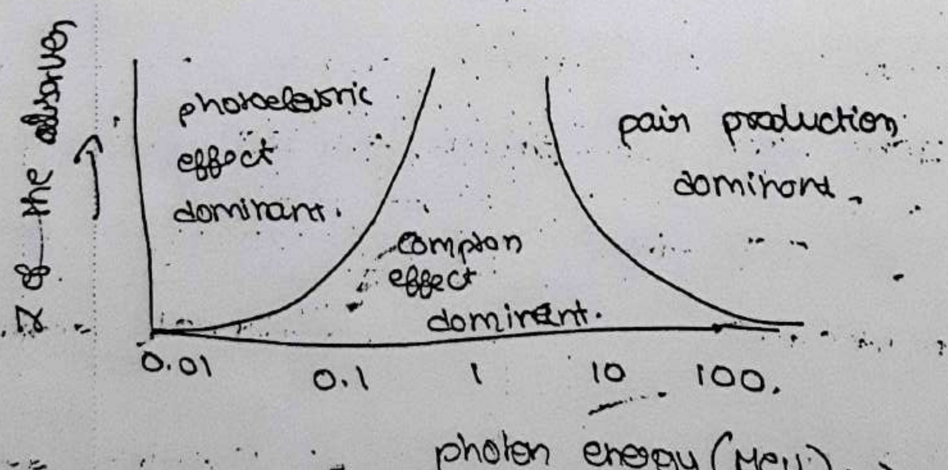
* occupational
* public
* medical.

309. what are the sources of potential exposure when assessing a practice?

* The two radiation sources against which user and public must be protected are

* leakage radiation from x-ray tube assembly
* scattered radiation (primarily from patient)

310. what is the effect of high z materials in the photoelectric / compton / pair production.?



Neutron detection & Shielding:-

301) why should you worry about 'Neutron' when patient are treated with high energy photon

beam for management of cancers?

* photoneutrons are produced from (gamma) nuclear reactions due to interaction of high energy photon with any matter. This is a threshold reaction.

302) what is the threshold energy for production of photo-neutron in medical linear accelerators.

* It depends on the structural materials and the energy of the LINAC. for tungsten and lead the threshold energy (~~≥6 MeV~~ 8–10 MeV). (roughly 7MeV for heavy metals)

303). what do you understand by the term 'neutron cross-section? How neutron cross section is expressed?

It gives probability of a given nuclear reaction or the effective area offered by the target nucleus to that projectile. (neutron) for a specific reaction. (ex. fission, capture). It microscopic cross section is defined as the number of collisions per unit volume per second for unit incident flux and unit nuclear density

unit: barn (10^{-24} cm^2).

304. could you please explain why 'Lead' materials is considered to be ~~too~~ 'transparent' when compared to 'water' for neutron shielding?

* The two important processes of neutrons with matter are scattering and absorption. By scattering, the energy of the neutron reduces. one can show that the number of interaction (scattering) required to bring down its energy is inversely proportional to the mass number. higher the mass number more interaction required, also less decrement in its energy per collision. hence water is good material to reduce the energy by elastic scattering. once the energy is reduced the neutrons may be absorbed in the matter.

305. Let us assume that you are given four different materials such as ordinary concrete, borated concrete, lead and iron. Which material do you choose for neutron shielding? why did you choose such material?

*. Borated concrete. Boron in the concrete absorbs neutron and emits (~0.5 MeV) gamma energy (refer 303).

306. How do you measure the neutron dose? what detector should be used?

* Neutrons are indirectly ionising radiation. Two major principle are used in their detection. one is ionization produced by the secondary particle radiation. other one is measuring the path or track of recoil nuclei. (interacted with neutrons). The neutron activation technique are also used for the detection. (ex. BF_3 or He detectors)

Biological effects of Radiation

307). Explain the methods by which the irradiation of cell leads to death?

* Apoptosis.
* ~~Necrosis~~.
* Mitotic catastophe
* senescence.

308) Five factors that influence the biological effects on the whole body from exposure to radiation?

* Total absorbed dose.
* Dose rate. (Acute (sec, mins), chronic (days, yrs))
* Type of radiation.
* Source of radiation. (external, internal.
* Age at exposure.

309 What are the three general catogories of effect resulting from exposure to low dose of Radiation?.

* Genetic
* Somatic;.
* In - Utero.

310 What are the effects resulting from exposure to high dose of radiation.

* Skin burns..
* Hair loss..
* Sterility.
* Cataracts

311) What is the threshold dose for producing cataracts? Why neutrons are especially effective in producing cataracts?

* Cataracts (clouding of the lens of eye) appears to have a threshold of about 200 rad
* Neutrons are especially effective in producing cataracts, because the eye has a high water content, which is particularly effective in stopping neutrons.

312 How acute Radiation syndrome (ARS) classified

* Hematopoietic
* Gastrointestinal.
* Central Nervous System.

313) What is Radiolysis of water? Why it is so important in radiation biology?

* If a cell is exposed to radiation, the probability of radiation interacting with DNA molecule is very small. However, each cell just as is the case of human body is mostly water.

* Therefore, there is much probability of radiation interacting with water that makes up most of cell volume.

* When radiation interact with water, it may break the bonds that hold the water molecule together, producing fragments such as hydron (H) and hydroxyles (OH). This is called Radiolysis of water.

* It is important because these fragments may recombine or may interact with other fragments or ions to form a compound, such as water, which would not harm the cell. However, they combine to form toxic substance such as hydrogen peroxide (H_2O_2), which can contribute to distruction of cell.

314) What are the symptoms of ARS?

Nausea, vomitting, fatigue, and loss of

315) what is the typical dose for producing temporary / permanent sterility in Men/women?

* Sterility can be temporary or permanent in males, depending upon the dose.

* In females, it is usually permanent, but it requires a higher dose. To produce permanent sterility, a dose in excess of 400 rad is required to reproductive organs.

316). what is the typical threshold dose by which chromosome aberration could be detectable?

* Sensitivity threshold a few cGy but method not feasible for dose less than ~~0.2 Gy~~ (100 mGy) because of expense and time needed.

317). what is the Relation between RBE and LET?

* The LET at which the RBE reaches a peak is much the same (about 100 keV/μm) for a wide range of mammalian cells.

* As the LET increases, the RBE increases slowly at first, and then more rapidly as the LET increases beyond 10 keV/μm.

* Between 10 and 100 keV/μm, the RBE increases rapidly with increasing LET and reaches maximum at about 100 keV/μm. Beyond that RBE fa

318). what is mean by term 'Radiation poisoining'?

* Acute radiation syndrome (ARS), also known as radiation sickness or radiation poisoning, is a collection of health effects due to exposure to high amount of ionizing radiation over a short period of time. symptoms can begin within an hour and may last for several months.

319). calculate BED for standard fractionation

$2 Gy \times 30\# = 60 Gy$.

1). For normal tissue.

$$BED = nd\,(1 + d/(\alpha/\beta)).$$

$$= 60\,(1 + 2/3) = 100\,Gy_3$$

2). For tumors.

$$BED = nd\,(1 + d/(\alpha/\beta)).$$

$$= 60\,(1 + 2/10) = 72\,Gy_{10}.$$

320). what new total dose should be used if dose per fraction is changed from d_1 to d_2.

For example. total dose used for arm 60Gy $= 2Gy/\# \times 30\#$ is to be converted into. $3Gy/\#$ (# fraction).

$$D_2/D_1 = \frac{(1 + d_1/(\alpha/\beta))}{(1 + d_2/(\alpha/\beta))}$$

$= 60 \times (1 + 2/10) / (1 + 3/10)$.

$= 60 \times (1.2)/(1.3)$

$= 60 \times 0.92 = 55.2 Gy$.

That is, $55.2 Gy / 3 Gy$ per #

$= 18.4$ #.

Radiation physics.

1). what is the typical range of 1 Mev beta particles in air?

A 1 Mev beta particle can travel approximately 3.5 metres in air.

2). why atomic number of low is chosen for minimizing bremsstrahlung radiation?

* with materials of high atomic number, the energy loss is higher. The energy loss by bremsstrahlung >99% of Kinetic E loss as heat production, it increases with increasing electron energy.

* Low-density materials should be used instead for screening such as plexiglass, plastic, wood or water with atomic no. that would decelerate less the electron and generate less energetic and penetrating bremsstrahlung radiation

Transport of Radioactive material.

1). Could you please give a few examples of off-normal transport conditions?

* Eg:- 1) Damage to the package due to improper handling or accident.

  2). package engulfed in fire.

  3). Misplacement or theft of the package.

  4). Loss of identity of the package.

  5). package unclaimed.

2). what is the significance of UN number marked on the exterior of package?

* It is a regulatory requirement that the appropriate UN number should be marked on the exterior of each package.

* The UN numbers, each of which is associated with a unique proper shipping name, have the function of identifying dangerous goods. UN numbers also uniquely identify the emergency response operations.

3). what is the information one should look for on the package?

  1). complete address of the consignor (sender).

  2). complete address of the consignee (Reciever).

  3). Type of package.

4). category and transport index of the package, name of the radioactive content and its activity.

5). Total weight of the package, if it exceeds 30Kg.

6). UN Number and proper shipping name.

4). what are the 'general' measures should be undertaken for any off-normal conditions during transport of radioactive material?

General measures:-

* Do not panic.

* Rescue the injured, if any and provide medical aid.

* fight fire, if any.

* cordon off at least 5m distance around the package.

* send a message to the consignor and to the following person and act as advised by them.

5). what are the 'SPECIFIC' measures should be undertaken for any off-normal conditions during transport of radioactive materials?

* In case of damage to the package due to mishandling or accident do not open

the package.

* If the package is engulfed in fire.
* Remove the affected people to a safe place.
* provide medical aid, if necessary.
* Do not allow any one to touch the package.
~~unle~~ unless cleared by experts from RPAD, BARC.
* contact for advice from RPAD on phone no. given above.

* In case of misplacement or theft of the package.
* Investigate the matter thoroughly and try to locate the package.
* Inform police if required.
* Look for the package at scrap shops.
* Try to locate the consignee or consignor from the available documents. In all cases, contact head, RPAD, BARC at above address.

5) why the transport of radioactive materials in Type B(U) M should be accompied by TREM CARD?

* Transport emergencency card. (TREM) card includes the information on the primary steps to be taken in case of emergency and emergency contact numbers.

* In case of any incident reported on the way, it shall be promptly reported by the consignor to AERB.

* If the package gets involved in accident or damaged during transport, the instructions specified in TREMCARD should be implemented.

7. How many package types are, in general, deployed for transport of radioactive materials?

Types of package as defined by the IAEA Transport regulations.

* Excepted package.
* Industrial package Type 1, 2, 3.
* Type A package.
* Type B (U) package.
* Type B (M) package.
* Type - C package.

8. what criteria should be fulfilled before transporting any radioactive materials in 'EXCEPTED' package?

* They are designed to survive normal condition of transport.
* Excepted packagings are used for transportatio of materials that are either LOW SPECIFIC

Activity (LSA) or surface contamiated objects (SCO) and that are limited quantity shipments.

* Radiation level should be less than 0.5 mR/hr

Dosimetry protocal (TRS-398 & TG-51).

1). What do you understand by the term:. Refrence instrument and field instrument?.

Refrence instrument :. An instrument of the highest metrological quality available at a given location, from which measurement at that location are derived.

Field instrument :. A measuring instrument used for routine measurement whose calibration is releated to the refrence instrument.

2). What do you understand by term:. (PSDL) and (SSDL)?.

* PSDL - A national standardizing laboratory designated by the government for the purpose of developing, maintaining and improving primary standards in radiation dosimetry.

* SSDL - A dosimetry laboratory designated by the competent authorities to provide calibration services, and which is equipment with at least one secondary standard that has been calibrated against primary standard

3. what are the advantages of calibration in terms of absorbed dose to water?

* Reduced uncertainity:-

* Measurement based on calibration in air in terms of air Kerma (N_K) require chamber dependent conversion factor to determine absorbed dose to water.

* A more robust system of primary standards:-

* good agreement among these standard gives much greater confidence in their accuracy.

* Use of a simple formalism:-

* No use of several coefficient, perturbation and other correction factors, unlike N_K based formalism.

4. could you please tell us at least five quantities that influence the determination of election beam quality?

* Influence quantity:- phantom material, chamber type, Refrence point on chamber, SSD, field size at phantom serface, position of refrence point of chamber.

5. what type of phantom material are recommendent as the refrence medium for TRS 398 / TG-51 for photon beams?

* In horizontal beams, the window of the phantom should be made of plastic and of thickness between 0.2 cm and 0.5 cm.. The water-equivalent thickness (in g cm^{-2}) of the phantom window should be taken into account when evaluating the depth at which chamber is to be positioned. commonly used plastic PMMA and clear polystyrene

6. How may perturbation effects are considered and embedded in the overall perturbation factor (PQ) for a given beam quality?

$$P_Q = (P_{cav} \cdot P_{cell} \cdot P_{dis}\ P_{wall})_Q$$

⇒ overall perturbation factor for an ionisation chamber for in phantom measurement at beam quality Q.

P_{wall} = corrects for non-medium equivalence of chamber wall.

P_{dis} = corrects for replating a volume of water with detector cavity, when the reference point of the chamber is takes to be chamber centre - alternatie to P_{eff}

P_{cell} = corrects for the effect of the central electrode during in-phantom measurement.

P_{cav} = corrects for effects related to the air cavity, predominantly the in-scattering of electrons.

7. what type of uncertainties are classified in dosimetry protocols?

* uncertainties of measurement are expressed as relative standard uncertainties and the evaluation of standard uncertainties is classified into 'type A' and 'type B'.

* The method of evaluation of Type A standard uncertainity is by statistical analysis of a series of observation.

* The method of evaluation of type B standard uncertainty is based on means other than statistical analysis of series of observation.

8. where is our secondary standard dosimetry laboratory located in india?

* BARC has been recognized as a secondary standard dosimetry Laboratory (SSDL-BARC) by IAEA.

9. How the beam quality specification is done for high-energy electron beam in TRS-398 and TG-51 protocols?

* For electron beam, the beam quality index is the half value depth in water R_{50}.

* This is the depth in water (in $g cm^{-2}$) at which the absorbed dose is 50% of its value at the absorbed - dose maximum, measured with a constant SSD of 100 cm and a field size at a phantom surface at least 10cm × 10cm for $R_{50} \leq 7 g cm^{-2}$.

Q. what are the refrence conditions recommended for determination of photon beam quality?

Influence quantity.	Refrence value
phantom material	water.
chamber type	cylindrical or plane - parallel
Measurement depth.	20 $g cm^{-2}$ and 10 $g cm^{-2}$.
Refrence point of chamber.	* For cylindrical chambers, on the central axis at the centre of cavity volume. * For plane - parallel chamber, on the inner surface of the window at its centre
position of refrence point of chamber.	For cylindrical and plane parallel chamber, at the measurement depth.
SCD	100 cm.
Field size at SCD.	10cm × 10cm².

11. Beam quality specification for high-energy photon beam in TRS-398 and TG-51 protocals?

TG-51.	TRS-398.
* The quantity %.dd(10)$_x$ is the photon component of photon beam percentage depth-dose at 10cm depth in a 10×10 cm^2 field size on the surface of water phantom at SSD of 100cm.	* The quantity TPR$_{20,10}$ is the radio of dose measured at constant source detector distance SSD for depth of 20 cm and 10 cm for 10×10^{2}cm field at the point of measurement.

12. what is the relation between stopping-power ratio and beam quality index for photon beams in TRS-398 / TG-51 protocal?

$$K_{Q,Q_0} = \frac{(S_{w,air})_Q \; (W_{air})_Q}{(S_{w,air})_{Q_0} \; (W_{air})_{Q_0}} \times \frac{P_Q}{P_{Q_0}}$$

In therapeutic electron and photon beam:

$$(W_{air})_Q = (W_{air})_{Q_0}$$

hence :

$$K_{Q,Q_0} = \frac{(S_{w,air})_Q}{(S_{w,air})_{Q_0}} \times \frac{P_Q}{P_{Q_0}}$$

K_{Q,Q_0} → (beam quality)

$(S_{w,air})$ → stopping power ratio.

P_Q → perturbation factor

13. which protocal do you resort for absorbed dose determination for proton beam and heavy ion beams?

*. IAEA TRS - 398.

Basic Radiation Safety:

1). what percent of leakage radiation through the beam limiting Devices for telegamma unit is permitted at normal treatment distance when the beam is 'ON'?

In case of beam ON position, beam limiting devices are used to attenuate the radiation so that absorbed dose at the normal treatment distance (NTD) anywhere in the area protected by the beam limiting device shall not exceed 2% of the maximum absorbed dose for a 10cm x 10 cm radiation field.

2). what is the acceptable neutron leakage level in the medical linear accelerator facilities?

* The neutron leakage specification of all major medical linear accelerator are below 2-3 mSv per isocenter photon Gy.

3). what is the leakage radiation dose at 5cm

Surface of storage or 1 metre from the storage for manual after loading system / emergency storage container / in house trasport portable container?

* when the radiation source is in the storage position, the dose rate of leakage radiation must not exceed 2 mSv/hr on the surface of the container, and 0.02 mSv/hr at a distance of one metre from the container surface.

4). what do you know about induced radioactivity? when should you worry about induced radioactivity?

* Induced radioactivity, also called artificial radioactivity or man-made radioactivity, is the process of using radiation to make a previously stable material radioactive. Neutron activation is the main form of induced radioactivity.
It occurs in high energy linac. >10 Mev.

5). what is the effective dose limit set for occupation exposure of apprentices and trainess?

* Apprentices and student in radiation work area must not be less than 16 years old.

	year
Dose limit to whole body exposure	6 mSv
lens of eye.	15 mSv
Equivalent dose to extremities	150 mSv
Equivalent dose to skin	150 mSv.

6. what are the criteria for permanent implant discharge patients?

* The effective dose to any ~~Fat~~ member of the general public should not exceed 1 millisievert in a year.

*. The ambient dose equivalent rate at a distance of 1metre from a patient who is under going treatment with radioactive substance should not exceed 25 μSv/hr at the time of patient's discharge from hospital.

7. could you please name atleast four sealed source performance test requirement for radiation therapy source?

* Drop test * crush test * puncture test.

* fire test.

8. what is therapeutic housing or source housing?

* outside the geometric limits of the beam and the penumbra, the dose variation is the result of side scatter from the field and both leakage and scatter from the collimator system. Beyond this collimator zone, the dose distribution is governed by the lateral scatter from the medium and leakage from the head of the machine (often called source housing)

unit - 1

Basic physics.

radiu of atom = 10^{-10} m.

radiu of nucleus = 10^{-15} m.

isotopes - atoms with same atomic & diff mass number.

isobars - atoms with same no of nucleons but different no. of protons. (n/p ratio ↑ with Z↑ >20)

isomers - atms having same no. of protons as well as neutrons.

rest mass of neutron 939 MeV.

1 amu = 1/12 of mass of $^{12}_{6}C$.

* when nucleus is formed, a certain mass is destroyed and converted into energy that acts as a 'glue' to keep nucleons together. The mass difference is called 'mass defect'.

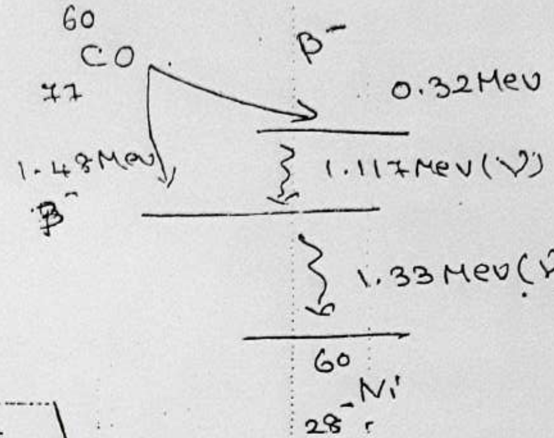
rest mass of proton - 938 MeV

* The amount of energy equal to mass defect must be supplied to seperate the nucleus into individual nucleons. this energy is called binding energy of nucleus.

* 1 ev = 1.6×10^{-19} C.

Four types of force

* strong nuclear force.
* electromagnetic force.
* weak nuclear force.
* gravitational force.



Radiation: The term applies to the emission & propagation of energy through space or a material medium.

↑ n/p ratio → β^- decay.

↓ n/p ratio → electron capture & β^+ decay.

1 amu = 931 MeV.

energy equivalent of electron at rest (E_0) = 0.511 MeV.

* 12 fundamental particles → six quarks & six leptons.

* $c = \nu\lambda$ and $E = h\nu$.

* $E = \frac{1.24 \times 10^{-6}}{\lambda}$

* potential well formed as result of mass defect and provide the nuclear binding energy. It acts as a potential barrier against any nucleon escaping the nucleus.

* Height of potential energy ~(30MeV)

Radioactivity → henri Becquerel (1852)

Radioactivity decay based on fact that change in number of atoms per unit time ($\Delta N/\Delta t$), is proportional to the no of radioactive atoms (N) present.

Activity - no. of disintegration per unit time.

$$\boxed{A = N\lambda}$$

$1\ ci = 3.7 \times 10^{10}$ Bq.

half life ⇒ $T_{1/2} = \frac{0.693}{\lambda}$

Mean life ⇒ $1.44\ T_{1/2}$.

Activity/unit mass = Specific activity.

* Radioactive elements grouped into three series; the uranium series, actinium series, thorium series.

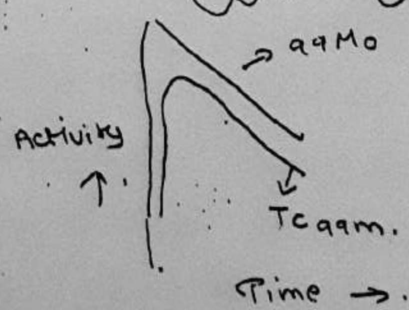
U_{238} have $T_{1/2} = 4.5 \times 10^9$ years

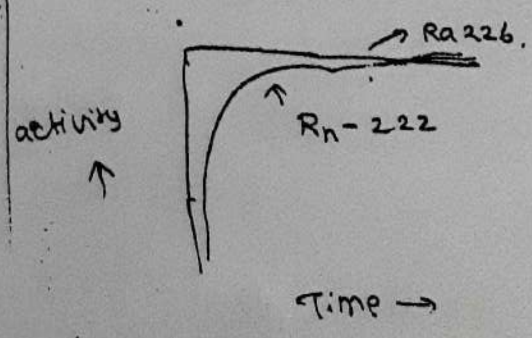
* If the $T_{1/2}$ of parent is longer than that of daughter, then after a certain time, a condition of equilibrium will be achieved.

* Two types:

1) If $T_{1/2}$ of parent is not much longer than that of daughter, then the type of equilibrium is transient equilibrium.

2) if $T_{1/2}$ of parent is much longer than that of daughter, then it is called as secular equilibrium.





* Transient :.

$$\frac{A_2}{A_1} = \frac{T_1}{T_1 - T_2}$$

* Secular ..

$$A_2 = A_1$$

* α- particle decay :.

Atomic no. decreases by '2' and mass no. decreases by '4'.

$$_{Z}^{A}X \longrightarrow _{Z-2}^{A-4}Y + _{2}^{4}He + Q$$

$$_{88}^{226}Ra \xrightarrow[1622\,yrs]{} _{86}^{222}Rn + _{2}^{4}He + 4.87\,MeV$$

* β- particle decay :.

ejection of +ve or -ve electron from nucleus.

$$_{0}^{1}n \rightarrow _{1}p^{1} + _{-1}\beta^{0} + \bar{\nu} \; (\beta^{-} \text{ decay}).$$

$$_{1}p^{1} \rightarrow _{0}n^{1} + _{1}\beta^{0} + \nu \; (\beta^{+} \text{ decay}).$$

$$_{15}^{32}P \xrightarrow[14.3\,days]{} _{16}^{32}S + _{-1}\beta^{0} + \bar{\nu} + 1.7\,MeV.$$

$$_{11}^{22}Na \longrightarrow _{10}^{22}Ne + _{+1}\beta^{0} + \nu + 1.8\,MeV.$$

* electron capture.

$$_{1}p^{1} + _{-1}e^{0} \longrightarrow _{0}n^{1} + \nu$$

* PET < 0.511 keV, 0.511 keV ; annihilation.

positron - electron pair.

* Filtered back projection algorithm.

The probability of fluorescent x-ray emission (vs) auger electrons depends on the atomic number of atom involved.

'ω' is defined as ratio of no. of characteristic photons emitted to the no. of electrons shell vacancies.

↑ with ↑ in atomic number.

large 'z' → Characteristic x-ray favored.

low 'z' → auger electrons are more probable. ($z < 30$).

Internal conversion..

* The excess nuclear energy is passed on to one of the orbital electrons, which is then ejected from the atom..

Isomeric transition :.

* In some cases, the excited nucleus said to exist in the metastable state. It is a isomer of the final product nucleus which has same atomic and mass number but different energy state.

eg. Tc-99m which is isomer of Tc-99.

Nuclear reactions:

first nuclear reaction observed by Rutherford.

['Q' generally represents the energy released or absorbed during a nuclear reaction]

* If 'Q' is +ve, energy has been released, called 'exoergic', and if 'Q' is negative, energy has been 'absorbed'

α, p reaction:

↓ ↳ ejection particle.

bombarding particle.

'α' particle intrades with a nucleus to form a compound nucleus which in turns, disintegrates immediately into new nucleus by ejection of proton is called α, p reaction.

α, n Reaction:

Bombardment of nucleus by "α" particle with emission of neutron is designated as α-n reaction.

neutron capture:

most common process

[n, γ reaction]

* nucleus is excited, and immediately returns to normal state with emission of γ-ray photon. called as capture γ-rays, can be observed coming form hydrogenous material such as paraffin used to slow down neutron and capture some slow neutrons.

$$^{1}_{1}H + ^{1}_{0}n \rightarrow ^{2}_{1}H + \gamma$$

* (n, α reaction)

$$^{10}_{5}B + ^{1}_{0}n \rightarrow ^{7}_{3}Li + ^{4}_{2}He$$

In this reaction, ionisation chamber filled with BF_3 dection is used for detection. The α-particle released by n, α reaction with boron produces the ionization detection by chamber.

* photodisintegration:

interaction of high energy photon with atomic nucleus can le to a nuclear reaction and to emission of one or more nucleons

$$^{63}_{29}Cu + \gamma \rightarrow ^{63}_{29}Cu + ^{1}_{0}n.$$

* Because of the rest energies of many nuclei are known for very high accuracy, the photodisintegration process can be used as a basis of energy calibration of machines producing high-energy photons.

* In fission rx, to induce a chain rx, neutrons have to be slowed down to thermal energies by collision with nuclei of low Z material (eg. graphite, water, heavy water) called moderators.

* For fusion rx to occur, the nuclei must be brought sufficiently close together so that repulsive columb force are overcome and the short range nuclear force initiate fusion rx. ($T > 10^7$ K).

* Yield of nuclear reaction depends on:
  1). no. of bombarding particles.
  2). no. of target nuclei.
  3). probability of occurance.

* probability is 'α' to cross section, which is given in unit barn to (10^{-24} cm^2).

* cross section depends on
  → nature of target material
  → type of bombarding particle & energy.

* activity of 1g of radium = 0.975 ci

* photodisintegration process responsible for contaminating of high-energy X-ray beam generated by linac.

Fission.

$$U\text{-}235 \xrightarrow{+\,{}_0^1n} Ba\text{-}141 + Kr\text{-}92 + 3\,{}_0^1n + Q$$

Fusion.

$${}_1^2H + {}_1^3H \rightarrow {}_2^4He + {}_0^1n + Q.$$

Q = 17.6 MeV.

* fusion of hydrogen into helium nuclei is source of our's

chapter - 3

X-ray → Roentgen (1895).

* while studying cathode rays, he observed another type of radiation produced that could be detected outside the tube. (X-ray tube)

* [The cathode is a tungsten filament which when heated emits electrons, a phenomenon known as thermionic emission.

cathode - tungsten.

anode - copper rod (thick).

(high voltage applied, the electrons emitted from filament accelerated toward anode and achieve high velocity before striking target]

* Thin beryllium window are used to reduce inherent filtration of x-ray beam.

Anode:-

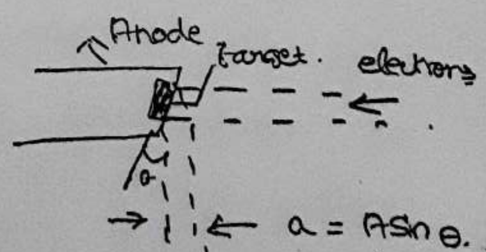
tungsten as target material coz of high atomic no. and high melting points. (3370°C). withstand intense heat produced in target

* Rotating anode is used in diagnostic x-ray to reduce the temperature of target at any one spot.

* Function of oil bath surrounding x-ray tube to insulate the tube housing from high voltage to tube as well as absorb heat from anode.

* In target, area of focal spot should be small as possible to produce sharp radiographic images.

* size of focal spot reduced by line focus principle - target mounted on steepy inclined surface of anode.



* heel effect :-> variation across the x-ray beam intensity from one cathode to anode.

* The problem of heel effect can be minimized by using compensating filer to provide differendial attenuation across the beam. and uniformity of beam.

Cathode :→ wire filament + circuit to provide filament current and -vely charged focusing cup.

* Size of focal spot depends on → filament size

Intensity - total energy carried by particles per unit area per unit time.

eg.

line voltage = 220V at 60 cycles/s.

peak voltage :> $220\sqrt{2}$ = 311 V.

step up transformer => 500 : 1.

. $220\sqrt{2} \times 500$ = 155.6kV,

resultant peak voltage.

* X-ray works on Self - rectified unit, means only through half voltage cycle, the tube current flows through it. During next half cycle, voltage is reversed and current ...

Disadvantage of Self - rectified circuit, no x-ray are generated during inverse voltage cycle. hence output of machine is low.

* During inverse voltage cycle, these electrons will flow from the anode to cathode and bombard the cathode filament. This can destroy the filament.

* The problem of tube conduction during inverse voltage cycle can be solved by using high voltage rectifiers. The current will flow only during anode is positive relative to cathode. This type of rectification called half - wave rectification.

- valve
- Solid state type.

rectifier consist of conductors which have contain Semiconducting elements - selenium, Silicon, germanium, these elements conduct electrons in one

& can withstand reverse voltage up.

Because of their small size, thousands of rectifiers can be stacked in series in order to withstand the given inverse voltage.

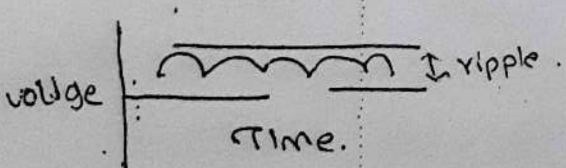
voltage across tube kept constant by high capacitance.

Three phase generators:.

High voltage applied to x-ray in three phases.

three ϕ { three seperate wire / step up transformer

3ϕ power, full wave rectification, six voltage pulses applied to x-ray tube during each power cycle.



ripple <2% provide highest x-ray output per mAS.

constant potential generators:

uses three phase (3ϕ) line voltage directly coupled [illegible]

High frequency generator:.

* Single - phase line voltage rectified and smoothed.

Direct current ⟹ high frequency ~~alternating~~ alternating current (AC)

advantages:.

* reduced weight & size.
* maximum x-ray output/mAS
* greater efficiency of x-ray production.
* short exposure times.

Two mechanism of x-ray production.

* Bremsstrahlung x-ray
* characteristic x-ray.

1) result of radiative collision between high sped electron and a nucleus. The electron passing near nucleus may be deflected from its path by columb force of attraction and lose energy as bremsstralung.

* Direction of emission of bremstralung depends on energy of incident ~~p~~ electron.

* below 100keV, x-ray emitted on all directions.

* As kinetic energy of electrons increases, direction of x-ray emission becoms increasingly forward.

* transmission type target are used in megavoltage x-ray tubes, in which ~~x-ray tube~~ e^- bombard the target from one side and x-ray beam produced from other side.

* In low voltage x-ray tubes, it is advantages to obtain the x-ray beam from same side of target, 90° with respect to electron beam.

* The energy loss per atom by electron depends on (Z^2). Thus probability of x-ray (bremstalung) production ~~depends~~ varies with Z^2 of target material.

* efficiency of x-ray production depends on 'z' and voltage applied to tube.

* efficiency = ratio of output energy emitted as x-ray / input energy deposited by electrons.

$$\text{efficiency} = 9 \times 10^{-10} Z V_0 .$$

efficiency of x-ray production with tungsten target ($z = 74$) for electrons accelerated through 100kV

characteristic x-ray:.

An electron, with kinetic energy interact with atom of target by ejecting orbital electron from K, L, M, N shells. when vacancy is created in a orbit, an outer shell electron will fall down to fill the vacancy. Thus difference in B.E is emitted as characteristic x-rays.

* The threshold energy that incident e^- must posses in order to knock out electron from atom is called critical absorption energy.

* no filteration, inherent or added, the beam assumed and calculated energy spectrum will be straight line and mathematically given by Kramer's equation.

$$I_E = K Z (E_m - E)$$

Z → atomic no.

I_E → intensity of photon with energy E

E_m = maximum photon energy

Inherent filteration:

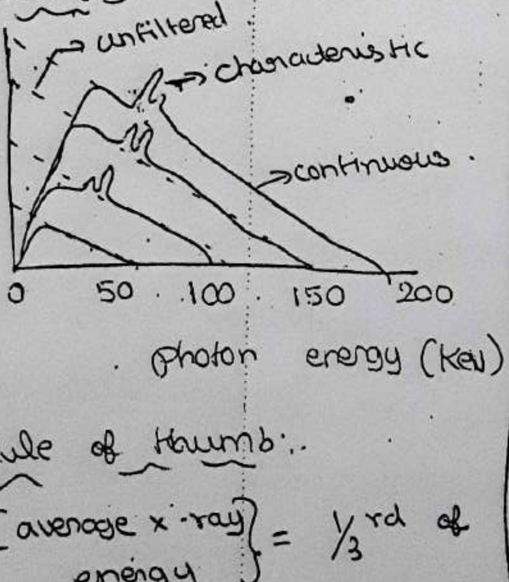
* absorption within target.
* glass wall of tube.
* thin beryllium window.

which is equal to 0.5 to 1mm aluminium.

Filteration ↑ - transmitted beam hardens.

Total intensity of beam decrease with increasing filteration, and increases with voltage.

*[x-ray having spectral distribution of energy depends on filteration & voltage]

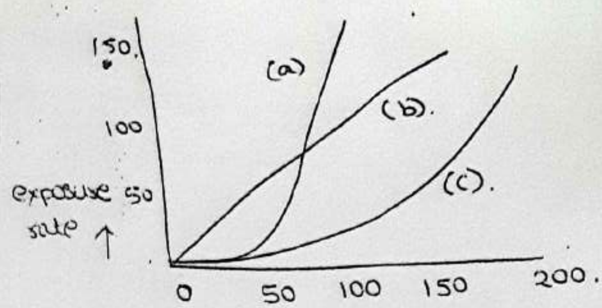


Rule of thumb:

[average x-ray energy = 1/3rd of maximum energy or KV_p.]

[half value layer is used to define the beam quality]

Operating characteristics:



→ Tube voltage (KVP) (c)

→ Tube current (mA)(b)

→ Filament current (A) (a)

Relationship b/w x-ray output, filament current, tube current, tube voltage.

* output of x-ray machine can expressed in terms of ionization it produces in air
↓
measure of ionization per unit mass of air is called exposure

* small change in filament current } → produces large change in exposure rate

* linear relationship b/w exposure rate and tube current.

* ↑ in x-ray output with increase in voltage. The shape of curve depend on filteration, output of x-ray machine, $\propto (KV_p)^2$.

Key points:

* x-ray have highly evacuated glass tube to prevent electron interaction with air.

* Use of tungsten to boost efficiency of x-ray production

* Rotating anode, oil bath, fans used to reduce & remove heat to prevent damage of target.

* The function of oil bath is to provide electrical insulation as well as heat absorption.

* The function of hooded anode (tungsten + copper shield around target) is to prevent stray electrons from striking non-target components of tube. and absorbing bremsstrahlung as result of their interaction.

* Apparent focal spot size $a = A \sin\theta$

'A' is the side of actual focal spot at ... 'a'.

* The apparent focal spot size for imaging.

→ 0.1 × 0.1 to 2 × 2 mm^2

* for orthovoltage therapy tubes:

→ 5×5 to 7 × 7 mm^2

peak voltage of x-ray tube = $\sqrt{2}$. line voltage . transformer turn ratio.

* x-ray output / mAS ↑ by applying three-phase power to x-ray tube.

* 3 ϕ, six pulse generator deliver high-voltage pulses with a voltage ripple of 13% to 25%.

* higher the energy of electron, more forward direction of x-ray.

output ∝ tube current.

output ∝ $(\text{voltage})^2$

output is very sensitive to filament current.

Clinical Radiation generators:

upto to 1950, EBRT was carried out with x-ray at voltage up to 300KVp.

i) grenz ray therapy:

* beam of very soft x-rays < 20KV.
* low depth of penetration.

ii) contact therapy: (endocavitary machine)

* potential 40 to 50 KV.
* SSD - very short.
* tube current - 2mA.
* filters 0.5 - 1.0mm thick aluminum.
* Beam completely absorbed with 2cm of soft tissue. (1 to 2mm)

iii). Superficial therapy:

* potential - 50 to 150KV.
* varying thickness of filtration (1 to 6mm aluminium) are added
* HVL of superficial therapy range 1 - 8 mm Al.
* SSD - 15 and 20cm
* tube current 5 to 8mA.
* tumor confined about 5mm depth. (~90% depth dose).

iv) orthovoltage therapy

* potential - 150 to 500kV.
* Tube current - 10 to 20mA
* HVL between 1 and 4mm Cu.
* SSD ~ 50cm.
* depth dose distribution depends on kilovoltage, HVL, SSD & field size.
* 90% of value occuring at depth of about 2cm.
* cannot be used for tumor deeper than 2 to 3 cm.
* problem: high skin dose.
* multiple beams were used.
* limitations: increased absorbed dose in bone. increased scattering.

Resonant transformer unit:

* x-ray from 300 to 2000kV
* The secondary of high voltage transformer is connected $\|^{el}$ to capacitor inside the x-ray tube.
* This combination exhibit resonance.
* The electrical insulation is provided by pressurized freon gas.

Megavoltage therapy:-

* >1 MV.

* eg: vande graff, linear accelenation, betatron microtron, teletherapy γ-ray unit such as Co-60.

RSO questions.

1. what is Hp(d)?

The personnal dose equivalent (Hp) d. is defined for both strongly and weakly penetrating radiation as the equivalent dose in soft tissue below a specified point on the body at an appropriate depth d. The relevant depth is generally d = 10 mm for penetrating radiation.

2). P-32 often preparation measured using portable contamination monitor 10cm square area value is 450cpm. is it safe? (contamination limit 4Bq/cm²).

→ for per cm².

$450/10$ = 45 cpm/cm².

1 Bq = 1 cps. 60 cps = 1 cpm.

$= \frac{45}{60}$ cps/cm².

= 0.75 Bq/cm². (It is safe)

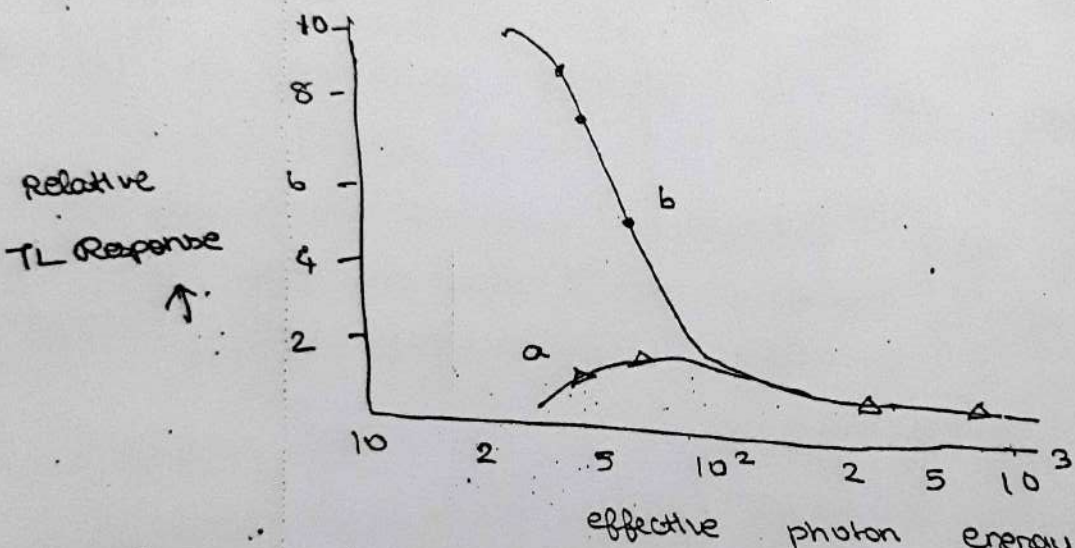
3). what will you do as RSO when dose limit exceeds of 100mSv?

* If the annual dose exceeds the operational limit of 30mSv the over exposure investigation committee appointed by AERB advices an

appropriate lay off from radiation work.

→ If the recorded dose exceeds 100 mSV the person will be asked to undergo the medical examination including a complete blood count and chromosome aberration test. CA test is the only test which ensures the genuiness of the whole body exposure recorded by the personnel monitoring badge. with negative CA results and convincing circumstance the recorded dose could be considered non-genuine, not actually recieved by person.

4). TLD energy response curve?



(a) → Response under metal filter, (1mm Cu + 1mm Al)

(b) → Response of bare disc.

5). why absolute dosimetry not performed in dose maximum depth and why 0.6cc chamber not used for beam profile measurement in RFA?

→ Due to dose gradient and effect of perturbation is high at Dmax, so we prefer measurement at the refrence depth.

→ And for relative dosimetry like profile measurement we are concerning about resolution and better to have small volume chamber reduce the volume over lap effect.

6). Dual scattering foil material?.

The primary scattering foil - high Z

Tantalum and gold.

secondary - Al low Z.

7). A lead container designed to store 7.4GBq (200mCi) of Co-60. what is the maximum activity of Cs-137 that can be stored in container?

→ HVL of Co-60 is 11 mm. of lead.

→ HVL of Cs-137 is 5mm of lead.

* So 200 mCi × $\frac{11}{5}$ => 440 mCi of Cs-137 stored in that container.

Measurement	units	formula.
→ Exposure.	–	columb / kg.
→ Air Kerma	Gy. R	R ! C/kg
→ Absorbed dose.	Gy	D = 1 J/kg
→ Equivalent dose.	SV.	= D × W_R.
→ Effective dose	Sv	= D × W_R × W_T.

1) The columb' of electric charge produced per kilogram of air is measure of

a). effective dose b). absorbed dose

c) exposure d) equivalent dose.

2) A radiation measurement discribing the energy of ionization in air is termed as

a) Entrance skin dose. b) Absorbed Dose

c) Exposure d) Air kerma

3). A radiographic exposure results in 0.015 J of energy absorbed by the liver. If the liver weights 0.9 kilogram, what is the total absorbed dose to the liver?

$$D = Gy = 1\ J/kg.$$

$$= 0.015/0.9 \Rightarrow 0.0167\ Gy.$$

4) A radiation worker recived a gonal dose 25mGy over the course of year. If 100% of this dose was from x-rays, what is the equivalent dose?

$$Eq\ D = D \times W_R.$$

$$= 25 \times 1 \text{ for x-ray.}$$

$$= 25\ mSv.$$

5). The thyroid of a radiation worker is exposed to an absorbed dose of 10 mGy from an alpha - emitting radionuclide. calculate the effective dose.

$\therefore$ Ef. D $= D \times W_R \times W_T$

$= 10 \times 20$ for alpha $\times 0.04$

$\Rightarrow 8$ mSv

6) During a AP x-ray, the breast, gonalds and stomach of patient recieve a dose of 3mGy. what is total effective dose?

EfD $= D \times W_R \times W_T$.

$= 3 \times 1$ for x ray $\times$ [0.12 breast + 0.08 gonald + 0.12 stomach]

$= 3 \times 1 \times 0.32 \Rightarrow 0.96$ mSv.

7) An accident in nuclear facility results in a whole body absorbed dose of 56 mGy.. what is the effective dose?

Ef. D $= D \times W_R \times W_T$.

$= 56 \times 1$ for x-ray $\times$ 1 for whole body.

$= 56$ mSv.

8). A radiograph is made with a 72 inch SID resulting in a receptor exposure of 0.01 mGy. what will be receptor exposure be if the SID is changed to 36 inches?

$$I_2 = I_1\left(\frac{d_1^2}{d_2^2}\right)$$

$$= 0.01\left(\frac{72^2}{36^2}\right).$$

$\Rightarrow 0.04$ mGy.

9). If a x-ray beam has a intensity of 1.2mGy at 40 inches, what is the intensity of beam. 60 inches?

$$1.2\left(\frac{40^2}{60^2}\right) = 0.53\ mGy$$

10) During surgical procedure the x-ray technologist stand at 1metre from the C-arm for 1hr and acquires an equivalent dose of 0.1mSv. If the technologist had stood at a distance of 5meters. what would their dose have been?

$$\Rightarrow 0.1\left(\frac{1^2}{5^2}\right) \Rightarrow 0.004\ mSv.$$

1) You have 50mci of P-32 ($T_{1/2}$ = 14.3days) and are ready to dispose of the remaining material what amount of P-32 is present after 35days if the vial has not been opened?

a) 9.16mci.
b) 18.3mci.
c) 9.16 µci.
d) 18.3 µci.

option :- (a).

2) All of the following are modes of energy loss for beta particles except?.

a) annihilation.
b) excitation.
c) ionization.
d) pair production.

option :- (d).

3). The current NRC regulation for occupational exposure that person under 18 yrs old may recieve.

a) 100mrem / yr.

Option :. (C).

b) - 500 mrem / yr.

c). one-tenth of maximum permissible adult occupational dose limit.

d). one-half of the maximum permissible adult occupational dose limit.

4). container of radioactive must be labeled with which of the following information?

a) Radionuclide present, quantity or radiation level.

b). Instruction for handling the radioactive material

c) personnel authorized to use the material.

d) Instructions for decontamination procedures to follow if spilled.

option :. (a)

5). what is the best recommended shielding for mixed beta and gamma emitters?

a) Thick lead.

b) concrete

c) plexiglass with lead or other high z-materials.

d) Aluminium foil with lead or other high-z-material.

option :. (C).

6. Shielding againt beta radiation may be complicated because

a) beta radiation usually cannot be completely absorbed.

b). deceleration of beta particles produces neutrons

c) beta particles are scattered by shields

d). deceleration of beta particles produces more penetration x-ray.

option :. d.

7) which of the following is a factor in x-ray production?

a) high voltage electron from an anode.

b). electron striking a cathode, such as tungsten.

c). electrons slowing down when they strike a target and convert to x-ray.

d. gamma ray, which typically have energy level less than 10keV.

option :. c)

8) some organs exhibit a threshold response to radiation effect, which is called a(n).

a) stochastic effect.

b). non-stochastic effect.

c) genetic - effect.

d). acute effect.

option :. b)

9). which of the following instrument would be best for quickly locating a source that contains I-125 (x-ray energies 27 to 35 keV).

a) pressurized ion chamber.

b). Survey meter with NaI detector containing a 1mm thick crystal.

c). survey meter with a pancake G-M probe containing a 1.7 mg / cm^2 mica window.

d). survey meter with ZnS probe.

option :- b)

10). Removable radioactive contamination can be described as material which.

a) has activity that is below 2000 dpm.

b). presents no hazards when personal protective clothing is removed.

c). can be easily decontaminated from exposed surfaces.

d). can be transferred from one location to another.

option :- d).

11). which type of meter is best for detecting high energy β?

a) G-M detector.

b). NaI detector.

c). open window gas-proportional counter.

d). ZnS scintillation detector.

12). which of the following personal protective clothing should be removed first to reduce the potential for personal contamination?

a) Tape from pant legs and sleeves.

b). coverall /lab coats.

c). Rubber boots.

d) outer layer of double gloves,

option: d

13) An EPA action level advises residential mitigation for radon level that are higher, than

a) 1 pci/litre.

b). 4 pci/ litre.

c). 7 pci/ litre.

d) 10 pci/ litre.

option: b.

Radiation protection:

Time: The amount of radiation an individual accumlates will depends on how long the individual stays in the radiation field. because

Dose (mR) = Dose Rate x Time (hr).

$$\text{Stay time} = \frac{\text{Limit (mR)}}{\text{Dose rate (mR/hr)}}$$

D. how long can a radiation worker stay in the 1.5 rem/hr radiation field if we wish to limit his dose to 100 mR?

$$\text{stay time} = \frac{100\,mR}{1500\,mR/hr} = 0.067\,hr.$$

$= 4$ minutes.

→ Inverse Square law:.

The intensity of radiation (I) decreases in proportion to the inverse of the distance from the source (d) squared.

$$I_1 d_1^2 = I_2 d_2^2$$

2). The exposure rate one foot from the source is 500 mR/hr. What would be the exposure rate three feet from the source.

$$I_2 = \frac{I_1 d_1^2}{d_2^2} = \frac{500\,mR/hr \times (1)^2}{3^2}$$

$$= \frac{500\,mR/hr}{9} = 55.6\,mR/hr.$$

3 → The exposure rate from the gamma point source can be approximated from the following expression:,

$$mR/hr = \frac{6CEF}{d^2}$$

where 'C' is the activity of the gamma emitter, in millicurie.

'E' is the gamma ray energy, in MeV

'F' is the fraction of disintegration yielding the gamma of energy 'E'.

'd' is the distance from the source in feet.

3) What would be the exposure rate by one feet away from 100 mci of I-131

$I\text{-}131 \rightarrow \gamma_1 = 0.364\,MeV, \quad 81.2\%$

$\gamma_2 = 0.636\,MeV. \quad 7.3\%.$

R/hr @ 1 foot $= 6(0.1\,ci)\,[0.364 \times (0.812) + 0.636 \times (0.073)]$

$= 0.21\,R/hr$ at 1 foot.

$= 210\,mR/hr$ at 1 foot.

4). The intensity of an unshielded Cs-137 source is 1 R/hr. If the source is put into a lead shield of 2 inches thick, what would be the intensity of the outside of shield? Assume your distance from the source has not changed. (Density of lead $= 11.35\,gm/cm^3$

$I = I_0 \cdot e^{-\mu x}$,

wrong.

$= (0.114\,cm^2/gm) \times (11.35\,gm/cm^3$

$= 0.0014 R/hr = 1.4 mR/hr.$

→ half value layer :

thickness of a shielding material, required to reduce intensity to one half of its original intensity. It is calculated by setting $I = \frac{1}{2} I_0$. and solving we get :

$$0.5 = e^{-\mu x_{1/2}}$$

$$x_{1/2} = -\frac{\ln(0.5)}{\mu}$$

$$x_{1/2} = \frac{0.693}{\mu} = HVL.$$

5) How much lead shielding must be used to reduce the exposure rate from I-131 source from 32mR/hr to 2mR/hr? HVL of lead of I-131 is 0.178 cm

$$2^n = \frac{I_0}{I} = \frac{32 mR/hr}{2 mR/hr}$$

$$2^n = 16.$$

$$2^n = 2^4.$$

$$\boxed{n = 4} \Rightarrow 4\,HVL \times \frac{0.178\,cm}{HVL}$$

$$= 0.71 cm.$$

6). Estimate the thickness of a lead container for 30 GBq of Tc-99m. Dose rate at 1m should be 2 µSv/hr. (when Dose rate ... is ... TVL = 0.9mm lead

Dose rate for unshielded source : $0.017\ \mu Sv(h^{*}MBq)$

$\times$ 30000 MBq = 510 $\mu Sv/h$

Reduce exposure 255 times which equals :

$\ln(255) / \ln(10) = 2.4$ TVL

$= 2.4 \times 0.9$ mm

$= 2.2$ mm lead.

7). What thickness of lead is required to reduce the exposure rate to 20 $\mu Sv/hr$ at 1m for a container designed to store 15GBq I-131?

where $\Gamma = 0.0764\ \mu Sv h^{-1} MBq^{-1}$

→ where, unshielded dose rate at 1metre will be $15000 \times 0.0764 = 1146\ \mu Sv h^{-1}$

The shield should be designed to reduce dose rate by factor of $\frac{1146}{20} = 57.3$.

which is achieved by: $\frac{\ln(57.3)}{\ln(10)} = 1.76$

TVL for I-131 is 9.5mm hence

$9.5 \times 1.76 \Rightarrow 16.7$ mm of lead

8). A vial containing 2GBq of F-18 is put in a 2mm lead shield generally used for Tc-99m sources. How much will this shield reduce the dose rate at the surface? (TVL for F-18 is 13.5mm lead)

The attenuation co-eff $= \frac{\ln(10)}{TVL} = 0.1706$ mm

→ The dose rate will be reduced to } $= D/D_0 = \exp^{(-0.1706\times 2)}$

$\Rightarrow D/D_0 = 0.71$

$D = 0.71$ of the unshielded dose rate (D_0)

9). How many rad dose a 100kg person receives if they absord 0.5J of energy?

where $1\,rad = \frac{0.01J \text{ of energy}}{kg}$.

$1\,rad = 1\,cGy = 10^{-2}\,J/kg$.

$rad = \frac{100kg}{0.5J} \times \frac{0.01J}{kg} = \frac{1}{0.5} = 2\,rad$

10). In 1year a worker recieves a γ dose of 0.01Gy a thermal neutron dose of 0.002Gy and a fast neutron dose of 0.0002Gy. What is the total equivalent dose?

Equivalent dose = Absorbed dose × Radiation weighting factor.

$\gamma = 0.01\times 1 = 0.01\,SV$.

Thermal neutron $= 0.002\times 2.5 = 0.005\,SV$.

Fast neutron $= 0.002\times 20 = 0.004\,SV$.

Total equivalent dose $= 0.019\,SV$.

11) If a person is permitted to recieve a total dose of 200 µSv in a week, for many hours during that week may

they work in an area in which the dose rate is 10 μSv/hr.

Dose = Dose rate × time.

Time = Dose / Dose rate

$$= \frac{200\ \mu Sv}{10\ \mu Sv/hr} = 20\ hrs$$

11). Calculate the flux at a distance 0.5m from a source which emits 2×10^7 n/s.

$$\phi = \frac{Q}{4\pi r^2}$$

$Q = 2 \times 10^7$ n/s.

$$= \frac{2 \times 10^7\ ns}{4 \times 3.14 \times (0.5)^2} = 6.4 \times 10^6\ n/m^2/s$$

12) Calculate the γ photon flux at 1m from a 0.1 TBq cobalt-60 source.

where 0.1 TBq = 10^{11} dps, but Co-60 there are two γ-photons/disintegration.

$Q = 2 \times 10^{11}$ photons/s.

$$\phi = Q/4\pi r^2$$

$$= \frac{2 \times 10^{11}}{4\pi \times 1^2} = 1.6 \times 10^{10}\ \gamma\ photons/m^2/s$$

13). A useful expression for calculating the approximate dose rate from a 'γ' point source is

$$D = \frac{ME}{6r^2}$$

⇒ calculate the approximate, dose rate at a distance of 2m from a 240 MBq cobalt source. Co-60 emits two γ-rays per disintegration of 1.17 and 1.33 MeV.

$$D = \frac{ME}{6r^2} \cdot \mu Sv/hr.$$

$$= \frac{240 \times (1.17 + 1.33)}{6 \times 2^2} = \frac{240 \times 2.5}{24}$$

$$= 25 \ \mu Sv/hr.$$

14) Calculate the activity of a Sodium-22 source which gives a dose rate of 64 μSv/hr at 1 metre. Assume that Na-22 only emits one γ-photon of energy 1.28 MeV per disintegration.

$$D = ME/6r^2$$

$$64 = M \times 1.28/6(1)^2$$

$$\therefore M = (64 \times 6)/1.28 = 300 \text{ MBq}.$$

15) A calibrated C-137 beam has an exposure rate $\frac{2000R}{hr}$ at 100cm from source. Given - Specific activity (88 Ci/g) and exposure rate const 3.43 $Rcm^2/(mCi.hr)$, what is mass of CS-137 source?

$$\Gamma = \frac{\Gamma \times A}{d^2} \Rightarrow A = \frac{\Gamma \times d^2}{\Gamma} \Rightarrow \frac{2000 R/hr \times (100)^2}{3.43 R\,cm^2/mCi\text{-}hr}$$

$$\Rightarrow 5830903.7 \text{ mCi}$$

$$A \Rightarrow 5830.9 \text{ Ci}$$

$$\Rightarrow 5830.9 \Rightarrow \boxed{66.2 g}$$

Q) What is the principle of dose optimization in radionuclide therapy?

→ The optimization requires an accurate ; and precise prescribed dose to the target tissue or organ being treated in order to reach the desirable biological effect. Therefore, optimization means individual dose planning and calculation based on uptake measurement, the volume of treated organ and correct determination of amount of activity to administer.

Q). Duane - hunt law?

In x-ray, Gives the maximum frequency of x-ray than can be emitted by bremstralung in a x-ray tube by accelerating electrons through an excitation voltage 'V' into a metal target.

$$eV = hc/\lambda$$

Q). A person (patient) get permanent implant of isotope of $T_{1/2}$ = 15 days. initial dose rate is 0.2Gy/hr. What will be cumulative dose?

Mean life = $1.44 \times T_{1/2}$.

$= 1.44 \times 15\text{days} \times \frac{24\text{hrs}}{\text{day}} \times 0.2\text{Gy/hr}$

$= 103.68\text{Gy}$.

Q). A point source of Co-60 exposure is reduced by 65% from its initial value by placing a shielding material of HVL is ... the ... thickness of lead?

$I = I_0 \cdot e^{-\mu x}$

$\mu = \frac{0.693}{HVL}$

$= \frac{0.693}{11}$

$\Rightarrow 0.063.$

$\frac{35}{100} = \frac{100}{100} = e^{-\mu x}$

$\frac{35}{100} = e^{-0.063 \times x}$

$\ln(0.35) = \ln e^{-0.063x}$

$-1.049 = -0.063x \Rightarrow \boxed{x = 16.65\ mm}$

Q). If a radionuclide decays at a rate of 30% / hr. what is the half life of source?

$\lambda = \frac{0.693}{T_{1/2}}$ $\qquad \lambda = \frac{30}{100} = 0.3$

$T_{1/2} = 0.693 / 0.3$ $\qquad T_{1/2} = 2.31 days$

Q). calculate the cumulative exposure of radiation worker recieves from 15mci, F-18 source by standing for 2hrs @ 2cm. $\gamma = 6.93\ Rcm^2/mci\text{-}hr$

$$Exposure = \frac{Exposure\ rate\ const \times A}{d^2}$$

$$= \frac{6.93\ Rcm^2/mci\,hr \times 15mci}{(2cm)^2}$$

$$\Rightarrow \frac{103.95\ R\,cm^2/hr}{4\,cm^2} \Rightarrow 25.9\ R/hr.$$

$$\text{cumulative exposure} = 1.44 \times T_{1/2} \times \{\text{Exp rate}\} \times (1 - e^{-\lambda t})$$

$$= 1.44 \times \frac{110}{60} \times 25.9R/hr\ [1 - e^{-\lambda t}]$$

$$= 1.44 \times 1.833\ hr \times 25.9\ R/hr\ [1 - e^{-\frac{0.693 \times 2}{1.83}}]$$

$$= 1.44 \times 1.833 \times 25.9R \times ~~0.3137~~\ 0.53$$

$= 36.20\ R/2hr$

Q) HVL of 511kev photons is 0.55 cm calculate the thickness of lead shield required to reduce the exposure to 90% of initial value exposure?:

$$HVL = \frac{0.693}{\mu} = \frac{0.693}{0.55} \Rightarrow 1.26\ cm.$$

$$I = I_0 . e^{-\mu x}.$$

$$\frac{10}{100} = \frac{100}{100} . e^{-\mu x}.$$

$$0.1 = e^{-1.26 \times x}.$$

$$\ln(0.1) = \ln e^{-1.26 \times x}$$

$$-2.302 = -1.26 \times x$$

$$\boxed{x = 1.83\ cm}$$

Q. While handling the 25mci of zinc-65 source, 15cm forceps, within how much time, the operator will recieve weekly permissible limit?

(ERC = 2.7R cm² /mci-hr).

$$Exposure = ERC \times A / d^2. \Rightarrow \frac{2.7 R\ cm^2 / mci\text{-}hr \times 25 mci}{(15 cm)^2}$$

$$= 0.3 R/hr \text{ (or) } 300 mR/hr.$$

weekly limit = 40 mR.

$$time \Rightarrow \frac{Dose}{Dose\ rate} \Rightarrow \frac{40 mR/week}{300 mR/hr}.$$

$\Rightarrow$ 0.13 hr.

$\Rightarrow$ 8 minutes.

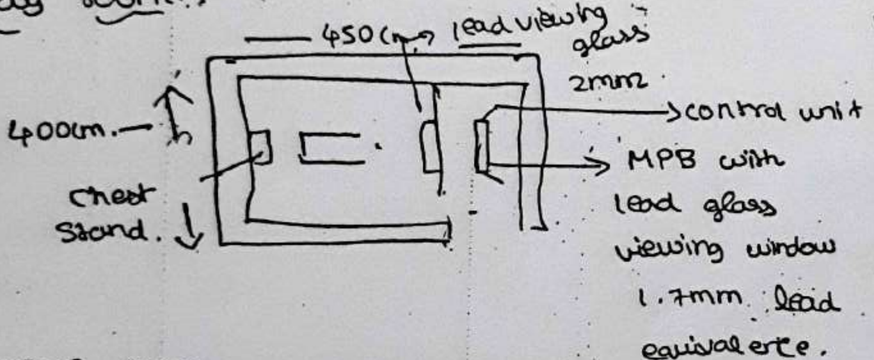
Q) Main features of bhabhatron-II :

- capacity to load 15K curie Co-60.
- X jaw symmetric, whereas Y jaw asymmetric (FAW).
- Minimum possible field size 0×0.
- Gantry rotation 180°.

Q). Features of theratron -780E1.

- capacity to load only 12K curie Co-60.
- symmetric jaws.
- minimum possible field size 4×4.
- Gantry rotation 360°.

LAYOUT OF DIAGNOSTIC X ray room :



leakage:- averaged over an area not larger than 100 cm^2 with no linear dimension greater than 20cm, shall not exceed 1 mGy in 1hr at distance of 1m from target.

room area = 400×450cm.

Shield material (cm)	(1.5m)	(2m).
Lead :	0.17	0.15.
Concrete :	15	12.
Brick :	23	20.

workload in Radiology:

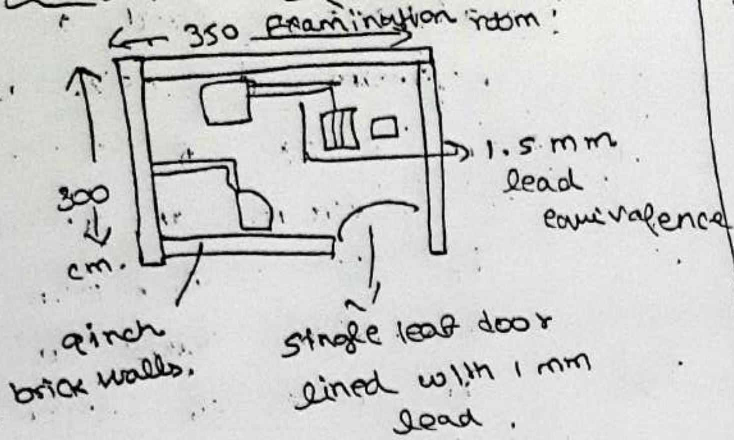
$$W = \frac{\text{No. of pt}}{\text{day}} \times \frac{\text{No. of days}}{\text{wk}} \times \frac{\text{No. of Films}}{\text{patients}} \times \frac{\text{mAs}}{\text{film}} \times \frac{1\text{ min}}{60\text{ sec}}$$

(Floor & ceiling thickness of 6-8 inch concrete is adequate)

peak voltage	TVL (lead:)
50	0.17
100	0.88
125	0.93.

According to IEC, maximum air kerma rate is 0.87 mGy in 1hr

Mammography room:



room area: 320 x 350 cm.

leakage:

leakage radiation averaged over an area of $10cm^2$ with no linear dimension greater than 5cm and located at 5cm from any point of external surface of x-ray tube, shall not exceed 0.02mGy in one hr.

occupancy factor:

- Full : (office, lab, ward, nurse station) – 1.
- partial : corridor, rest room, parking lot – 1/4.
- occasional : waiting room, toilet, stairway – 1/16.

Shielding material: (Mammo)

	(m)	(1.5m)
Gypsum wallboard (cm).	1.5	1
plate glass	1	1

Q) fast neutron production:

1) Neutrons can be produced in a cyclotron by accelerating deutrons or protons and impinging them on a beryllium target.

2) protons or deutrons must be accelerated to ≥ 50 MeV to produce neutron beam with penetration comparable to MV x-rays.

Q) Neutron leakage limit (AERB)?

i) Neutron leakage limit radiation outside the BLD (in the patient plane). Beam limiting device	Shall not exceed a maximum of 0.05% and an average of 0.02% of maximum absorbed dose in 10cm x 10cm radiation field at the point of intersection with radiation beam axis.
ii) Neutron leakage outside the patient plane.	Shall not exceed 0.05% of the maximum absorbed dose due to electron or x-radiations.

Q) How to shield neutrons.

→ 45mm TVL for borated polyethylene (Maze door shielding)

→ 161 mm TVL for concrete wall adjacent to the door.

→ The average neutron energy at maze entrance is 100keV or 0.1MeV. TVL required is 1.6 cm. which is the secondary barrier itself sufficient to attenuate (TVL - 8.3" - concrete
3.8" - polyethylene)

Q) Controlled area ? Supervised area: (Definition).

i) A delinated area to which access is controlled and in which specific protection measures and safety provisions are, or could be, required for (i) controlling normal exposures or preventing the Spread of contamination during normal working conditions:.

b) preventing potential exposure or limiting their extent should they occur.

ii) Supervised area:.

Any area not designated as a controlled area but for which occupational exposure condition are kept under review even though specific protective measures and safety provision are not normally needed.

Q) Name low activity gamma source used for permanent implant?

Iodine -125 (low γ- energy 0.035MeV).

$T_{1/2}$ = 60 days

other permanent implants: Pd-103 : 33keV characteristic x-ray.

$T_{1/2}$ = 17 days.

Au -198 - β-decay. (1.6 MeV).

(2.8 days)

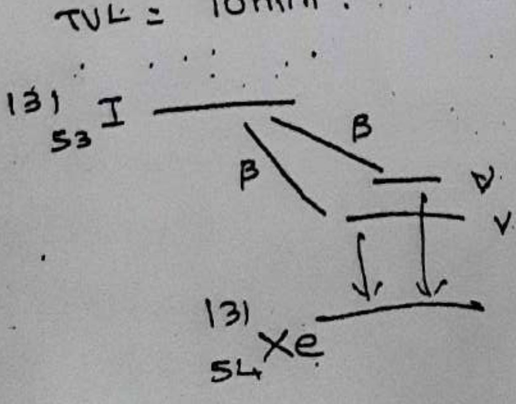
Q) I-131 $T_{1/2}$, energy, HVL.

$T_{1/2}$ = 8. days.

energy = β (606 keV) γ (364 keV).

HVL = 3mm.

TVL = 10mm.



Q) How to optimize dose?

optimization is defined in IAEA safety as process of determining what level of protection and safety would result in magnitude of individual doses, the number of individual subject to exposure and the likelihood of exposure being as low as reasonably achievable.

→ we have to optimize dose by choosing correct exposure to the patient and also to get good quality image

Q) what is TADR & IDR.

Time averaged dose rate is the barrier attenuated dose rate averaged over a specified time. TADR is proportional to IDR

$$TADR = IDR \cdot \frac{\text{Daily beam on time}}{\text{Length of working days}}$$

$$RS = IDR \times \frac{W_d U}{8 \times DR_0}$$

Q) Formula to find maximum leakage from tube housing.

Max leakage from tube housing

$$= \frac{\text{mA-min in one hr} \times \text{Max. leakage radiation level (mR/hr)}}{60\text{min} \times \text{mA used for measurement}}$$

Radiation Leakage at 1m distance < 1 mGy/hr

5cm from Surface of mammography < 0.02mGy

Radiation Leakage limit from 1m distance from focus to dental unit < 0.25 mGy in 1 hr.

Q) Explain in patient plane & other than patient plane?

* In patient plane - radiation level measured at couch (2.5 m) circular radius.

* other than patient plane - radiation measured near treatment head.

Q). why other than patient plane have more percentage (0.5% of max absorbed dose at NTD) of permissible absorbed dose than in patient plane (0.1% & avr is 0.2% max).

Because Radiation will be higher near treatment head when compared with radiation near couch.

Q). If you are RSO and radiation worker TLD was missing and you find it in radiation area the next day? what action you take as RSO?

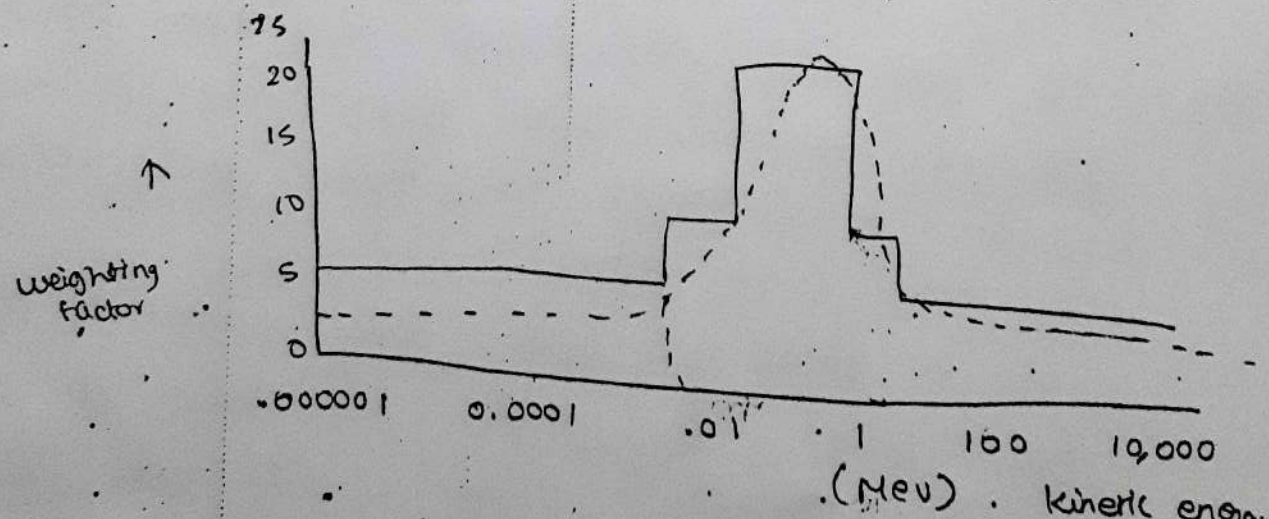
As a RSO, I will ask respective person about details of when he lost it and I will send that TLD to a lab and intimate the competent authority that the radiation dose recieved in that tld for that particular person of particular period is not due to genuine exposure.

Q) If patient is not well, how to take image?
lead apron for attender standing as far away distance as possible.

Q) How to check if lead apron is good and working?

All lead protective apron should be tested for shielding integrity on receipt & approx. 12-18 months interval. Testing is performed using fluoroscopy on a floating top table. While this will not measure lead equivalence, it will quickly show faults, holes and apron deterioration.
lead apron is considered to be defect if greater than 15 mm².

Q) Neutron weighting factor difference between ICRP 60 and 103. From where the neutron curve starts in icrp 103, it is greater or lesser than ICRP 60.



Q) why 10cm for output measurement?
we can keep 5cm also for certain beam qualities. Idea is chamber should be positioned in less uncertainity depth. (depth : where electron equilibrium exists

Q) If patient is not well, how to take image?

lead apron for attender standing as far away distance as possible.

Q) How to check if lead apron is good and working?

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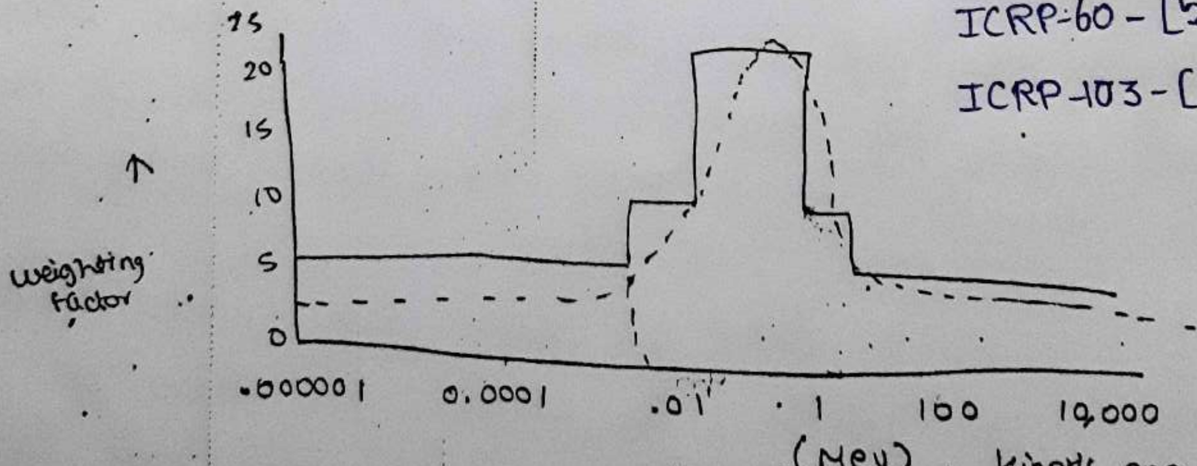
Q) Neutron weighting factor difference between ICRP 60 and 103. From where the neutron curve starts in icrp 103, it is greater or lesser than ICRP 60.

Starts from:-

ICRP-60 - [5]

ICRP-103 - [2]



Q) Why 10cm for output measurement?

we can keep 5cm also for certain beam qualities. Idea is chamber should be positioned in less uncertainty depth (depth : where electron equilibrium existing ... maximum contamination depth & less head scattering depth

(8) A radiographer is performing barium examination under fluoroscopy and the equipment is 'ON' for 3 minutes for each examination. The radiation level at the location of the radiographer is 100mR/hr. How many such procedures the radiographer can carry out per week?

The annual equivalent dose limit = 20mSv

$$= 2000\,mR/yr$$

$$= \frac{2000\,mR}{50\,wk}$$

$$\Rightarrow 40\,mR.$$

Exposure rate at location

$$100\,mR/hr \Rightarrow \frac{100\,mR}{60\,mins} \times 3\,mins = 5\,mR.$$

the no: of procedures the radiographer can take in one week is $\frac{40}{5} \Rightarrow 8$.

(9). An operator is handling 10mCi of I-131 source with 30cm tongs. within how much time the technician will recieve the weekly permissible equivalent dose. ($\Gamma = 2.18\ R\text{-}cm^2/mCi\text{-}hr$).

$$\Gamma = \frac{\left.\begin{matrix}\text{Exposure}\\ \text{rate const}\end{matrix}\right\} \times A}{d^2} \Rightarrow \frac{\frac{2.18\,R\text{-}cm^2}{mCi\text{-}hr} \times 10\,mCi}{(30\,cm)^2}$$

$$\Rightarrow 0.02\,R/hr$$

$$\Rightarrow 24\,mR/hr.$$

$$\text{Allowed time of week} = \frac{40\,mR}{24\,mR/hr} \Rightarrow \frac{40\,mR}{\frac{24\,mR}{60\,min}}$$

$$\Rightarrow \frac{40\,mR}{0.4\,\frac{mR}{min}}$$

$$\Rightarrow 100\,mins.$$

Q) why the public dose limit is less than worker?

For variety of reason, dose limit to public are set lower than radiation worker. Justification for this approach include.

→ The public inclue children who might represent a group at increased risk and who may be exposed for their whole lifetime.

→ It is not the decision or choice of public that they are exposed.

→ public are exposed for their entire lifetime; workers are exposed only during their working lifetime.

→ The public may receive no direct benefits from exposure

→ The public is not subject to the selection, supervision and monitoring afforded radiation worker.

Q) why the lead apron is 0.25mm thickness?

The lead apron of 0.25 mm : > 90% scattered radiation is attenuated.

0.5mm : 95-99% scattered radiation is attenuated.

→ Though higher thickness apron offer greater protection, it weight 50 - 100% more than 0.25mm thickness. It is great matter of concern in fluoroscopy.

Q) what you will do if spillage occurs?.

The steps involves in radioactive spill are

→ To inform.

→ To contain.

→ To decontaminate.

1). Individual in the immediate work area should be informed that the spill has occurred so that they can avoid contamination if possible. Individual outside area should be warned so that they do not enter it.

2) The laboratory personnel should attempt to control the spill prevent further spread of contamination, without risking themselves. "Absorbent pad should be thrown over a liquid spill. Door should be closed to prevent the escape of air borne activity.

3) personnel decontamination procedure should recieve first priority followed by decontamination of work areas.

Q) Discharge limit of delay tank?

monthy limit - 22 MBq / m³. daily - 3.7 MBq / m³.

Q). Acute, chronic radiation effect?

→ Acute - short term exposure to relatively high level of contaminant. acute exposure may result in acute effects which can range from relatively mild (eye irratiation) to extreme asthma attack)

→ Chronic exposure may result in chronic effect (cancer, chronic obstructive pulmonary disease) Long term exposure relatively low level of contaminants

1) During radiation protection survey of x-ray installation. The radiation level was 200mR/hr at control console panel and 150mR/hr at the door outside the room for 100kV and 20mA current. The workload of the x-ray installation was 800mA.min/wk. Find out the total weekly dose recieved by the occupational worker and general public. whether dose is within limit or not?

→ operating mA = 20 mA.

→ Beam on time = $\frac{800 mA.min/wk}{20mA}$

= 40min/wk.

in hours = 0.666hrs/wk.

1) Exposure at control console = $\frac{200mR}{hr} \times \frac{0.666 hr}{wk}$

= 133 mR/wk.

allowed limit $\frac{40mR}{wk}$. It is exceeding limit.

2) Exposure at door outside patient waiting area } = $\frac{150mR}{hr} \times \frac{0.666 hr}{wk}$

= $\frac{99.9 mR}{wk}$

allowed limit $\frac{2mR}{wk}$. It is exceeding limit.

1.

Find out Radiation level beyond the wall of room housing diagnostic X-ray machine, if radiation survey was found to be 10 mR/hr when operated with 50 mA and 120 kV. Find out whether radiation level is within limit or not if location occupied by radiation worker? Assume workload = $\frac{500 \text{ mA-min}}{\text{wk}}$.

→ operating mA = 50 mA

→ Beam on time = $\frac{\text{workload}}{\text{mA}}$ = $\frac{500 \text{ mA-min/wk}}{50 \text{ mA}}$

$$\Rightarrow \frac{10 \text{ min}}{\text{wk}} = \frac{0.166 \text{ hrs}}{\text{wk}}$$

1). Exposure at control console ⇒

Measured Radiation level × Beam on time.

$$= \frac{10 \text{ mR}}{\text{hr}} \times \frac{0.166 \text{ hr}}{\text{wk}}$$

$$\Rightarrow \frac{1.66 \text{ mR}}{\text{wk}}.$$

allowed limit is $\frac{40 \text{ mR}}{\text{wk}}$. It is within limit.

3). Radiation level observed during the protection survey of high dose rate brachytherapy facility is 3 mR/hr at control console with activity of 8 Ci of Ir-192 source. Find out whether the radiation is in acceptable workload = 296 GBq (8 ci) × 111 $\frac{\mu Gy \cdot m^2}{GBq\text{-}hr}$ × $\frac{10\ pts}{day}$ × $\frac{5\ day}{wk}$ × $\frac{10\ min\ (0.167\ hr)}{pt}$

$\Rightarrow$ 274347.6 μGy/wk.

= 274.3 mGy/wk $\Rightarrow$ 27430 mR/wk.

$$R_w = \frac{IDR \times W \times U \times T}{D}$$

$$\Rightarrow \frac{\frac{3\,mR}{hr} \times 27430\,mR/wk}{D}$$

where D (Dose rate) = 296 GBq × 111 $\frac{\mu Gy \cdot m^2}{GBq \cdot hr}$

$\Rightarrow$ 32856 μGy/hr at 1 metre

= 32.85 mGy/hr at 1 metre

D. = 3285 mR/hr at 1 metre

$$R_w \Rightarrow \frac{\frac{3\,mR}{hr} \times \frac{27430\,mR}{wk}}{3285\,mR/hr} \rightarrow \frac{685.75\,mR}{hr}$$

$$= \frac{\frac{2057.25\,mR^2}{hr^2}}{3285\,mR/hr} \Rightarrow \frac{0.6262\,mR}{hr}$$

allowed limit for radiation worker is 1 mR/hr. It is within limit.

Q). The Radiation level of photon and neutron dose is 20μSv/hr and 0.5μSv/hr at the primary wall, which is adjacent to the account office room of RT of 15MV machine. Dose rate is 500MU/min. workload is 0.5×10^5 cGy/wk. Notify whether the exposure is safe or not?

IDR = 20μSv/hr for photons. (1cGy = 1MU)

$W = 0.5 \times 10^5$ cGy/wk.

D = 500 MU/min.

$U_p = 1/4$ T = 1.

i) $TADR = R_W \Rightarrow \frac{IDR \times W \times U_p \times T}{D}$

$$= \frac{20\,\frac{\mu Sv}{hr} \times 0.5 \times 10^5\, cGy/wk \times \frac{1}{4} \times 1}{500\, MU/min}$$

$$= \frac{\frac{20\,\mu Sv}{60\,min} \times \frac{0.5 \times 10^5\, MU}{wk} \times \frac{1}{4} \times 1}{500\, MU/min}$$

$$= \frac{8.333\,\mu Sv}{wk} = \frac{8.333\,\mu Sv}{5 \times 8\,(hr)}$$

$= 0.2083\ \mu Sv/hr.$

$= 0.0208\ mR/hr.$ [photon]

ii) Neutron

$$R_W = \frac{\left[\frac{0.5\,\mu Sv}{hr} \times \frac{0.5 \times 10^5\, MU}{wk} \times \frac{1}{4} \times 1\right]}{500\, MU/min}$$

$= 0.2083\ \mu Sv/wk.$

$= \frac{0.2083\ \mu Sv}{40\,(hr)} \Rightarrow 5.2083 \times 10^{-3}\,\frac{\mu Sv}{hr}.$

$= 0.5208\ \mu R/hr \Rightarrow 0.0005\ mR/hr$

Q) Exposure rate in adjacent area of primary wall is 25 μR/hr and 1 μR/hr of photon and neutron. The workload is 0.5×10^5 cGy/wk and 500 MU/min is dose rate. It is safe?

i) For photons:-

1 cGy = 1 MU

IDR = 25 μR/hr

$W = 0.5 \times 10^5$ cGy/wk

D = 500 MU/min. U = 1/4 T = 1.

i) TADR ⇒ $R_W = \dfrac{IDR \times W \times U \times T}{D}$

$= \dfrac{25\,\mu R/hr \times 0.5 \times 10^5 \frac{cGy}{wk} \times \frac{1}{4} \times 1}{500\,MU/min}$

$= \dfrac{\frac{25\,\mu R}{60\,min} \times \frac{0.5 \times 10^5\,MU}{wk} \times \frac{1}{4} \times 1}{500\,MU/min}$

$= 10.41\,\frac{\mu R}{wk}$

$= 0.0104\,\frac{mR}{wk}$ within limit.

ii) For neutron.

TADR = $R_W = \dfrac{IDR \times W \times U \times T}{D}$

$= \dfrac{\frac{1\,\mu R/hr}{60\,min.} \times 0.5 \times 10^5 \frac{cGy}{wk} \times \frac{1}{4} \times 1}{500\,MU/min}$

$= 0.41\,\frac{\mu R}{wk.}$

$= 0.00041$ mR within limit

(3) In diagnostic Radiology 25mR/hr at console level. It is safe for worker and public? workload is $\frac{600 mA \cdot min}{wk}$ and 200 mAS in 2S.

$\Rightarrow \frac{200 mAS}{2S} = 100 mA.$

Beam on time $= \frac{\frac{600 mA \cdot min}{wk}}{100 mA}$

$= 6 min/wk.$

$= 0.1 hr/wk.$

1) Exposure at controle console $\}$ = Measured Radiation $\}$ × Beam on time

$= \frac{25 mR}{hr} \times 0.1 \frac{hr}{wk}$

$= 2.5 \frac{mR}{wk}.$

→ allowed limit for worker $\frac{40 mR}{wk}$ it is within limit.

→ allowed limit for public $\frac{2 mR}{wk}$. it is not within limit.

Q) Shielding calculation of HDR brachytherapy. (Iridium - 192).

Typical workload

Source activity = 10 Ci.

no. of patients/day = 10/day

No. of working days / week = 5 day/wk.

Max. treatment time : 10 mins (for 10 ci) workload = $10{,}000 \times 10 \times 5 \times 10 \times (1/60) \times 4.1 \, \frac{\mu Gy.m^2}{wk.}$

$= 3.4 \times 10^5 \, \frac{\mu Gy.m^2}{wk}$

$= 3.4 \times 10^2 \, \frac{mGy.m^2}{wk}.$

Reduction factor (R.F) = $\frac{WUT}{Pd^2}$.

$U = 1 \quad T = 1$

$P = 0.4 \, mGy/wk$ for radiation worker.

$P = 0.02 \, mGy/wk$ for general public.

i) calculation of wall 1

$W = 3.4 \times 10^2 \, mGy \, m^2/wk.$

$U = T = 1.$

$P = 0.02 \, mGy/wk.$

$d = 2 + 0.45 = 2.45$ (2m distance from source to wall, 0.45 m is inside the wall to point of interest.

$R.F = \frac{WUT}{Pd^2} = 2832.15.$

$\log R.F = \log(2832.15)$

$= 3.45 \, TVT.$

$\because$ 1 TVL = 13.5 cm for Ir-192 (concrete)

$= 3.45 \times 13.5 cm$

Concrete thickness } = 46.6 cm

Q) what is security & safety?

Security ~~measures~~ means measures to prevent unauthorized access or damge to, and loss, theft or unauthorized transfer of, radioactive sources.

Safety means measures intended to minimize the likelihood of accident with radioactive sources and should such an accident occur, to mitigate its consequences.

Q). what will be the thickness of the wall of Brachytherapy ward with one patient treated with 10ci Ir-192 HDR unit?

Activity = 10ci. RHM = $0.45 \frac{R.m^2}{hr.ci}$.

TVT = 15cm. d = 2m. Beam on time = $\frac{3hr}{wk}$.

Full occupancy = 1.

~~Barrier~~. workload = $10ci \times 0.45 \frac{R.m^2}{hr.ci} \times \frac{3hr}{wk}$

= 13.5 R/wk at 1 metre.

Barrier thickness

$$R.F = \frac{WUT}{Pd^2} \Rightarrow \frac{13.5\times10^3 \frac{mR}{wk} \times 1 \times 1}{2 mR/wk \times (2.45)^2}$$

$$= \frac{13500 \text{ mR/wk}}{12.005 \text{ mR/wk}} = 1124.53$$

$x = \log(1124.53) \times 15cm.$

$= 3.05 \times 15cm = 45.75 \simeq 45cm$

8. The maximum photon and neutron radiation level in the account office of the hospital which is adjacent to primary wall were found to be $20\frac{\mu Sv}{hr}$ & $0.5\ \mu Sv/hr$ through primary barrier of 15MV Linac room when the linac was operates with the dose rate of 500MU/min. Explain whether the office is safe from radiation safety point (or) not.

1MU = 1cGy   wkload = 0.5×10^4 cGy/wk at isocentre

$D = 500MU/min.$

wkload $= 0.5\times10^4$ cGy/wk.

$T = 1$ $U = 1/4$.   (for photons)

$$TADR = \frac{IDR \times W \times U_p \times T}{D}.$$

$$\Rightarrow \frac{20\frac{\mu Sv}{hr} \times 0.5\times10^4\frac{cGy}{wk} \times \frac{1}{4} \times 1}{500\ MU/min}$$ 1MU = 1cGy

$$\Rightarrow \frac{20\ \mu Sv \times 0.5\times10^4}{4\times500\ min.}$$

$$\Rightarrow \frac{100000\ \mu Sv/hr}{2000\ min.} \Rightarrow \frac{\frac{100000}{60}}{2000}$$

$$\Rightarrow \frac{1666.6}{2000}\frac{\mu Sv}{wk}.$$

$$= \frac{0.83\ \mu Sv}{wk.} \Rightarrow \frac{0.83\ \mu Sv}{8\times5}.$$

$$\Rightarrow 0.0208\ \frac{\mu Sv}{hr}$$ for photons

For neutrons:

$$TADR = \frac{IDR \times W \times U_P \times T}{D}.$$

$$\Rightarrow \frac{\frac{0.5\,\mu Sv}{hr} \times 0.5\times10^4 \frac{cGy}{wk} \times \frac{1}{4} \times 1}{500\,MU/min}.$$

$$\Rightarrow \frac{\frac{0.5\,\mu Sv}{60\,min} \times 0.5\times10^4 \frac{cGy}{wk} \times 1}{500 \frac{cGy}{min} \times 4}.$$

$$\Rightarrow \frac{0.0083\,\mu Sv \times 0.5\times10^4}{2000\,wk} \Rightarrow \frac{41.5\,\mu Sv}{2000\,wk}$$

$$\Rightarrow \frac{0.0207\,\mu Sv}{wk} \Rightarrow \frac{0.0207\,\mu Sv}{40\,hr}.$$

$$\Rightarrow 0.00051 \frac{\mu Sv}{hr}.$$

∴ Total radiation dose due to photon & neutron is

$$\Rightarrow 0.0208 \frac{\mu Sv}{hr} + 0.00051 \frac{\mu Sv}{hr}.$$

$$\Rightarrow 0.02131 \frac{\mu Sv}{hr}.$$ It is within tolerance. $[0.05 \frac{mSv}{hr}]$.

Q) An individual was involved in exposure incident. He stated that he was about 4m from an unshielded Cs-137 source $A = 3.7\times10^{12}$ Bq for about 10 mins. The TLD worn by individual was processed and registered as 22.4 mSv. What is your estimation on dose actually he recieved.

$\Rightarrow$ $A = 3.7\times10^{10} \times 10^2$ Bq $\Rightarrow$ 100 Ci source.

$$\dot{X} = \frac{\left.\begin{matrix}\text{Exp. rate} \\ \text{const}\end{matrix}\right\} \times \text{Activity}}{D^2} \Rightarrow \frac{100\ ci \times \frac{3.26\ R\ cm^2}{mci - hr}}{(400\ cm^2)}$$

$$\Rightarrow \frac{100000\ mci \times 3.26\ R\ cm^2}{160000\ cm^2\ mci - hr}$$

$$\Rightarrow \frac{326000}{160000}\ R/hr$$

$$\Rightarrow 2\ R/hr$$

$$1\ Gy \Rightarrow 100\ R$$

$$\Rightarrow 0.02\ Gy/hr \Rightarrow \frac{20\ mSv}{hr}$$

$$\Rightarrow \frac{20\ mSv}{60\ min} \times 10\ min \Rightarrow 3.4\ mSv$$

Q In a incident a radioactive source Ir-192 having activity 10 ci was stolen along with other scrap material from a site. The person who was stolen the source transported it in an auto and, kept it 50cm away from his body. The auto driver was 2m away from the source. It took 25mins to reach a scrap dealer shop. What will be the whole body dose to the person and the auto driver. whether they will have any deterministic effect of radiation?

$$\dot{X} = \frac{\begin{matrix}\text{Exp. rate} \\ \text{constant}\end{matrix} \times \text{activity}}{D^2}$$

$$\Rightarrow \frac{\frac{4.69\,R\,cm^2}{mci\text{-}hr} \times 10\,ci}{(50\,cm)^2} \Rightarrow \frac{4.69\,R\,cm^2 \times 10000\,mci}{2500\,cm^2\text{-}mci\text{-}hr}$$

$$\Rightarrow \frac{46900}{2500}\frac{R}{hr} \Rightarrow 18.76\frac{R}{hr} \text{ (for person)}$$

$1R = 1cGy$ $\Rightarrow 18.76\frac{cGy}{hr} = 187\frac{mSv}{hr}.$

for 25 mins

$$= \frac{187\,mSv \times 25\,mins}{60\,mins} \Rightarrow 78\,mSv..$$

[whole body dose]

ii) for auto driver.

$$\dot{X} = \frac{\text{Exp rate constant} \times \text{Activity}}{D^2} \Rightarrow \frac{\frac{4.69\,R\,cm^2}{mci\text{-}hr} \times 10\,ci}{[200\,cm]^2}$$

$$\Rightarrow \frac{46900}{40000} R/hr \Rightarrow 1.17\frac{R}{hr}$$

$1R = 1cGy$ $\Rightarrow 1.17\frac{cGy}{hr}$ or $11.7\frac{mSv}{hr}.$

For ~~25~~ 25 mins

$$\Rightarrow \frac{11.7\,mSv \times 25\,mins}{60\,mins} \quad 4.87\,mSv$$

[whole body dose for auto driver]

∴ This will not cause any determinsitic effect because threshold for determinsitic effect is (1Gy)

One marks

1) x-ray discovered Roengten 1895. used in India for treatment in 1898. $1 R = 2.58 \times 10^{-4} C/kg$.

cannot be used of Photon energy above 3MeV.

unit of kerma = J/kg (or) rad

Absorbed dose = J/kg. 1R = 1cGy.

Exposure rate constant = $\frac{R}{ci \cdot hr}$ @ 1metre.

$\frac{RHM}{60}$ = RMM. = $\frac{1}{curie}$.

→ ICRP -26 report introduced equivalent dose. [AERA]

photon, electron - 1 alpha particle - 20

Neutron - continuous function of energy.

→ 1SV = 100 rem 1 SV = 1Gy.

→ Sievert is for radiation absorbed.

Equivalent dose = organ dose × Radiation weighting factor.

Effective dose = Equivalent dose × tissue weighting factor.

Average annual exposure to natural occuring source (2-3 mSv)

Natural source - cosmic rays, terrestrial, internal

Artificial source - Medical exposure, nuclear fall out.

check contribution level of each exposures. in flow chart.

② Radiobiology :

Radiation deposits energy via excitation, ionization, thermal heating.

Biological effects : chromosomal abberation, cell death, oncogenic transformation, acute radiation sickness.

Interaction ┬ direct - intracts with DNA, RNA.
└ indirect - intracts other than DNA and release electrons.

CA test is useful in determining radiation dose recieved above 100 mGy (minimum threshold).

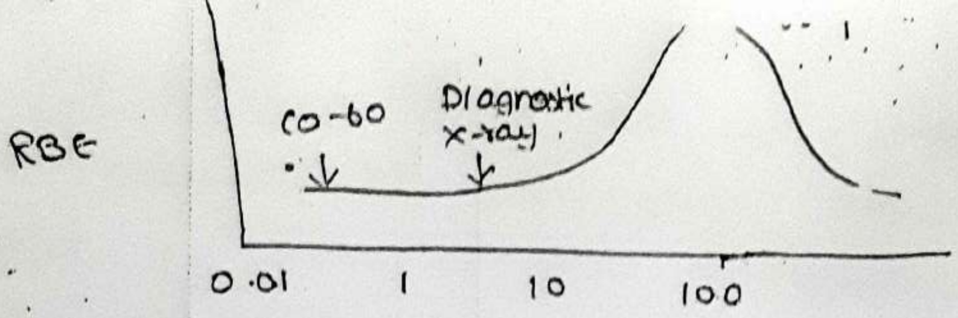
* Absorpion of radiation by water molecule (radiolysis)

LET = average energy deposited per unit path length. unit : keV/μm.

$$RBE = \frac{\text{Dose of 250 kVp X-rays required to produce certain effect.}}{\text{Dose of test radiation to produce same effect.}}$$

RBE value.	LET value.	
	0.3	cobalt-60
1	2	250kVp X-ray.
electrons (1)	4.7	10MeV proton.
protons (1.1 to 1.5)	0.5.	150 MeV protons.
MV X-ray (1)		

Beyond 100keV/μm, RBE decreases with



Biological effects - Genetic [damage due to reproductive cells]
somatic [exposed during his life time].

acute - large dose over short period.
chronic - smaller dose over large period.

Somatic effects due to whole body exposure

<0.1Gy - No detectable damage
Above 0.1Gy - chromosomal aberration detectable
0.5 Gy - Reduction in WBC count.
1Gy - NKD (Radiation sickness.
3-5Gy - death in 4-6 weeks. (Bone marrow syndrome. LD 50,60
8-15Gy - GI syndrome.
>25Gy - central nervous system syndrome.

Somatic effect due to partial body exposure

0.15 Gy - temporary sterility } Male
3.5-6 Gy - permanent sterility } Male
1.5-2 Gy - temporary
2.5-6 Gy - permanent sterility
3Gy - fall of hair.
5Gy - cataract
6Gy - skin reddening.

Deterministic :. has a threshold dose [catarcact, sperm count reduction]

stochastic :. no threshold dose . [cancer , genetic effects]

chromosome damage occur before DNA replication is called chromosome abberation and after DNA synthesis is called chromatid aberration.

Q) → risk is 4 / 10,000 person. latency period - 10 yrs. what is risk of developing cancer next 40 yrs. from 0.1SV.

Actual duration = 40-10 yrs = 30 yrs.

Dose = 0.1 SV.

risk = 4/10,000

Risk of cancer = $30 \times 0.1 SV \times \frac{4}{10,000}$ => $4 \times 3 \times 10^{-4}$

=> 12×10^{-4}.

If 10000 people are exposed to dose of 0.1 SV, 12 cases of cancer seen in next 40 yrs.

ICRP estimates 4% per seivert [adult worker]
5%/sievert [for whole population].

Fatal effect	Non factal	genetic effects	
4×10^{-2}/SV	0.8×10^{-2}/SV	0.8×10^{-2}/SV.	workers.
~~1×10^{-2}/S~~	1×10^{-2}/SV.	$1.3 \times \frac{10^{-2}}{SV.}$	public.

[Genetically significant dose - estimate radiation induced mutation in germ cells of given population]

[Doubling dose - 1Gy/generation]

Fetus Risk- dose below 100mGy no negligible risk. abortion advised, only when doses are >100mGy.

Q) calculate risk of radiation worker and public for annual effective dose of 20mSv and 1mSv. (risk co-efficient = 4×10^{-2} per Sv).

$20mSv = 0.02Sv \Rightarrow 0.02 Sv \times \frac{4 \times 10^{-2}}{Sv} \Rightarrow 8 \times 10^{-4} = \frac{8}{10000}$

$1mSv = 0.001Sv \Rightarrow 0.001 Sv \times \frac{4 \times 10^{-2}}{Sv} \Rightarrow \frac{4}{1,00000}$

NCRP-49 (structural shielding design and evaluation for medical use of x-ray and γ-rays

* Dose limit to controlled area - 0.1mSv/wk
* Dose limit to uncontrolled area - 0.02mSv/wk

→ Dental (IOPA) - area not larger than 100 cm², with No linear dimesion 20cm. } - 0.25mGy in 1hr

→ Leakage radiation from x-ray tube housing } = 1mGy or 115mR @1m

In mamography = 0.02mGy @ 5cm.

→ for 5-50KVp ∴ leakage not exceed 0.1R in any 1 hour @ 5cm.

→ for 50-500kVp ∴ leakage not exceed 1R in 1hr @ 100cm . or 30R/hr @ 5cm.

→ Greater than. 500kVp ∴ leakage radiation at any point outside the maximum field size, but within circular plane of radius '2m', shall not exceed 0.2% of useful beam.

At cobalt-60 : teletherapy

leakage limit @ 5cm - $\frac{20mR}{hr}$ and @ 1m - $\frac{2mR}{hr}$. and $\frac{10mR}{hr}$ maximum at any direction.

In beam on position, the leakage radiation @ 1m should not exceed 0.1 % of useful beam.

Leakage limit of brachytherapy.

For brachytherapy.

→ @ 1m should not exceed 20 μGy/hr or 200 μGy/hr @ 5cm. [NCRP 1mR/hr @ 10cm of shielded container]

→ for emergency storage container

@ 1cm should not exceed 100 μGy/hr.

@ 1m should not exceed ~~100 μGy/hr~~ 10 μGy/hr

Contamination check - 6 months once, limit 200 Bq.

barrier shielding material:

lead, concrete, steel, gypsum.

workload x-ray → $\frac{mA \cdot min}{wk}$ (diagnostic)

therapy → cGy/wk.

use factor : primary barrier - 1

secondary barrier - 1/4

cielding, floor - 1/4.

Monitoring instruments shall be calibrated to an accuracy ± 20 %.

occupancy factor:

office, reception, staff room, shops, control room. } - 1

corridor - 1/4.

Toilet, bath room, store room - 1/16.

Door from room to corridor - 1/8.

workload for diagnosis } = $\frac{\text{No of pts}}{\text{day}} \times \frac{\text{days}}{\text{wk}} \times \frac{\text{No. of film}}{\text{pt}} \times \frac{\text{mAs}}{\text{film}} \times \frac{\text{min}}{60\text{s}}$.

$$TADR = IDR \times \frac{\text{Beam on time}}{\text{Length of working day}}$$

→ personnel monitoring is done by i) film badge ii) TLD, iii). OSLD iv) pocket dosimeter.

Film badge - x, beta, gamma, thermal neutrons

1. open window 2. plastic 3. cadmium.
4. thick copper 5. thin copper 6. lead.

→ Minimum dose film can detect is 0.2 mSv

advantage - permanent record, least expensive.

accuracy - 10%. [disadvantage - fading]

TLD :- X, beta, γ-rays.

consist of $CaSO_4$: Dy - teflon disc.

→ 0.8 mm thick and 13.2 mm dia

→ Thickness ($12\ mg/cm^2$) makes measurement equivalent to 10mm depth below skin surface.

Disc one :- Cu + Al filter. (1 mm Al + 0.9 mm Cu)
Disc two :- perspex. (1.5 mm)
Disc three :- open.

$CaSO_4$: Dy - effective atomic number - 15.3

Tissue equivalent LiF : Mg : Ti - 8.14
tissue - 7.4.

OSLD :-

aluminum oxide with carbon. is OSL dosimeter.

Pocket dosimeter:- instantaneous dosimeter.

-> quartz fibre suspended with air filled chamber

-> Accuracy - 10%.

over exposure:- Exposure more than 10mSV in one quarter is over exposure.

Area survey:- ionization type (air)
geiger-muller type (Neon or halogen)
scintillation detector (NAI (TI))

Ionization chamber:- (Survey meter)
central electrode - aluminum.
outer electrode - graphite.

[Ionization chamber for low level x-ray monitoring are fabricated out of air-equivalent material (bakelite, tufnol) [used energy 7KeV - 2MeV]
end window - thin mylar film for beta radiation detection]

* volume -> 200 - 350 cc [phenolic wall material]

* Argon, neon [electronegative gas].

G-M survey meter:-
(500 - 1300V), amplification factor = ($10^8 - 10^9$)
usually have mixture of gas [argon, neon and chlorine / bromine]
cathode - chromium or copper.
sensitive to particle radiation.
~~expo~~ Radiation level twice the background level is called contamination.

⇒ 0.01 μci for Tc-99m 0.0001 μci for I-131
per 100 sq.cm. [limits].
>100 mci for Tc-99m [major spill]
>1 mci for Iodine-131 [major spill]

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4) unshielded opening or windows should be present above height of 2m from finished floor level.

Room size minimum requirement:
- 18 m^2 for radiography & conventional fluroscopy.
- 25 m^2 for CT.
- 10 m^2 for mammography.

→ Thickness - wall of x-ray where primary x-ray beam falls should not be less than 35cm brick.

→ scattered x-ray - All other walls of 23cm brick or 1.7mm lead equivalence.

→ ceiling thickness of concrete 13.5cm.

→ x-ray above 125 kvp, seperate console.

→ <125kvp, protective barrier of 1.5mm lead equivalence.

→ Doors - 1.5mm lead sheet.

→ viewing window - 1.5mm lead glass equivalence (45 x 45 cm)

Mammography → 25 - 30 kvp.
lead lined door - 1mm - lead sheet.
wall thickness - 23cm, 15cm - celing.

target.
Be + Mo (filter)
Be + Rh (filter)
Mo + Mo (filter)
Rh + Rh (filter)
W + Mo
W + Rh

→ fast neutron interaction with concrete wall in process of elastic scattering interaction with hydrogen.

→ Boron, cadmium have large cross section for capture of slow neutrons.

→ conduict - 15° to 45° dia ~~[illegible]~~ : 10 cm.

→ Laser at height of 2.4 to 2.6m from finished floor level.

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6). Mammography:- additional test.

→ compression needs to be calibrated.

→ Automatic exposure control device must be checked.

Mammography test phantom } – acrylic block, wax insert, acrylic disk

mimic standard breast of } = 4.2cm [50% adipose & 50% glandular tissue]

Radioactive transport :-

Surface contamination – 0.4 Bq/ cm² for beta & γ

– 0.04 Bq/cm² for alpha.

∴ class -7 radioactive

Special form radioactive test:-

Dimension > 5mm.

→ Impact test:- height of 9m

→ percussion test:- 1.4kg @ 1 metre height.

→ Bending test:-

→ heat test:- 800°c for 10mins.

Excepted package

radiation level @ surface should not exceed 5 µSv/ hr

Test for Type-A package.

1) water spray test } - 5cm/hr for 1 hour

2) Free drop test

<5000 kg - 1.2 m.

5000 - 1000 - 0.9m.

1000 - 15000 - 0.6m.

>15000 - 0.3m

3) Stacking test:

5 times the load of max weight for 24 hrs

4). pnetration test :-

bar of 3.2cm diameter and mass of 6kg dropped from height of 1metre.

Additional test for gas and liquid for type-A

1) Free drop test :.

Drop from height of 9 metre.

2) penetration test :.

3.2 Cm dia bar and mass of 6kg dropped from height of 1.7m.

Type-B package test :-

Drop-1 :. 9 metre.

Drop-2 :. bar of 20cm long and 15cm dia height 1metre.

Drop ... way 9 metre dynamic crush.

Thermal test :- 800°C for 30min.

water immersion :. 15m for not less than 8 hrs.

Enhance water immersion for Type B containing $10^5 A_2$ 200m for 1 hr.

Radiation level on surface of package should not exceed 2mSv/hr and @ 1metre 10mR/hr.

In any condition of exclusive use radiation level @ surface should not exceed 10mSv/hr. ~~and @ 1metre~~

8. lead apron - 0.25 - 5mm

0.25 - 90% of scattered radiation attenuated

0.5mm :- 95-99% of Scattered radiation attenuated.

increase KVp } - greater transmission of x-ray.

To reduse patient dose } - reduse mAS but reduce in image quality

MA → quatity

KVp → quality & quality.

Fluoroscopy:

{10R/min with AEC
{5R/min without AEC

Focal spot (0.3, 0.6, 1.2mm)

Intensifier size } = {4.5, 9, 12 inch}

Dose reduction:

* limit beam ON time.
* use last image hold facility.
* pulsed fluoroscopy.
* Reduce field size by collimator.
* Maintain much distance b/w patient and source.
* Magnification ↑ spatial resolution and ↑ patient dose.

mAs for thinner patient.

→ higher kVp & low mAs.
→ Increased filteration.
→ limit field size
→ shield of gonads, eye.
→ ↑ SOD.

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2) adult thorax - 120kVp, 0.5s.

200mA, pitch=1 and FOV=35.

what is appropriate for 5 years old?

Pediatric mA = Baseline × RF.

=> 200mA × 0.57

effects of Radiation in utero :- 84

Fetal dose of >100mGy may result in decrease of IQ,

Grenz ray	contact therapy	superficial therapy	orthovoltage therapy
>20KV	40-50KV	50-150KV	150-500KV
surface very low penetration.	SSD:- <2cm. ~2mm	SSD:- 15 to 20cm ~5mm	SSD:- 50cm. -2cm.

Super voltage	megavoltage therapy
500-1MeV	>1MeV.

In telegamma unit, surface dose of radiation beam shall not exceeds, 70% of the absorbed dose at the depth of 5mm for 10cm × 10cm irradiation field size, for distance not less than 30cm

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telegamma, source transferring personnel should not expose more than 1mSv.

interlock with terminate beam if dose monitor delivery in any 15° arc more than 20% of specified value.

[Anode - 10% Rhenium, 90% tungsten]

↓ used to prevent crazing of anode surface.

Couch - less than 1mm Al equivalence.

Quality :- describes penetrability of x-ray beam with ↑ energy. ↑ quality and HVL. [Tube potential, filteration]

Quantity :- No of photons comprising the beam.

Quantity :- Tube current, Tube potential.

Intensifying screen phosphor - Gadolinium Oxy Bromide

Lanthanum oxy sulphide

CR - imaging plate BaFBr and BaFI.

1) Mechanical. CCT

* Alignment of table to gantry ± 5mm.
* gantry tilt. ± 2°
* positioning of patient support. 1mm. [couch travel accuracy].
* Axial patient positioning accuracy. ± 2mm.

High generator

* Accuracy of KVp. - ± 5KVp.
* linearity of mA. - 0.1
* constancy of Radiation output. } - COV 0.05
* Total filteration. - > 100kVp - 2.5mm Al
* linearity of exposure timer. - 10%.

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* CTDI. - 20%.
* CT number uniformity.
* CT number linearity.
* Noise. - 15%. 5mm at 1%
* Low contrast resolution - ~~8 lines/inch~~.
* high contrast resolution - ~~8mm~~. 0.5 lp/cm.

AERB - RF - MED - SC.3

Radiation safety in manufacture & Medical Diagnostic x-ray equipment.

classified worker:- who recieves effective dose in excess 3/10 of the average annual dose limit.

ICRP 103:- Skin erythema deterministic threshold : 2Gy

AERB/RF-MED/SG/MED-1

AERB/RF/SM/G-3.

SG/RF/RW-6.

AERB/RF-RPF/SC-1.

Dosimetry:-

-> x-ray flatness, x-ray symmetry electron flatness, electron symmetry, Backup monitor chamber linearity, SRS arc rotation mode, x-ray monitor unit consistency, electron monitor unit consistency, wedge transmission factor, x-ray beam quality, electron beam quality x-ray output constancy with gantry angle, dose rate, electron output constancy with gantry angle off-axis factor, field size

SRS/SBRT.

dose rate output constancy [2%]

Treatment couch position indication: [1 mm/0.5°]

Localizing laser [< ±1 mm]

ODI [2mm].

collimator size indicator. [1mm]

Stereotactic interlocks [functional].

SRS arc mode rotation. [1 MU or 2%]

x-ray monitor unit constancy. ±2%

coincidence of isocenter = ±1 mm.

MLC:-

-> Spoke test. < 1 mm radius

-> Leaf travel speed -> 0.5 cm/s.

-> Leaf position accuracy: - 1mm.

-> Leaf position repeatability - ±1 mm

-> MLC transmission - 0.5%.

-> congurence of radiation & optical field - 2mm

Beam ON Telecobalt

In patient plane circular radius of 2m @ normal treatment distance - 0.2% max 0.1% average for 10x10cm field

other than patient plane 0.5% of max absorbed dose rate @ distance 1m from source.

Stray radiation:

@ 1 metre - 20 μGy/hr

@ 5cm - 200 μGy/hr.

Linac:

< 2% of max @ NTD in 10x10 cm.

< 0.75% of max absorbed dose @ NTD in 10x10 cm.

MLC: 5% of max

In plane plane

0.2% max & 0.1% average.

	Non-fixed		Fixed		Both	
	Beta & γ	α	β γ	α	β γ	α
SAI	4	0.4	4×10^4	4×10^3	4×10^4	4×10^3
SCO-2	400	40	8×10^5	8×10^4	8×10^5	8×10^4

6 am.

8 am ~~9 am~~ 10 am.

0.7937 ~~0.[illegible]~~ 1.587,

1.

30.

12.59. ~~14.14~~ 15.87

7.93

12.59

$A = A_0 e^{-\lambda t}$

12.598 => $A_0 \times 1.2598$ => 10

14.141 => $A_0 \times 1.4141$ => 10

15.87 => $A_0 \times 1.587$ => 10

42.6

Interventional Radiology	1 to 100 mSv
CT	2-20 mSv
General Radiography	0.1-1 mSv
Mammography	0.4 mSv
Dental Radiography	0.005-0.0[illegible]
BMD	0.001
chest CT	7 mSv
Abdominal CT	8 mSv

Q) Advantages of dual or triple head gamma camera over single head ?

→ Multiple head γ-camera provides accelerated acquisition.

→ 2 projections of the image are acquired simultaneously, with gantry rotation of 180° for dual and 120° for triple

Q) what is PET-CT ?

PET-CT combines the advantage of excellent functional information provided by PET and superb spatial and contrast resolution of CT.

advantages:- accurate localization of diseased structure, improved image quality, less scanning time.

Q) what is TOF in PET ?

Time of flight is a new concept in PET in which difference in time between two γ of coincidence event is used to localize in annihilation. it will improve the SNR and image quality. [improved localization of coincidence event].

Q) principles of waste management ?

→ protection to human health & environment

→ concern about future generation.

→ Establishing legal framework.

→ waste minimisation, Management & safety.

Q) waste treatments

pretreatment.

i) waste collection ii) waste segregation iii) volume reduction iv) removal of radionuclide v) change in composition vi) storage and disposal.

Q) Directly measurable dose & not directly measurable dose?

→ Directly measurable:. (physical quantities)

Fluence, Absorbed dose, Kerma.

→ not directly measurable:.

protection quantities like equivalent dose, effective dose

operational quantities

Ambient dose equivalent

Directional dose equivalent

personnel dose equivalent

Q) why unit in Sv?

1Sv = 100 rem (radiation biological effects of different types taken into account) in human body

whereas Gy is used to define absorbed dose per gram of material such as human body.

Q). Dmax?

cobalt 60 - 0.5cm.

caesium - 137 - 0.1cm.

4MV = 1cm.

6 MV = 1.5cm.

10 MV = 2.5 cm.

20MV = 3.5. cm.

25MV = 5cm.

Q) Advantage of PET over SPECT.

→ higher spatial resolution
→ higher sensitivity
→ improved attenuation and scatter correction.

Q2 Advantage of SPECT?
→ Many radiotracer are available
→ is less costly than PET scanner.
→ isotope are readily available produced by generator can lasts for week.

Disadvantages:-
→ Sensitivity is low, because of collimator is needed
→ Less spatial resolution than PET.
→ high energy photons more lead is needed in collimator.

Q) Disadvantages of ~~SPE~~ PET?
→ Short lived isotope, imaging should be done within 45-60 mins,
→ isotopes are produced from ~~cyclo~~ cyclotron
→ more costly than γ- isotope.
→ higher tissue dose than SPECT.

Q) where ~~is~~ natural Background radiation level is high and why?
Kerala, due to large amount of monazite sand (thorium content). range of 12 mSv/

Q) lead free material ➢

CSIR developed a lead free material for shielding of x-rays, γ-rays by using industrial red mud alumina. Shielding tiles are fabricated by mixing appropriate proportion of Red mud, $BaSO_4$, kaolin clay power. Thickness of 12-15 mm of tiles is equivalent to 2mm lead to attenuate radiation.

Q). Disadvantage of lead for shielding?

→ high toxicity,

→ Due to gravity effect, poor flexibility and over ageing, loss of shielding integrity.

Q) What are the radiation measuring equipment should be available in nuclear medicine facility?

→ portable Beta- γ area monitor.

→ contamination monitor for personnel / area.

→ dose calibrator.

Q) Discharge of β- emitting isotope administered to patient in nuclear medicine:

1) Sm-153 → Activity < 4000 MBq.

2) Yr-90 → Activity < 4000 MBq

3) P-32 → Activity < 1200 MBq

4) Sr-89 → activity < 300 MBq.

Q). Dose rate limit for discharge limit of permanent implant patient?

Au-198	0.21 mSv/hr
Pd-103	0.03 mSv/hr
I-125.	0.0[illegible]1 mSv/h

Q) Reason for choosing $CaSO_4:Dy$ in TLD?

→ high radiation sensitivity.

→ easy of manufacture & cheap.

→ simple glow curve structure

→ Stability of glow curve even after repeated use

→ good storage facility before and after irradiation.

Q) why Teflon?

Teflon withstand about 300°c of temperature and able to reuse without having any damaage.