

Re: ABR Part II type written questions from 2002

Which of the following is used for palliative treatment of bone mets? Sr-89, I-125, P-32

β emission 1.46 MeV.
 $T_{1/2} = 50$ day
diffuse bone metastases

The NRC requires HDR shielding to be surveyed: daily, weekly, monthly, annually, after source change. quarterly \Rightarrow also check hood leakage < 0.25 MR/hr @ 1m.

also initially & 5 years

What detector is best for calibrating an Ir-192 IVRT source? (well chamber)?

for β source \Rightarrow extrapolation ion chamber in water ($r = 2$ mm, $\theta = \frac{\pi}{2}$)
for γ -emitted source Ir Re-entrant chamber
or free-space ion chamber

What is the TG-40 photon field flatness spec?

(2% for constancy) (3% for e^- flatness) (3% for both photon e^- symmetry)

According to the report by Kersey (sp?), what is the attenuation TVL of linac neutrons in a maze? 5m

$$H = H_0 \frac{S_0}{S} \frac{1}{d^{1.2} 10^{0.15/L}} \rightarrow TVL$$

$$\text{slope} = \frac{\sqrt{\frac{I_0}{I_1}} - \sqrt{\frac{I_0}{I_2}}}{\log \frac{I_1}{I_2}}$$

The largest contributor to dose at a point behind the gantry stand is _____: patient scatter, head leakage, neutrons from (gamma, n) in the walls

$$\text{slope} = \frac{\sqrt{\frac{100}{44}} - \sqrt{\frac{100}{25}}}{\log \frac{44}{25}} = 0.0254$$

$$f = \frac{1}{\text{slope}} - d_{\text{cm}} = \frac{1}{0.0254} - d_{\text{cm}} = 39.4 - d_{\text{cm}}$$

Electron virtual source- for linac with end of applicator at 100cm.

Given ion chamber readings at several distances, the virtual source position is _____ cm.

At 100cm, 100; at 120cm, 44; at 140cm, 25.

$$\frac{I_0}{I_1} = \left(\frac{f+d_1+0}{f+d_1} \right)^2 \Rightarrow \frac{100}{44} = \left(\frac{f+d_1+20}{f+d_1} \right)^2 \Rightarrow \frac{100}{25} = \left(\frac{f+d_1+40}{f+d_1} \right)^2$$

$$\Rightarrow f+d_1 = 39 \text{ cm}$$

AAPM Report 54 (TG-42? SRS)- What is the max size of a scanning ion chamber for SRS beams? \Rightarrow for Linacs $\rightarrow \leq 2$ mm for beam profiles (ion chamber, film, diode, TLD) ex. PPL PWN N23342

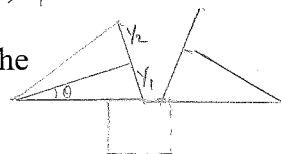
\Rightarrow for Gamma knife $\rightarrow < 1$ mm \times 1 mm \times 1 mm

cyl. 0.07 cm³

According to NCRP-49, what is the max allowed exposure/dose for films in a storage area? 0.1 mGy for the period the film is stored (0.025 mGy/wk)

Pick out the false statement about TG-51 (applicable to 3-50 MeV e^-) photon: ^{60}Co in 50mV

For a H&N case, calculate couch kick given the field sizes to match the inferior borders to an SCLAV field. $\theta = \tan^{-1}(1/\text{SAD})$



Calculate the gantry angle for a half-beam blocked medial breast tangent beam, given a bunch of geometrical distances.

Numerous calculate TVLs, Blx, Bsx for shielding needs. On one, the patient scatter area was 20 sq cm rather than 40 sq cm.

An I-125 implant gives 95% of the total dose in _____ days?

$$D = D_0 T_{\text{avg}} (1 - e^{-\lambda t}) \Rightarrow 0.95 = (1 - e^{-\lambda t}) \Rightarrow 0.95 = (1 - e^{-\frac{\ln 2}{59.4} t}) \Rightarrow t = 257 \text{ days}$$

Calculate Dy/Dx for a train of 10:10:10 mgRaeq sources at a spacing of 2cm, X and Y are 2cm off the transverse axis of the middle and an end needle.



$$\text{Assume point source.}$$

$$D_x = D_1 \cdot \left(\frac{1}{\sqrt{2} \cdot 2} \right)^2 + D_2 \cdot \left(\frac{1}{2} \right)^2 + D_3 \cdot \left(\frac{1}{2\sqrt{2}} \right)^2$$

$$= \frac{1}{2} D$$

$$D_y = D_1 \cdot \left(\frac{1}{\sqrt{4+2^2}} \right)^2 + D_2 \cdot \left(\frac{1}{\sqrt{2}} \right)^2 + \left(\frac{1}{2} \right)^2 \cdot D_3$$

$$= \frac{68}{160} D$$

Numerous RAPHEX-type MU calculations. Find cord dose given CAX dose from AP/PA treatments.

$$\Rightarrow D_x/D_y = \frac{10}{17}$$

What is the range of a Sr-90 beta in air?

$\left\{ \begin{array}{l} \text{Strontium-90} \\ \downarrow \text{decay} \\ \text{Yttrium (Y}^{90}) \end{array} \right. \beta^- \text{ emission}$
max energy $\rightarrow 0.5$ MeV
Avg energy $\rightarrow 0.02$ MeV
 $T_{1/2} = 28$ yr
max energy 2.03 MeV
Avg energy 0.97 MeV
 $T_{1/2} = 64$ hr

\Rightarrow range for 2 MeV β^- in air $\approx 10^3$ cm - 10m

2004 ABR Exam Questions

<http://www.haweb.bea.org/nahu/dmmp/syllabus.stm> is a book with several chapters. It is OK for refreshing.

(1) Find the angle for lateral breast tangent...

If tangent fields are LAO and RPO and angle of LAO is given then for IEC convention:

$$\text{Angle of RPO} = \text{Angle of LAO} + 180 - 2 \cdot \arctan(\text{Width}/(2 \cdot 100))$$

If tangent fields are RAO and LPO and angle of RAO is given then: $\text{LPO} = -180 + \text{RAO} + 2\beta$

$$\text{Angle of LPO} = \text{Angle of RAO} - 180 + 2 \cdot \arctan(\text{Width}/(2 \cdot 100))$$

For Varian Convention:

$$\text{Angle of RPO} = \text{Angle of LAO} + 180 + 2 \cdot \arctan(\text{Width}/(2 \cdot 100))$$

For Varian Convention:

$$\text{Angle of LPO} = \text{Angle of RAO} - 180 - 2 \cdot \arctan(\text{Width}/(2 \cdot 100))$$

(2) Given: X cpm for a source of Y mCi of activity find the allowable cpm for not surpassing the NRC wipe test limit for activity.

The NRC limit is 5 nCi. Therefore first I determine the efficiency of the counting system = X cpm / Y E-03 Ci.

$$\text{From there I obtain that the allowable cpm} = \text{efficiency} \cdot 5 \text{ E-09} = (\text{X cpm} / \text{Y E-03 Ci}) \cdot 5.0 \text{ E-09 Ci} = \text{X cpm} \cdot 5 \text{ E-06}$$

(3) Craniospinal setup angle of collimator rotation for matching the cranial field with the spinal field:

$$\text{collimator angle} = \arctan(1/2 \text{ Lspinal}/100)$$

$$\text{table kick angle} = \arctan(1/2 \text{ Lcranial}/100)$$

Always half of the ratio of length of "other field", i.e. the one that is being "moved" over 100

(4) Derive a relationship between HVL and TVL

$$\begin{aligned} \text{HVL}/\ln 2 &= \text{TTL}/\ln 10 \\ (0.5)^{\frac{\text{X}}{\text{HVL}}} &= (0.1)^{\frac{\text{X}}{\text{TTL}}} \\ \ln(0.5)^{\frac{\text{X}}{\text{HVL}}} &= \ln(0.1)^{\frac{\text{X}}{\text{TTL}}} \\ \frac{\ln(0.5)}{\text{HVL}} \cdot \text{X} &= \frac{\ln(0.1)}{\text{TTL}} \cdot \text{X} \\ \frac{\ln(0.5)}{\text{HVL}} &= \frac{\ln(0.1)}{\text{TTL}} \\ \frac{\ln(0.5)}{\ln(0.1)} &= \frac{\text{HVL}}{\text{TTL}} = 0.302 \end{aligned}$$

↑ of (HVL)(TTL) to reach the equivalent shield (HVL < TVL)

$$\text{FVL}/\ln 5 = \text{TVL}/\ln 10 = \text{HVL}/\ln 2$$

FVL would be the "five value layer".

$$1/2^{**}(\text{X}/\text{HVL}) = 1/10^{**}(\text{X}/\text{TTL})$$

$$\text{X} \ln 2 / \text{HVL} = \text{X} \ln 10 / \text{TTL}$$

$$\text{HVL}/\ln 2 = \text{TTL}/\ln 10$$

(5) TG51 correction factors for photons and electrons:

Both:

Temperature and pressure correction factor: Ptp

Ion recombination correction: Pion = (1 - VHV/L) / (MrawH/MrawL - (VHV/L))

Voltage polarization correction: Ppol = Absolute value ((Mraw+ - Mraw-)/2Mraw)

Electrometer correction factor: Pelec

Electrons: Pgradient for cylindrical chambers from tables. For plane parallel chambers is one.

Photons: Pgradient is part of Prepl and is considered inside kQ = [(L/ro)w to air * Prepl * Pwall * Pcell] Q to Co-60

(6) Given Khan's equation for the effective source distance (f) ...

$$\text{Sqrt}(\text{Io}/\text{I}) = \text{g}/(\text{f} + \text{dmax}) + 1$$

$$\text{Slope} = 1 / (\text{f} + \text{dmax}) \text{ from there } \text{f} = 1/\text{Slope} - \text{dmax}$$

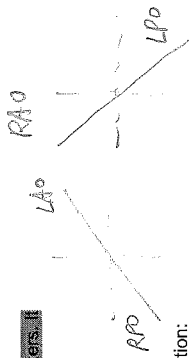
(7) TG-40:

Almost everything is 2 % for radiation field. 3 % for electron flatness.

Mechanical things is 2 mm for isocenter, collimator rotation, couch rotation, 2 mm for radiation field and light field coincidence, and the rest of them.

(8) Electron flatness/symmetry: 3 % and 3 %
Photon flatness/symmetry: 2 % and 3 %

(9) To check light field vs radiation field:



$$\begin{cases} \text{RPO} = 180 + \text{LAO} - 2\beta \\ \text{LPO} = -180 + \text{RAO} + 2\beta \end{cases}$$

$$\text{efficiency} = \frac{\text{X cpm}}{\text{Y mCi}}$$

$$\begin{aligned} \text{allowable counts} &= \frac{\text{X cpm}}{\text{Y mCi}} \times 0.005 \text{ mCi} \\ &= (1000 \times 10^{-6}) \times (0.001) \\ &= 5 \times 10^{-6} \text{ X cpm} \end{aligned}$$

$$\begin{cases} \frac{\text{FVL}}{\ln 5} = \frac{\text{TVL}}{\ln 10} = \frac{\text{HVL}}{\ln 2} \\ \Rightarrow \frac{\text{HVL}}{\ln 10} = \frac{\text{TTL}}{\ln 2} \\ \text{HVL} = \frac{\ln 10}{\ln 2} \cdot \text{TTL} \end{cases}$$

$$\text{HVL} = \frac{\ln 10}{\ln 2} \cdot \text{TTL} = 3.32 \cdot \text{TTL}$$

the equivalent shield (HVL < TVL)

Source to Film distance = 100 cm
Source to Phantom SSD = 100

(10) TBI:

Compensators can be used.
Dose uniformity increases with increasing energy
Up to 15% in dose uniformity is expected
AP/PA patient irradiation better uniformity than lateral irradiation. Of course large distance for field covering and better uniformity

(Please if you know more add them)

(11) Electron beams:

depth of 10% PDD = $E_0/2$

- $E_0 = 2.33 R_{50}$

- $E_z = E_0 (1 - z/R_p) = 2.33 R_{50} (1 - z/R_p)$

- Depth Ionization curve is more upstream than PDD curve ($R_{50} > I_{50}$)

- $R_{50} = 1.029 I_{50} - 0.06$

- $E_{p0} = c_2 + c_3 R_p + c_4 R_p^{**2} / E_{p0} = 0.22 + 1.98 R_p + 0.0025 R_p^{**2}$

- $R_p = E_0/2$

- For planning at 90% isodose line (IDL) use rule of thumb: Energy = Tumor depth * 3.2

- For planning at 80% isodose line (IDL) use rule of thumb: Energy = Tumor depth * 2.8

The R_{50} depth should, if possible, coincide with the distal treatment margin. This depth is approximately given by $E/4$ in cm of water, where E is the nominal energy in MeV of the electron beam. R_{50} , the depth that corresponds to the 80% PDD, is also a frequently used parameter for defining the therapeutic range, and can be approximated by $E/3$ in cm of water.

- An electron field can be blocked down to R_p without altering the PDD. If dimension of block are less than R_p then PDD shifts towards surface (dmax decreases, PDD's decreases).

- Penumbra: bulges out.

- Isodose distribution: 80 and 90% IDL shrink.

For example, 12 MeV. $R_p = 6$ cm
 \Rightarrow ICRU $r > 6/2$ cm = 3 cm $\Rightarrow \phi = 6$ cm x 6 cm
or 12 MeV / 2.5 = 4.8 cm $\Rightarrow 5$ cm x 5 cm
or $r > 0.88 \sqrt{12} = 3.05$ cm $\Rightarrow \phi = 6.1$ cm x 6.1 cm

- X ray contamination increases with e- energy
- Oblique incidence: dmax shifts towards surface, depth of penetration decreases.

- Surface irregularities: electron beam encounters depression hot spot behind depression. If encounters protrudent area: hot spot outside protruding area, cold spots behind it.

- Thickness of lead for blocking electrons in mm = $E_0/2 + 1$

- Thickness of cerrobend for blocking electrons in mm = $(E_0/2 + 1) \cdot 1.2$

- In general is OK to abut electron fields at the surface due to the majority of tumors treated with e- are superficial.

- X-ray field abutting with e- field: hot spot under X-ray field, cold spot under e-field.

- How to obtain PDD from Depth Ionization: $PDD = \frac{M \cdot (L_{ro})_{water} \text{ to air} \cdot Prep)}{(the same at dmax)}$
 $D_{med} = M_{air} \cdot Prep \cdot (1/4)_{air} \cdot K_{med}$
depth independent constant = cavity-gas collection factor M_{gas}

- TG-51 for measuring the Depth Ionization curve place chamber at $d + 0.5$ R_{cav}. There is no need to shift the curve if done like this. If not, place the chamber half in half out on water surface and after measuring the Depth Ionization curve shift it 0.5 R_{cav} upstream. From this curve obtain PDD with expression given before.

- TG-51 for electrons: $D_W = D_{W0} \cdot K_{eal} \cdot K_{50} \cdot M \cdot P_{grad}$

$D_W \cdot Q = ND \cdot W - Co60 \cdot M \cdot P_{grad} \cdot K_{eal} \cdot K_{R50}$

ND.w - Co60: given by ADCL

M corrected reading = $M_{raw} \cdot P_{pol} \cdot P_{ion} \cdot P_{e} \cdot P_{elec}$

$P_{grad} = M_{raw} (dref + 0.5 R_{cav}) / M_{raw}(dref)$

K_{eal} from table

K_{R50} from table

$KQ = P_{grad} \cdot K_{eal} \cdot K_{R50}$

(12) Given E_0 and depth find Energy at depth:

$E_z = E_0 (1 - z/R_p)$ I think R_p should have been given also. If not I think we could use $R_p = E_0/2$.

$$E_z = E_0 \left(1 - \frac{z}{R_p}\right)$$

(13) Three fields each weighted equally... I found this problem better formulated on the Rosemark files for ABR Part II (problem 1):

Dose per beam 60 cGy at isocenter.

Post beams traverse 9 cm of lung: 15 cm is physical depth. Then radiological depth = $15 - 9 \times 0.33 = 8.97$

$$\text{TMR}(10 \times 10, 3) = 0.97, \text{TMR}(10 \times 10, 6) = 0.891, \text{TMR}(9) = 0.8, \text{TMR}(10 \times 10, 12) = 0.719, \text{TMR}(10, 15) = 0.639$$

Determine the ratios MU AP / MU post.

$$\text{MU AP} = 60 / \text{TMR}(10 \times 10, 15) \text{ OF}(10) = 60 / 0.639 = 94$$

$$\text{MU RPO} = 60 / \text{TMR}(10 \times 10, 9) \text{ OF}(10) = 60 / 0.8 = 75$$

$$\text{Ratio MU AP / MU RPO} = 94 / 75 \text{ or } 94 / (75 + 75)$$

(14) I don't understand the formulation of the problem, couldn't find it neither on the Rosemark file for 2004.

(15) See answers for (11)

(16) Patient simulated at 102 SSD with film at 140 cm. Want to treat patient at 110 SSD. Calculate distance to cut block.

This problems are solved using similar triangles rules:

$$\text{SSD1/SFD1} = \text{SSD2/SFD2}$$

$$\text{SFD2} = \text{SSD} \times \text{SFD1/SSD1} = 110 \times 140 / 102 = 151 \text{ cm.}$$

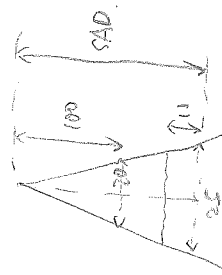
(17) A wedge has a field size limit of 20 cm. A patient is planned SAD with a FSize of 25 cm. Calc the SSD to be able to use the wedge (I noted that the separation is needed and the problem of Rosemark file 36 has it= 22 cm):

The wedge has a fsz limit of 20 cm at SAD = SSD = 100 cm. To cover a field size of 25 cm at midplane the SSD has to be extended. In reality patient thickness should've been given because in that way:

$$(\text{new SSD} + \text{dplane}) / 25 = 100 / 20$$

$$\text{new SSD} = 25 \times 100 / 20 - 12 = 113, \text{ Which makes more sense.}$$

$$\text{for separation} = 22 \text{ cm.}$$



(18) This one I completed with question 41 from Rosemark files:

Isocenter 5 cm RT of midline (midplane) of patient. Therapists swings gantry of simulator to RT lat and takes a film to measure cord depth, but therapist forgets to reset isocenter to midline. Measured cord depth from the film is 6.7 cm. What is the true cord depth?

depends on if mag is already considered or not.

Question (18): Simulator/LINAC scale is valid just at isocenter. If I well understand patient has been shift laterally 5cm. In that case lateral film will not have cord at isocenter (100cm) but at 105 or 95cm depending on gantry angle and lateral displacement. I would calculate true cord by applying 5% correction to the 6.7cm measured (0.95 to demagnify and 1.05 to magnify scale at isocenter) $\text{mag} = 105/100 \Rightarrow 1.05$ $\text{mag} = 100/95 \Rightarrow 1.05$ $d_1 = 6.7 \text{ cm}$

(19) Superficial shielding calc given workload.

$$B = X_p d^{*2} / (\text{Workload} \times U \times T) \quad B = \frac{P d^2}{W U T}$$

$$X_p = 50 \text{ mSv / year} = 1 \text{ mSv / week} \rightarrow \text{for radiation workers (0.1 rem per week)} \rightarrow 0.1 \text{ mSv/week} \rightarrow 0.01 \text{ R/week}$$

$$X_p = 1 \text{ mSv / year} = 0.02 \text{ mSv / week} \rightarrow 0.02 \text{ mSv/week} \rightarrow 0.002 \text{ R/week}$$

(20) Location of the chamber for TG-51 absolute measurements: 10 cm

For electrons is 0.6 R50 - 0.1 $d_{ref} = 0.5 \times R50 - 0.1$ (close to dmax if $E < 10 \text{ MeV}$)

(21) Find required lead thickness for an e- cutout given MeV, density of lead, and mass stopping power in lead (S/rho)

It says not a Rp/10 type of problem... < --- My question is what is a Rp/10 type of problem?

I would solve this problem using: $S/rho \times \rho \times \text{tho} = S$ in MeV/cm. Then the required thickness will be: $t = e \cdot \text{Energy} / S$

(22) Radial Dose functions of Pd-103 VS I-125 $\text{radial function } g(r) \rightarrow \text{exclude LVS only account for interaction scatter}$

As the average energy of I-125 is 28 KeV and the average energy of Pd-103 is 21 KeV, I-125 photons have more penetration and therefore the radial dose function is bigger all the time than the one for Pd-103 after 1 cm. confirmed by table values in TG 43

(23) Question regarding dose limits for shielding design:

R neutron production coefficient
($\mu Sv \text{ cm}^2 \text{ m}^{-2}$) per μSv of beam area

18mV 15mV 10mV 15mV 18mV
19 $\mu Sv/cm^2$ 3.5 $\mu Sv/cm^2$ \Rightarrow 5.4 times
Varian 10mV 15mV 18mV
1.22

Neutron source strength (Bq) \rightarrow Figure B.1 \rightarrow $B(10^6)$
From (Other - 18mV) \times 10 times in 20 times
Beta emitter sources calibrated in plastic with extrapolation chamber at a depth of 2 mm.
15mV - 18mV \times 2 times volume

(31) % in increase on neutron contamination as you go from 15 MV to 18 MV photons: 10 times bigger. This was answered by Clewys, but I am not sure about it.

(32) Not correct measurement of PDD can happen when the position of the scanning chamber is not setup correctly. For photons TG-21/25 half in and half out, for electrons half in and out but shift of 0.7 RcaV (don't remember this exactly, please check). For photons TG-51 half in and out and shift of 0.6 RcaV and same for electrons (0.5 RcaV), or for no shift position zero is 0.6 RcaV or 0.5 RcaV deeper.

two purposes: 1) eliminate end effect of electric field ensure electric field near the edge remain straight \Rightarrow define the volume

(33) Purpose of the guard electrode in a parallel plate chamber? straight \Rightarrow define the volume
To eliminate end effect of the electric field of the chamber and to define the measuring volume of the chamber. \leftarrow ?

(34) Radiobiology question... Purpose of the guard ring: attenuates the lateral inscattering of electrons into the chamber volume \leftarrow ?

This is what I have collected regarding radiobiology: \Rightarrow ORE

- RBE = Dose at 250 kVp Dose test radiation
- RBE increases with increasing LET of particles: alpha, proton, heavy charged particles high RBE due to high LET
- Charged particles LET: around 100 KeV/micrometer
- Electrons and photons LET: 2.5 KeV/micrometer or less.
- NTCP: normal tissue complication probability
- 1-NTCP: normal tissue uncomplication probability
- TCP: Tumor control probability
- TCP * (1-NTCP): Uncomplicated tumor control probability.

\Rightarrow average LET 0.2-0.3 keV/ μm
according to AAPM review of G. Luxton
cause notes page 21

- The 4 R's of radiobiology: Repair (normal cells repair themselves between fractions), repopulation (both normal and cancer cell repopulate between fractions, reoxygenation (tumor cell reoxygenate between fractions so they become more radiosensitive (oxygen enhancement effect), reassortment (tumor cell reassort to regions of better blood supply).

0.144m from

H₀ (Neutron dose equiv per unit absorbed x-ray dose at 150)

Varian H₀ (mSv/Gy)
10mV 0.04 \Rightarrow
15mV 0.79-1.3 \Rightarrow
18mV 1.02-1.6 \Rightarrow (0.19%)

Occupational worker: 50 mSv/year = 1 mSv/week = 0.1 Rem/week

Public: 1 mSv/year = 0.02 mSv/week and 2 mrem in any hour.

Patient in room contiguous a Cs-137 implant room: up to 6 mSv/week \leftarrow ?

Take into consideration that the patient with the Cs-137 implant attenuates the radiation of Cs-137 in 30% (multiply Xpat * 0.7)

Exposure rate constant of Cs-137 is 3.26 R-cm²/(mCi-h). For air kerma rate constant multiply 3.26 by 0.876 cGy/R \Rightarrow 2.86 \times 0.876 \times 0.7 = 1.999 cGy/mCi-h

$B = Xp \text{ d}^{*2} / (WUT) \rightarrow 0.96 \text{ cGy/hr}$ in tissue. according to McInerley
 $B = 1/12 \text{ in}$, where n is the number of HVL. n HVL = -ln B / ln 2 and the number of TVL's is n TVL = -log B

(24) If Bscatter and Bleakage are comparable regarding TVL then add 1 HVL to the bigger one.

(25) 2 Gy given to 238% IDL. Each field setup to 100 SSD. 3 fields equally weighted 100% at dmax. Find given dose to each field. (Problem 72 in Rose, NCRP)

Each field will deliver 2 Gy/3 = 0.67 Gy at 238% IDL. 238% / 3 = 79.3% PDD for one field. Then Dmax = 0.67 / 0.793 = 0.84 Gy. \Rightarrow Dmax = 2.52 Gy
Inversely, if 84 cGy is delivered at Dmax with a SSD setup and the three field deliver 200 cGy at isocenter and around it. Then each beam delivers at isocenter 67 cGy. 67/84.5 = 0.793 * 100 = 79.3% if assume 200 cGy \rightarrow 130 cGy at 150 for each beam
PDD = 67/84 = 79.8%

(26) Treating prostate with 4 field box to 40 cGy. Dose to anterior rectal wall = 40 cGy.

(27) Gas pressure gauge of the accelerator is low: concerns the RF waveguide.

(28) Dual foils in e-beams: 1st foil spreads the beam, second foil flatten it. 3% flatness and 3% symmetry. For photons is 2% and 3%.

(29) Allowable dose in mSv to let a patient in a room adjacent to a Cs implant be exposed to: 5 mSv

(30) What criterion is the most important to the success/failure of an IVBT Tx?

It looks like is the appropriate delivery of the dose at 2 mm.

Objective of IVBT: Deliver a target dose of 15 to 20 Gy to 2 mm in 2 to 3 cm of arterial wall. Dose rate 5Gy/min

Gamma emitter sources calibrated in a well chamber.

Target volume: 2-5 cm in length of artery & 0.5-2 mm in thickness of arterial wall. for intracoronary irradiation

Temporary implants: AAPM \rightarrow depth of dose prescription to be 2mm from center of the source and for the peripheral arteries 2mm beyond the average human radius. For each case, 3 dose planes \perp to catheter should be reported.

Permanent implants: β source \rightarrow higher specific activity, higher dose rate (P³², Sr⁹⁰) } activity 30-40 mCi
longer half-life, greater safety
gamma source \rightarrow more uniform target dose (Ir-192) } 1-4 Ci
better radial dose distribution

$$D_A = D_{\text{skin}} + D_A = \frac{1}{2} D_{\text{sep}} + \frac{0.5 \text{ cm}}{\text{PDD}(0.5 \text{ cm}, 0.5 \text{ cm})} \cdot \text{PDD}(0.5 \text{ cm}, d-d_0)$$

Hard questions ABR exam 2004.

(1) AP/PA fields, treated with 4 MV and 20 MV photons. Obtain the ratio of max doses (4 to 20).
 \Rightarrow check where is the max dose of combined AP/PA.
 SSD setup, separation given, PDD tables for both energies given, including the depth of max dose for both energies. Midplane, and separation and sep - dmax.

4 MV photons:

Dose at Dmax = Dmax AP (FS, dmax, 4MV) + Exit dose PA (FS, sep-dmax, 4mV)
Dose at Dmax = 1/2 Dose MPlane / PDD (FS, sep/2, 4MV) + 1/2 Dose MPlane / PDD (FS, sep/2, 4MV) * PDD (FS, sep - dmax, 4MV)

Dose at Dmax 4MV = 1/2 Dose at MPlane / PDD (FS, sep/2, 4MV) (1+ PDD (FS, sep-dmax, 4MV))

18 MV photons:

Dose at Dmax 18MV = 1/2 Dose at MPlane / PDD (FS, sep/2, 18MV) (1+ PDD (FS, sep-dmax, 18MV))

Dmax 4 to 18 MV = PDD (FS, sep/2, 18MV) / PDD (FS, sep/2, 4MV) (1+ PDD (FS, sep-dmax, 4MV)) / (1+ PDD (FS, sep-dmax, 18 MV))

(2) Jc-192, exposure rate constant = 4.69 R cm2 (mCi-h). HVL = 2.5 mm Lead, 2 cm diameter lead pig, source inside of unknown activity, lead pig encased in 30 cm diameter shipping drum. Calculate max activity to keep the exposure on surface below 50 mR/hour

(This would be a radioactive white I type of shipping container and the Transportation Index would be 1.0 (50 mR/h * 0.15**2 / 1**2 = 1.13)

(Radioactive White I Surface dose: 0.5 to 50 mR/h, TI: 0 - 1.0
Radioactive Yellow II Surface dose: 50 to 200 mR/h, TI: 1.0 to 10.0
Radioactive Yellow III Surface dose: 200 to 1000 mR/h, TI > 10.0)

$$50 \text{ mR/hr} = (A \text{ mCi}) \cdot 4.69 \text{ R cm}^2 / \text{mCi-h} \times 1000 \text{ (m}^2/\text{cm}^2) \times (1/15 \text{ cm})^2$$

$$X (15 \text{ cm, t=2.0 cm lead}) = X_0 \exp(-\ln 2 * 1.0 / 0.25)$$

$$X_0 = \text{GammaIr-192} * \text{Activity} / (15)^{**2}$$

(3) Co 60 time calculation given TAR, BSF, PDD, and output at Dmax for 80 SSD.

1 - SSD type setup: Use PDD (although TMR can be used, see 2). The BSF is used for

$$\begin{aligned} \text{MU} &= \frac{\text{Output} \cdot \text{Sc}(\text{r}) \cdot \text{Sp}(\text{d}) \cdot \text{BSF}(\text{r}) \cdot \text{PDD}(\text{r}, \text{d}, \text{SSD}_{\text{ref}})}{\text{Output} \cdot \text{Sc}(\text{r}) \cdot \text{Sp}(\text{d}) \cdot \text{BSF}(\text{r}) \cdot \text{PDD}(\text{r}, \text{d}, \text{SSD}_{\text{ref}})} \cdot \left(\frac{\text{SSD}_{\text{ref}}}{\text{SSD}} \right)^2 \quad \text{if Output calib in air} \\ \text{MU} &= \frac{\text{Output} \cdot \text{Sc}(\text{r}) \cdot \text{Sp}(\text{d}) \cdot \text{BSF}(\text{r}) \cdot \text{PDD}(\text{r}, \text{d}, \text{SSD}_{\text{ref}})}{\text{Output} \cdot \text{Sc}(\text{r}) \cdot \text{Sp}(\text{d}) \cdot \text{BSF}(\text{r}) \cdot \text{PDD}(\text{r}, \text{d}, \text{SSD}_{\text{ref}})} \cdot \left(\frac{\text{SSD}_{\text{ref}}}{\text{SSD}} \right)^2 \quad \text{if Output calib in water} \\ \text{where} \quad \text{PDD}(\text{r}, \text{d}, \text{SSD}_{\text{ref}}) &= \text{PDD}(\text{r}, \text{d}, \text{SSD}_{\text{ref}}) \cdot \left(\frac{\text{f+d}}{\text{f+d}_{\text{ref}}} \right)^2 \end{aligned}$$

when the calibration is in air and multiplying it by the Dose Rate in Free Space one gets the Dose Rate in water at Dmax. The output factor is usually given in cGy/min for a particular field in air or in water. If it is in air use the BSF if not there is already a BSF intrinsically on the Dose rate in water.

$$\text{Time} = \text{Rx Dose} / (\text{Output in cGy/min in Air}(\text{Fsize}) * \text{BSF}(\text{Fsize}) * \text{PDD}(\text{Fsize}, \text{depth}) / 100 * \text{Trayfactor} * \text{Wedge factor} * (\text{SCD} / (\text{SSD} + \text{dmax}))^{**2}) \quad (a)$$

$$\text{Time} = \text{Rx Dose} / (\text{Output in cGy/min in Water}(\text{Fsize}) * \text{PDD}(\text{Fsize}, \text{depth}) / 100 * \text{Trayfactor} * \text{Wedge factor} * (\text{SCD} / (\text{SSD} + \text{dmax}))^{**2}) \quad (a)$$

Where SCD: source to calibration point distance, it can be 80+ 0.5 in SSD + dmax setup for calibration in such case, in (a) the ISC would be 1 for SSD setup or it would be (80.5/80) for a SAD setup.

Or it can be 80.0 cm in SAD setup calibration, in (a) it would be (80/80.5)**2 for a SSD setup, or 1 for a SAD setup.

If the treatment is done at an extended SSD then the PDD at extended SSD is to be obtained from the Mayneord Factor.

$$\text{MF} = (\text{SSD2} + \text{dmax})^{**2} / (\text{SSD1} + \text{dmax})^{**2} * (\text{SSD1} + \text{d})^{**2} / (\text{SSD2} + \text{d})^{**2}$$

New PDD at SSD2 = PDD at SSD1 * MF

If we are dealing with extended distance, we should alter (a) as follows:

$$\text{Time} = \text{Rx Dose} / (\text{Output in cGy/min in Water} * \text{New PDD at SSD2} / 100 * \text{Trayfactor} * \text{Wedge factor} * (\text{SCD})^{**2} / (\text{SSD2} + \text{dmax})^{**2})$$

Where SCD: source to calibration point distance, it can be 80+ 0.5 in SSD + dmax setup for calibration (in (a) the ISC would be 1 for SSD setup or it would be (80.5/80) for a SAD setup, or it can be 80.0 cm in SAD setup for calibration, in (a) it would be (80/80.5)**2 for a SSD setup, or 1 for a SAD setup.

Output in Cgy per minutes can be equal to: Output (10x10, dmax) * Sc(Fsize at Nominal SSD) * Sp(Field size at Tx SSD)

2 - SSD type setup using TMR: (TAR)

Time = Rx Dose/ (Output in Water (or Air)) for 10x10 Field size * TMR (Fsize at depth) (or TAR Fsize at Depth)) * Sc (Field size at nominal SSD) * Sp(Field size at depth d) * TF*WF* (SCD/SPD)**2

Where: SPD is the source to calc point distance.

The expression given in 2 is general enough to calculate any setup. In case of SAD setup and calculating the dose at SAD, SPD = SAD, and if the machine is calibrated at isocenter, then the ISC factor is 1.

As a rule of thumb do not use BSF when TAR is in the equation (or TMR).

$$\begin{aligned} \text{MU} &= \frac{\text{Output} \cdot \text{Sc} \cdot \text{Sp}(\text{d}) \cdot \text{TAR}(\text{d}, \text{d}) \cdot \left(\frac{\text{SSD}}{\text{f+d}} \right)^2}{\text{Output} \cdot \text{Sc} \cdot \text{Sp}(\text{d}) \cdot \text{TMR}(\text{d}, \text{d}) \cdot \left(\frac{\text{SSD}}{\text{f+d}} \right)^2} \\ \text{MU} &= \frac{\text{Output} \cdot \text{Sc} \cdot \text{Sp}(\text{d}) \cdot \text{TMR}(\text{d}, \text{d}) \cdot \left(\frac{\text{SSD}}{\text{f+d}} \right)^2}{\text{Output} \cdot \text{Sc} \cdot \text{Sp}(\text{d}) \cdot \text{TMR}(\text{d}, \text{d}) \cdot \left(\frac{\text{SSD}}{\text{f+d}} \right)^2} \end{aligned}$$

Calculate time of irradiation for a tumor dose of 200 cGy, FS= 15x15, d=8.0 cm. Given Sc(12x12) = 1.012, Sc(15x15)=1.015, Sp(15x15) = 1.014. Output in water 130 cGy/min at 80 SSD + dmax.
The unit is calibrated at 80 cm SSD + dmax.

- Using PDD and an 80 SSD PDD table:

$$\text{Time} = 200 / ((130 \text{ cGy/min}) \cdot \text{Sc}(80/100 \cdot 15 = 12 \times 12) \cdot \text{Sp}(15 \times 15) \cdot \text{PDD at SSD} = 100 (\text{FS } 15 \times 15, d=8) \cdot ((80+0.5)^2 / (100+0.5)^2))$$

$$\text{PDD} = \text{PDD}_1 \cdot (100 + 0.5)^2 / (80 + 0.5)^2 \cdot (80 + 8)^2 / (100 + 8)^2 = 66.5 \cdot 1.0348 = 68.8$$

$$\text{Time} = 200 / (130 \cdot 1.012 \cdot 1.014 \cdot 0.688 \cdot 0.642) = 3.40 \text{ min.}$$

- Using TMR:

$$\text{Time} = 200 / (130 \cdot \text{Sc}(12 \times 12) \cdot \text{Sp}(15 \cdot 108/100 = 16.2) \cdot \text{TMR}(16.2, 8) \cdot (80.5)^2 / (108)^2) = 200 / (130 \cdot 1.012 \cdot 1.0175 \cdot 0.7905 \cdot 0.555) = 3.40 \text{ min}$$

I would prefer to use TMR table all the time and avoid confusions, and in this kind of problems of extended SSD's one doesn't have to calculate the Mayneord factor and apply it to the PDD's.

(4) A TG-51 problem. Almost everything was given:

For photons:

$$\text{Dose, water} = M \cdot k_Q \cdot N_d \cdot \text{waterCo-60}$$

$$M = \text{Mraw} \cdot \text{Ptp} \cdot \text{Pion} \cdot \text{Ppol} \cdot \text{Ppel}$$

$$\text{Pion} = 1 - \text{VHVL} / (\text{Mraw} / \text{Mraw}_d - \text{VHVL})$$

$$\text{Ppol} = \text{Abs}((\text{Mraw} - \text{Mraw}_d) / (2 \cdot \text{Mraw}_{\text{used}}))$$

$$k_Q \text{ from tables given the PDD}(10 \times 10)$$

For electrons:

$$\text{Dose to water} = M \cdot k_Q \cdot N_d \cdot \text{waterCo60}$$

$$k_Q = \text{Pgrad} (=1 \text{ for plane parallels}) \cdot \text{kecal} \cdot k_{R50}$$

From tables kcal and kR50

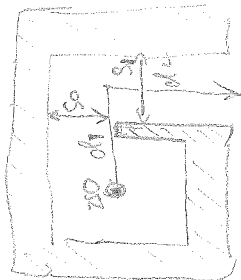
$$R50 = 1.029 \text{ ISO-0.06}$$

$$\text{dref} = 0.5 R50 - 0.1 \text{ cm}$$

$$0.5$$

be careful of photon
① SSD=100, 10x10 → 0.08x
② SSD=100, d=10 } calibration
or SAD=100, d=10
③ Convert to other depth
cal: SSD=100, d=10 → PDD(d')/PDD(10)
cal: SAD=100, d=10 → TMR correct

Electron: SSD=100, 15x15 → T50 → P50
① At dref, measure Mraw
② dref → dmax via correct
③ dref → dmax via correct



$$\text{Pgr} = M(\text{dref} + 0.5 R_{\text{cav}}) / M(\text{dref})$$

(5) Maze calc problem involving neutrons:

Distance isocenter to maze and maze length given.

Ratio of outer maze entrance to inner maze entrance given (T/T0)

Given neutron dose equivalent mSv per cGy of dose of photons at isocenter.

Calculate the dose at door per cGy of photons given TVL of neutrons 5 m in maze.

See McGuinley's book, page 84. Problem 2: Equation 2.18 in NCRP 151 (Pg 444) - (d2/d1)^2

$$H = \text{Workload} \cdot H_0 \cdot (T/T_0) \cdot (d_0/d_1)^2 \cdot 10^{**}(-d_2/5 \text{ m})$$

do in McGuinley's book is 1.41 m. In this problem is they specify isocenter then do is 1.0 m.

$$H_n = (W \cdot H_0) / L$$

d1: distance from isocenter to inner maze entrance

d2: distance from inner maze entrance to door. The place where the door stands is called outer maze entrance by McGuinley.

Ho is given in units of mSv neutrons per cGy Xrays (see table 5-1) page 70, McGuinley, typical values are between .5 and 2.00.

If Workload is given then units of H are mSv per week.

(6) Calculate Effective source distance for superficial unit given: Io = reading without gap = 100 and I = reading with gap = 42. Gap = 10 cm. Nominal SSD = 15 cm.

$$\text{Effective source distance} = 1/\text{slope} - \text{dmax}$$

$$\text{slope} = (\text{Sqrt}(100/42) - \text{Sqrt}(100/100)) / (10) = (1.54 - 1) / 10 = 0.054$$

$$\text{Effective source distance} = 1/0.054 - 0.0 = 18.5 \text{ cm}$$

(7) Basic SAD MU calc, output factors given at 100 cm SSD:

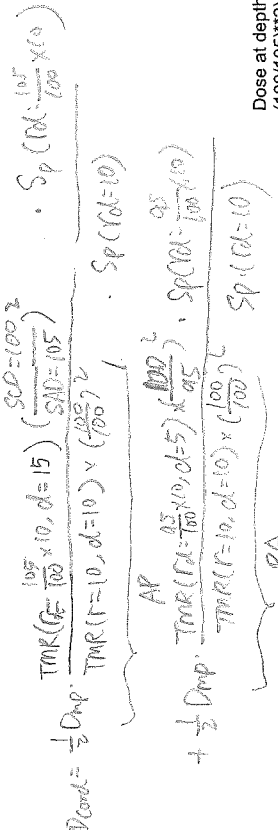
When using TMR, Sc is at the field size defined at SAD = 100 cm = Nominal SSD, Sp is for the field at the depth of calc.

(8) AP/PA and SAD setup. Given dose to isocenter, calculate dose to cord.

I will try to formulate a problem like this and solve it with beam data from Khan's book.

$$\text{FS at SAD} = 10 \times 10, \text{ separation} = 20 \text{ cm, 6 MV, depth of cord } 15 \text{ cm.}$$

$$\text{Dose at isocenter} = 200 \text{ cGy. Machine calibrated at isocenter (SAD} = 100).$$



.....

$$\text{Total Dose to Cord} = 0.5 * 200 / 0.77 * [0.9153 * 1.108 + 0.6425 * 0.9070] = 207 \text{ cGy}$$

$$\text{Dose from A to } dx = [1/2 \text{ MPD} / \text{TMR}(F_s \text{ at } d, d)] * \text{TMR}(F_s \text{ at } dx, dx) * (\text{SCD})^{**2} / (\text{SSD} + dx)^{**2}$$

$$\text{Dose total} = \text{Dose from AP to dmax} + \text{Dose from PA to dmax}$$

$$\text{Dose total} = 1/2 \text{ MPD} / \text{TMR}(\text{Fs at } dx, dx) * [\text{TMR}(\text{Fs at } dx, dx) * \text{SCD}^{**2}/(\text{SSD}+dx)^{**2} + \text{TMR}(\text{Fs at } dx \text{ from PA}, dx \text{ from PA}) * (\text{SCD}^{**2}/(\text{SSD}+dx \text{ from PA})^{**2})]$$

First calc MU setting, just as an extra exercise:

MU = 129

$$\frac{\text{Dose at isocenter} / (\text{TMR}(\text{FS at isocenter, diso}) * \text{Sc}(\text{FS at iso}) * \text{Sp}(\text{FS at iso}) * (\text{SCD}/\text{SAD})^{**2})}{* (\text{SCD}/\text{SPD})^{**2}} = \text{Dose at depth d} / (\text{TMR}(\text{FS at depth d, d}) * \text{Sc}(\text{FS at iso}) * \text{Sp}(\text{FS at d}))$$

From AP beam:

From PA beam:

$$\text{Total dose at Cord} = 130.6 + 75.3 = 206 \text{ cGy}$$

$$\text{Dose at } dx / (\text{TMR}(\text{FS at } dx, dx) * \text{Sc}(\text{FSisocenter}) * \text{Sp}(\text{Fs at } dx) * (\text{SCD}/\text{SPD})^{**2}) = \text{Dose at } dy / (\text{TMR}(\text{FS at } dy, dy) * \text{Sc}(\text{FSisocenter}) * \text{Sp}(\text{Fs at } dy) * (\text{SCD}/\text{SPD})^{**2})$$

For the sake of completeness I will solve here problems from Hendee's book:

$$\text{MU} = 100 / (\text{PDD}(13.7, 9) / 100 * \text{Sc}(13.7) \text{ Sp}(13.7) (101.5/101.5)^{**2}) = 100 / (0.7195 * 1.0 * 1.01) = 137.6 = 138 \text{ MU's}$$
$$\text{MU} = 100 / (\text{TMR} (13.7, 9) * \text{Sc} (13.7) \text{Sp}(13.7) (101.5/100) ** 2) = 100 / (0.817 * 1 * 1.01 * 1.03) = 118 \text{ MU's.}$$

As every field delivers 50 cGv to the target:

For RT and LT lat fields, Given dose = $D_{max} = 50 / PDD(10, 16) / 100 = 50 / 0.488 = 102.5 \text{ cGv}$

$$D_{max} AP * PDD (10.11)/100 = TargetDoseAP$$

$$D_{\max} PA * PDD(10,11)/100 = \text{TargetDosePA}$$

$$D_{\max} RT * PDD(10,16)/100 = \text{TargetDose RT}$$

$$D_{\max} LT * PDD(10,16)/100 = \text{TargetDose LT}$$

$$\text{From above problem } 2 * D_{\max} APPA * (PDD(10,11)/100 + 2 * D_{\max} Lats * (PDD(10,16)/100 = \text{Target dose}$$

$$\text{Target dose} = 2 * D_{\max} ((PDD(10,11)/100 + (PDD(10,16)/100)) = 2 * D_{\max} (0.637 + 0.488)$$

$$\text{Target dose} = 200 \text{ cGy}$$

$$D_{\max} = 200 / (2 * (0.637 + 0.488)) = 88.9 \text{ cGy}$$

(9) SSD setup, find MU setting to deliver dose at SSD = 125. PDD table at SSD = 100 cm given. This is similar to the problem we solved on bullet (3)

Things to bear in mind:

- Mayneord factor for obtaining new PDD at new SSD.

- Inverse square correction = $(SSD_{\text{New}} / SSD)^2$, SCD can be $SSD + d_{\max}$ ($100 + d_{\max}$) or $SAD = 100$.

(10) TBI question.... Doesn't say anything else.

(11) HDR; three dwell positions (1, 2, 3), 2 in middle, 1 cm apart in single channel. Dose points A, B, C at 1 cm perpendicular to dwell positions 1, 2 and 3. Dwell times in 1 and 3 are the same. Ratio of Dwell times 1 to 2 that makes doses A and B equal.

$$\begin{array}{ccccccc} A & \text{---} & B & \text{---} & C \\ | & & | & & | \\ | & & | & & | \\ | & & | & & | \\ 1 & \text{---} & 2 & \text{---} & 3 \end{array}$$

$$DA = T_1 / (1)^2 + T_2 / (1^2 + 1^2) + T_1 / (4 + 1)^2 = T_1 + T_2 / 2 + T_1 / 5$$

$$DB = T_1 / (1^2 + 1^2) + T_2 + T_1 / (1^2 + 1^2) = T_1 + T_2$$

$$DA = DB \quad T_1 + T_2 / 2 + T_1 / 5 = T_1 + T_2 \quad \text{---} \rightarrow \quad T_1 / 5 = T_2 / 2$$

$$T_2 = 2/5 T_1$$

Another one similar from Hendee's book:

13-3 Two 2-mg radium needles [0.5-mm P(r)] with active lengths of 1.5 cm are positioned in line with each other. The centers of the needles are 5 cm apart. A third needle is placed between the two needles. This needle also has an active length of 1.5 and is filtered by 0.5-mm P(r). What activity should the third needle possess to provide equal dose rates at locations 2 cm from the center of each source?

Using the point source approximation, that you suggested, the result is not quite exact due to the distances are too close for those line sources to be considered point sources.

$$\begin{array}{ccccccc} A & -2.5 \text{ cm} & \text{---} & B & -2.5 \text{ cm} & \text{---} & C \\ | & & & | & & & | \\ 2 \text{ cm} & & & 2 \text{ cm} & & & 2 \text{ cm} \\ | & & & | & & & | \\ -1 & \text{---} & -2.5 \text{ cm} & \text{---} & 2 & \text{---} & -2.5 \text{ cm} & \text{---} & 3 \end{array}$$

Sources: 1, 2 and 3, active length: 1.5 cm each, distance between centers of sources 2.5 cm, and between the ends 1.0 cm. Dose points: A, B and C

$$DA = DB = DC$$

a) Assuming point sources:

$$DA = \text{GammaRa} * A_1 / 2^2 + \text{GammaRa} * A_x / (2.5^2 + 2.0^2) + \text{GammaRa} * A_2 / (5^2 + 2^2)$$

$$\text{As } A_1 = A_2 = 2 \text{ mg-Ra} = A$$

$$DA = \text{GammaRa} * A / (1/4 + 1/29) + \text{GammaRa} * A_x / (10.25)$$

$$DB = \text{GammaRa} * A / (10.25) + \text{GammaRa} * A_x / 4 + \text{GammaRa} * A / (10.25)$$

$$DB = \text{GammaRa} * A * 2 / (10.25) + \text{GammaRa} * A_x / 4$$

As $DA = DB$ and same isotope then:

$$A (0.28445) + A_x * 0.097561 = A * 0.19512 + A_x * 0.25$$

$$A (0.08933) = A_x * 0.15244$$

$$A_x = 2.0 * 0.08933 / 0.15244$$

$$A_x = 1.18 \text{ mg of Ra eq.}$$

b) Assuming linear sources.

If we consider the sources as being linear sources then, we will have to use the tables given in Hendee's chapter for 1.5 active length linear sources (Table 13-1)

The formulation is the same as above but instead of $\text{GammaRa} \cdot \text{Al}$ we must use the value that the table gives us: Dose in cGy per $\text{mgRa} \cdot \text{hr}$ in tissue (across and along tables).

DA = Source 1 read from table at (0, 2.0 cm) * 2.0 mg + Source 2 read from table at (2.5, 2.0) * X + Source 3 read from table at (5, 2)

DB = Source 1 read from table at (2.5, 2) * 2 + Source 2 read from table at (0, 2) * X + Source 3 read from table at (2.5, 2) * 2

DA = 1.85 cGy / $\text{mg} \cdot \text{hr}$ * 2.0 mg + 0.74 cGy / $\text{mg} \cdot \text{hr}$ * X mg Ra + 0.23 * 2 mg

DA = 3.7 cGy / hr + 0.74 cGy / $\text{mg} \cdot \text{hr}$ * X mg Ra + 0.46 cGy / hr

DA = 4.16 + 0.74 * X (1)

DB = 0.74 * 2 + 1.85 * X + 0.74 * 2

DB = 2.96 + 1.85 * X (2)

As DB = DA (1) = (2)

4.16 + 0.74 X = 2.96 + 1.85 X

X = 1.08 mg!

c) Tx time to deliver 5000 cGy:

Taking equation (1) and substituting for 1.08 mg:

4.16 + 0.74 * 1.08 = 4.96 cGy / hr for obtaining 5000 cGy we get:

time = 1008 secs.

In Hendee's book the answer is 900 sec. I don't get it.

Problems, Hendee's Chapter 13 (Brachy)

$$10 \text{ mg} \times 8.25 \text{ R cm}^2 / \text{mg} \cdot \text{hr} \cdot \frac{1}{(2.0)^2} = 0.20625 \text{ R/hr} \text{ for } 0.5 \text{ mm filter.}$$

(13-1) Exposure rate at 20 cm from a 10 mg point source of Ra filtered by 1.0 mm Pt(Ir)?

Exposure Rate = mg Ra Gamma Radium * (0.98)**5 / (20 cm)**2

= 10 mg * 8.25 R cm² / $\text{mg} \cdot \text{hr}$ * 0.9039 / 400 = 0.186 R / hr

Key issue: Gamma Radium for filter not equal to 0.5 mm = Gamma Radium for 0.5 mm * (1.02)**x or (0.98)**x, where x is ABS(new thickness - 0.5)*10. In the example case:

ABS (1.0 - 0.5) * 10 = 5.

$$\Rightarrow \frac{(1.02)^5}{(0.98)^5} \quad X = (1.02 - 0.5) \times 10$$

(13-2) 1 mg Ra eq Cs source with 1.4 cm active length, filtered by 1 mm stainless steel.

a) Dose rate at 2 and 5 cm from the source along a line perpendicular to the center of the source using point source approximation and f factor 0.96

Dose rate = Activity * Gamma Ra / r**2

Dose rate (2 cm) = 1 mg * 8.25 * 0.96 / 4 = 1.98 cGy / hr

Dose rate (5 cm) = 1 mg * 8.25 * 0.96 / 25 = 0.32 cGy / hr

b) Dose rate as in a) but using across and along tables (13-3 page 299)

Dose rate (2 cm across and 0 cm along) = 1.866 cGy / $\text{mg} \cdot \text{hr}$ * 1 mg = 1.87 cGy / hr

Dose rate (5 cm across and 0 cm along) = 0.296 cGy / $\text{mg} \cdot \text{hr}$ * 1 mg = 0.296 cGy / hr

(13-4) Projection of a Radium needle is 2.2 cm in an AP xray. Lateral xray projection is 0.8 cm. Mags are 1.1 and 1.2 respectively. True length:

$$\Rightarrow \text{Length} = \text{sqrt}((2.2/1.1)**2 + (0.8/1.2)**2) = 2.1 \text{ cm}$$

(13-5) Amount and distribution of Ra in surface applicator to treat:

a) Area of 4 cm diameter at 1.5 cm, dose of 6000 cGy desired in 5 days.

Using Quimby system (table 13-4 page 304):

For 4 cm diameter at 1.5 cm we need: 506 mg - hr for 1000 cGy

Establishing the proportions: 506 mg ---> 1000 cGy / hr

X mg ----> 6000 cGy / (5 x 24 hr) = 50 cGy / hr

Therefore X mg = 25.3 mg are needed uniformly.

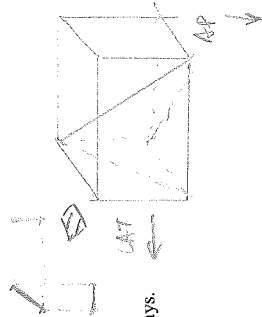
Using Manchester system:

Area = 3.1416 * 4**2 / 4 = 12.6 cm²

From table 13-5 page 305: For 12.6 cm² at 1.5 cm we need 769.5 mg hr for 1000 cGy.

Establishing the proportions: 769.5 mg ----> 1000 cGy / hr

X mg ----> 6000 cGy / (5 x 24 hr) = 50 cGy / hr



X mg = 38.5 mg on periphery

- b) A rectangular area of 12 x 4 cm at a dRx = 2.0 cm, 5000 cGy in 72 hours.

Using Manchester system:

12 x 4 = 48 cm. From table 13 - 5 for 1000 cGy we require 2037 mg - hr

Establishing the proportions: 2037 mg ---> 1000 cGy/hr
X mg ----> 5000 cGy/72 hr = 69.4 cGy/hr

X mg = 141.36 mg

But there is an elongation ratio: as the long side length / short side length = 12/4 = 3 then a correction of 1.09 should be applied to the mg.

X mg = 154 mg distr on periphery because the short side of the implant is not greater than twice the Tx distance 4 cm = 2 x 2 cm

(13 - 6) Design and interstitial iridium wire implant to treat a 6 x 6 cm volume of tissue 0.8 cm thick. Both ends may be crossed. Also give the dose rate at center of the volume. Desired dose 4500 cGy.

6 x 6 = 36 cm² * 1.2 (correction for the two crossed ends) = 43.2 cm
mg-hr required for 36 cm² at 0.5 cm is = 594 mg - hr ---> 1000 cGy
X mg-hr --> 4500 cGy

X mg-hr = 2673 mg-hr

Activity of Ir - hr = 2673 mg - hr * 8.25 / 4.69 = 4702 mCi - hr

6 ro/4 + 6 ro/4 + 5 ro 0.1 = 2673 mg - hr

....

(13 - 12) 15 1 mCi I-125 seeds. Sphere 2 cm diameter. *R₀ = 0.96 cm*

Initial Dose rate at 1 cm from 1 source = 1 * 1.45 * 0.96 / 1 cm² = 1.4 cGy/hr

From 15 sources = 15 x 1.4 = 21 cGy/hr

Total Dose delivered = 1.44 * 59.6 * 24 * 21 = 43255.3 cGy (using point source approx)

W/o using f factor = 0.96 and instead using 0.876 cGy to R factor

Initial Dose rate at 1 cm from 1 source = 1 * 1.45 * 0.876 / 1 cm² = 1.27 cGy/hr

From 15 sources = 15 x 1.27 = 19.1 cGy/hr

Total Dose delivered = 1.44 * 59.6 * 24 * 19.1 = 39245 cGy (using point source approx)

Using TG-43 approach: *According to Table 13-9: 1 mCi I-125 => 1270 cGy/hr*

Dose rate (r, theta) = Sk * Lambda * 1/r**2 * F(r, theta) g (r)

Dose rate (1 cm, 90 deg) = 1.27 cGy cm²/hr * 0.847 cGy/hr - U * 1 * 1 * 1

Dose rate (1 cm, 90 deg) = 1.37 cGy/hr *1076*

From 15 sources = 20.55 cGy/hr *1614*

Total dose delivered = 1.44 * 59.6 * 24 * 20.55 = 42328.4 cGy (using TG-43 approx)

Ans: 33 303 cGy ??? *33245 cGy*

(13 - 13) Fletcher applicator:

Source 1 : 3 along and 2 across = 0.591 cGy / mg - hr * 20 mg = 11.82 cGy/hr

Source 2 : 1 along and 2 across = 1.536 cGy / mg - hr * 15 mg = 16.5 cGy/hr

Source 3 : 1 along and 2 across = 1.536 cGy / mg - hr * 10 mg = 15.4 cGy/hr

Source 4 : 0 along and Sqrt (1**2 + 2**2) = 2.2 cm = 1.54 * 15 = 23.1 cGy/hr

Source 4 : 0 along and Sqrt (3**2 + 2**2) = 3.6 cm = 0.5958 * 15 = 8.9 cGy/hr

75.72 cGy/hr. 2000 cGy / 75.72 cGy/hr = 26.4 hrs

(13 - 14) 90 seeds * 0.35 mCi/seed = 31.5 mCi

Exposure rate no patient attenuation = 1.45 * 31.5 / 100 = 0.46 R/hr

Patient thickness acts like 2 HVL for I-125 photons energy.

Exposure considering pat attenuation = $0.46 / 2 \times 2 = 0.115 \text{ R/hr}$, ie 1.15 mR/hr

A patient can be released home if exposure less than 5 mR/hour at 1 m or activity remaining less than 5 microCi

30uCi activity to Khan Page 421

(13-15) Implant in prostate to deliver a total dose of 108 Gy . Initial dose rate

$$D = 1.44 \times 59.6 \times 24 \times \text{Initial dose rate}$$

$$\text{Initial dose rate} = 10800 \text{ cGy} / (1.44 \times 59.6 \times 24 \text{ hr}) = 5.24 \text{ cGy/hr}$$

To deliver 90 % of the dose

$$D = 1.44 \times 59.6 \times 5.24 \times 24 (1 - \exp(-\ln 2 / 59.6 \times t))$$

$$D = 10800 \times (1 - \exp(-\ln 2 / 59.6 \times t))$$

$$0.9 = (1 - \exp(-\ln 2 / 59.6 \times t))$$

$$\ln(1 - 0.9) \times 59.6 / (-\ln 2) = t$$

t = 198 days

(12) Given this 2.5 cm 1.5 cm film shows a factor 200 times less intense than the initial OD. find the dose to a particular exposed film. Table of OD vs Dose given.

OD = log (Initial no film / Light with film) = log (1 / Transmission) = log (200) = 2.3 with this value interpolate in table to obtain dose.

(13) Find the heterogeneity correction factors given TAR's at various depths and density of the material.

Heterogeneity correction factors:

- Ratio of TAR (TMR also) method:

$$CF = \text{TAR} (d', rd) / \text{TAR} (d, rd) \text{ Where } d' = d \times \text{relative electron density.}$$

- Power Law method:

$$CF = \text{TAR} (d3, rd) \times (3 - rd) / \text{TAR} (d3, rd) \times (2 + d3, rd) \times (1 - rd)$$

$$CF = \text{TAR} (d3, rd) \times rd^2 / \text{TAR} (d3, rd) \times rd \times \text{TAR} (d2 + d3, rd) \times rd^2 / \text{TAR} (d2 + d3, rd)$$

All layers of density = 1

$$T_p = T(d_1 + d_2 + d_3) \times CF (=1)$$

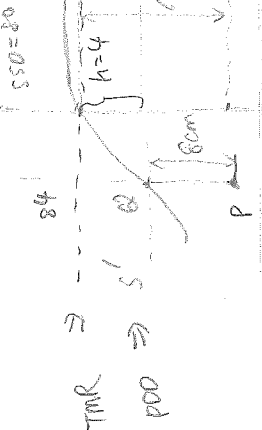
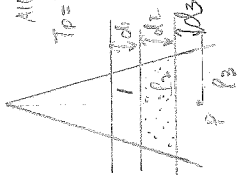
Now remove layers d_2, d_3 . replace with $p = p_2$

$$T_p = T(d_1 + d_2 + d_3) \times T(d_2 + d_3) / T(d_2 + d_3)$$

Now replace d_3 with $p = p_3$

$$T_p = T(d_1 + d_2 + d_3) \times T(d_3) / T(d_3)$$

$$T_p = T(d_1 + d_2 + d_3) \times T(d_3) / T(d_3)$$



4 problems out of Hendee's book:

8-5: Obliquely incident beam of 6MV x-rays. FSize = $8 \times 13 \text{ cm}$, SSD = 80 cm . Dose rate at $d_m = 1.006 \text{ cGy/MU}$. Target point is off axis at 8 cm depth as measured along the CAX. The SSD above the target is 84 cm . Use (a) the effective SSD method and (b) the ratio of TAR method to determine the correct dose rate at point P.

Dose rate at depth of point P at CAX:

$$\text{Dose rate} = \text{Dose Rate at } D_{max} \times \text{PDD} (8, 8 \times 13, 8) / 100 = 1.006 \times \text{PDD} (8, 9.9) / 100 = 1.006 \times (0.745) = 0.7495 \text{ cGy/MU}$$

(a) Using the effective SSD method:

$$CF = (SSD + d_m - h) \times 2 / (SSD + d_m) \times 2 = (80 + 1.5 - 4.0) \times 2 / (80 + 1.5) \times 2 = 0.9042$$

$$CF = 0.9042$$

Dose rate at target = $0.7495 \times 0.9042 = 0.677 \text{ cGy/MU}$ (Hendee's answer is 0.694 cGy/MU)

(b) Using the ratio of TAR method:

$$CF = \text{TMR} (d, rd) / \text{TMR} (d+h, rd), \text{ in this case } h \text{ is negative, its SSD is } 84 \text{ cm. } D_p = 0.695 \times 1.154 / 1.006 = 0.7702$$

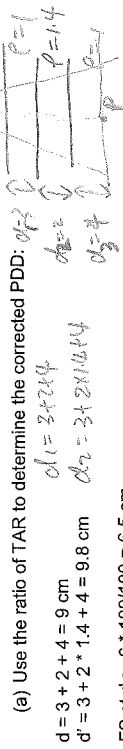
FSize at depth of target, 8 cm from isocenter = $8 \times 13 / (8 + 13) \times 2 \times 88 / 80 = 10.9 \times 10.9 = 0.702$

$$\text{Depth of target point } 8 + 4 \text{ cm} = 12 \text{ cm.}$$

$$CF = \text{TMR} (12, 10.9) / \text{TMR} (12-4, 10.9) = 0.7255 / 0.837 = 0.8668$$

Dose rate at target = $0.7495 \times 0.8668 = 0.6496 \text{ cGy/MU}$ (Hendee's answer is 0.673 cGy/MU)

8-6: A patient is to be treated to a point behind bone of $ro = 1.4$. 6MV, FS = $6 \times 6 \text{ cm}$ at 100 cm SSD. Bone is 2 cm thick, lies beneath 3 cm of soft tissue. The target point is 4 cm behind the bone in soft tissue.



(a) Use the ratio of TAR to determine the corrected PDD:

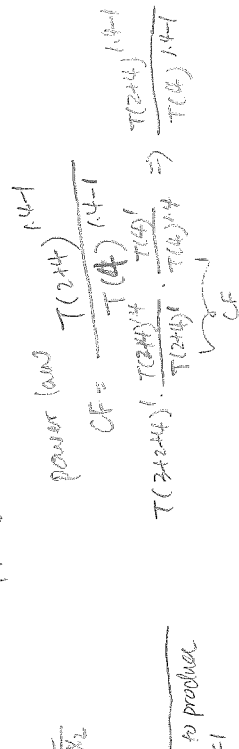
$$d = 3 + 2 + 4 = 9 \text{ cm}$$

$$d' = 3 + 2 \times 1.4 + 4 = 9.8 \text{ cm}$$

$$FS \text{ at } d = 6 \times 109 / 100 = 6.5 \text{ cm}$$

$$CF = \text{TAR} (d', rd) / \text{TAR} (d, rd) = \text{TMR} (9.8, 6.5) / \text{TMR} (9, 6.5) = 0.7524 / 0.7775 = 0.9569$$

$$\text{PDD} (9, 6) = 68.6 \% \rightarrow \text{Corrected PDD} = 0.9569 \times 68.6 = 66.38 \% \text{ (Hendee's answer is } 66.2 \%)$$



(b) Use the power law TAR method:

$$CF = (TAR(d2+d3, rd) / TAR(d3, rd))^{**} (ro e - 1) = (TAR(2+4, 6.5) / TAR(4, 6.5))^{**} (1.4-1) = (0.873/0.9355)^{**} 0.4 = 0.9727$$

$$\text{Corrected PDD} = 68.6 * 0.9727 = 66.72 \% \text{ (Hendee's answer is } \approx 66.7 \%)$$

8-7: Tumor treated with e-beam. Tumor lies immediately behind a rib. The bone is 2 cm thick and is covered by 2 cm of tissue. Determine the effective depth of the point:

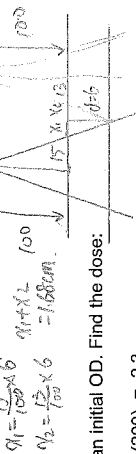
For electrons the CET method is used:

$$d_{eff} = d - z(1 - CET)$$

def = d - z(1 - CET), d physical depth, z depth of inhomogeneity, CET = 1.65 for bone and 0.5 for lung.

$$d_{eff} = 4 - 2(1 - 1.65) = 5.3 \text{ cm. (Hendee's answer is 5.3 cm)}$$

8-8: Two high energy photon beams abutted to treat spinal axis field. SSD = 100 cm. L1 = 30 cm and L2 = 26 cm. d = 6 cm. Calculate the GAP.



$$GAP = \frac{1}{2} (L1/100 + L2/100) * \text{depth} = 1.68 \text{ cm}$$

(12) Film OD shows a 200x less intense value than initial OD. Find the dose:

$$OD = \log I/T, \text{ where } T \text{ is transmission. } OD = \log(200) = 2.3.$$

(13) Simulator shielding. NCRP level to worker, allied health. Floor to floor distance 12 ft = 12 * 0.305 = 3.7 m. Isocenter 48 inches above floor (48 * 0.0254 = 1.22 m). SAD = 100 cm. U = 1/4, W = 800 mA-min/week. Shielding of concrete required. Graph from NCRP for 125 kVp, on the Y axis R per mA-min at 1 m. On the X axis Lead thickness.

$$d = 3.7 - 1.22 + 1.0 = 3.48 \text{ m}$$

$$B = Xp * d^{**2} / (W U T)$$

$$Xp = 0.02 \text{ mSv/week} = 0.002 \text{ R/week}$$

$$B = 0.002 \text{ R/week} * (3.48)^{**2} / (800 \text{ mA-min/week} * 0.25 * 1)$$

$$B = 1.21 \text{ E-04 R-m2/mA-min}$$

From graph we obtain 2.4 mm of lead.

(28-4) For a workload of 750 mA-min/week for a dedicated 125 kVp chest

radiographic unit, determine the shielding required behind the chest cassette at a distance of 6 feet from the x-ray tube if an office with uncontrolled access is behind the cassette.

The author suggest that for getting the workload in workable units one assumes that a Xray machine operating at 100 kVp produces 1 R / mA-min at 1 m.

Therefore Workload for a machine operating at 100 kVp = 1 R-m**2 / mA-min * 750 mA-min/week = 750 R-m**2/week.

(If I take into account that the Xray machine is operating at 125 kVp and therefore the workload would be equal to 1 R-m**2/mA-min * (125/100)**2 * 750 mA-min/week and this gives me a result even farther away from the answer as this would require a bigger shielding given the bigger workload).

$$B = Xp d^{**2} / WUT$$

$$Xp = 0.02 \text{ mSv/week} = 0.002 \text{ R/week}$$

$$B = 0.002 \text{ R/week} * 1.83^{**2} / (750 \text{ mA-min/week} * 1 * 1)$$

$$B = 0.000089 \rightarrow 2.7 \text{ mm of lead.}$$

Or if Hendee uses Xp = 0.1 mSv/week then

$$B = 0.01 * 1.83^{**2} / (750 \text{ mA-min/week} * 1 * 1)$$

$$B = 0.000045 \rightarrow 2.9 \text{ mm of lead.}$$

(14) AP/PA doses given to cord for 200 cGy to tumor at isocenter. 62 and 150 cGy. Cord block put in PA, new cord dose is 18 % of original. How many fractions the cord block needs to stay on to limit cord dose to 4500 cGy. Total dose is 6000 cGy to tumor.

$$62 + 150 = 212 \text{ cGy}$$

$$\text{New cord dose } 0.18 * 212 = 38 \text{ cGy}$$

$$4500 / 212 = 21 \text{ fractions if new dose 0. But new dose is 38 cGy.}$$

$$\text{Remaining dose } 6000 - 4500 = 1500$$

$$\text{Fractions: } 1500 / 200 = 7.5 \text{ fractions}$$

$$7.5 * 38 = 285 \text{ cGy more.}$$

$$\text{So } 21 * 212 + 285 = 4737, \text{ more than } 4500 \text{ therefore reduce to:}$$

$$19 \text{ fractions without PA block} = 3800 \text{ cGy to tumor and}$$

$$19 * 212 = 4028 \text{ cGy to cord.}$$

$$11 \text{ fractions with PA cord block.}$$

if we don't know exactly per fx or 30 fx total, we only know total 6000 cGy

$$38 * 11 + 212 * 7 = 4500$$

$$D_o: (11 * 38) = 6000$$

→ can't solve the problem. have to know D0 = 200 cGy

Assume

$$1 \text{ R/min}$$

$$1 \text{ R/min} @ 1 \text{ m. from}$$

x-ray tube.

per 1 mA?

$$38 * 11 + (30 * 11) * 212 < 4500$$

$$\Rightarrow 38 * 11 - 212 * 11 < 4500$$

$$-174 * 11 < -1860$$

$$11 > 10.68$$

$$= 11 \text{ fx.}$$

$$11 \text{ fx.}$$

0.2 mR/hr / 4 = 0.05 mR/hr if accelerator operates continuously.

(20) Slope of (Io/I) = 0.0111. dmax = 2.0 cm. Gap value: 10 cm.

$$SSD = 1/\text{slope} - d_{\text{max}} = 1/0.0111 - 2.0 = 88.1 \text{ cm}$$

(21) When scatter and leakage shielding requirements are equal or less than 3 HVL (approx. 1 TVL) then another TVL has to be added to the biggest of the two.

$$\text{Leakage for linacs: } BI = 1000 \times X_p \cdot d^{**2} / W T$$

$$\text{Leakage for Xray units: } BI = 600 I \cdot X_p \cdot d^{**2} / W T$$

In this equation W is given in mA-min/week, I is the max current in mA, Xp should be in R / week

Scatter for linacs: $B_s = X_p \cdot d_1^{**2} \cdot 400 / (a \cdot W \cdot T \cdot F)$. a is usually 0.001

Scatter when primary hits a barrier: $B_{sp} = X_p \cdot d_{sca}^{**2} \cdot dsec^{**2} / \alpha \cdot A \cdot W \cdot U \cdot T$

Alpha reflection coefficient

A : area of the wall being irradiated.

(22) Orders of material from inside to outside:

steel, borated polyethylene, lead, steel

lead → BPE → lead

(23) Electron backscatter from internal shield: bigger for lower energies and bigger Z. For same Z is bigger for lower energies. Pages 333 to 335 of Khan.

(24) Role of BSF and TAR in Co-60 calculations.

Calibration at 80.5 cm in air: $(cGy \text{ in air/min} \cdot BSF = cGy \text{ in water/min}) \cdot PDD / 100 = cGy \text{ in water at } D_{\text{max}} \cdot D_{\text{water}} \text{ at } d / D_{\text{water}} \text{ at } d_{\text{max}}$

Calibration at 80.5 cm in water: $cGy \text{ in water/min} \cdot PDD$ // No use of BSF is required.

Calibration at 80.0 cm in air: $(cGy \text{ in air/min at } d_{\text{max}} \cdot TAR) = cGy \text{ in air/min at } d_{\text{max}} \cdot \text{Dose in water/dose in air at } d_{\text{max}}$ // No use of BSF is required.

Calibration at 80.0 cm in water: $cGy \text{ in water/min at } d_{\text{max}} \cdot TAR / BSF = cGy \text{ in water/min at } d_{\text{max}} \cdot (\text{Dose in water at } d / \text{dose in air at } d_{\text{max}}) / (\text{Dose in water at } d_{\text{max}} / \text{Dose in air at } d_{\text{max}}) = cGy \text{ in water/min at } d_{\text{max}} \cdot \text{Dose water at } d / \text{Dose water at } d_{\text{max}}$

$$TAR(FS \text{ at } d, d) / BSF(FS \text{ at } d, d_{\text{max}}) = TMR (FS \text{ at } d, d)$$

Relationship between PDD and TMR:

$$TMR (FS \text{ at } d, d) = PDD (FS \text{ at surface, } d, SSD) \cdot (SSD + d)^{**2} / (SSD + d_{\text{max}})^{**2} \cdot Sp (FS \text{ at surface}) / Sp (FS \text{ at } d)$$

This relationship comes from:

$$TMR (FS \text{ at } d, d) \cdot Sp (FS \text{ at } d) (SCD)^{**2} / (SSD + d)^{**2} = PDD (FS \text{ at surface, } d, SSD) \cdot Sp (FS \text{ at surface}) (SCD)^{**2} / (SSD + d_{\text{max}})^{**2}$$

If SSD is not equal to 100 then PDD has to be calculated from PDD (FS at surface, d, SSD = 100 cm) times the Mayneord factor.

(25) Three beams, all weighted at 100 % at dmax. 200 cGy delivered to 238 % isodose line. Dose delivered by AP beam?

$$200 / 238\% = 84 \text{ cGy} \rightarrow 100\%$$

238% / 3 = 79.3 % contributes each beam to 200 cGy. Then:

$$200 / 3 = 66.7 \text{ cGy is } 79.3 \%, \text{ then } D_{\text{max}} = 66.7 / 0.793 = 84.0 \text{ cGy.}$$

(26) Dose 10 cm deep 5 cm outside field is: 100%

PD at the testicular phantom could be reduced to less than 1% of the therapeutic dose when it was situated more than 5cm distant from the caudal limit of the irradiation field.

(27) Frequency for surveying afterloading machines (HDR):

F. Before initiation of a treatment program, and after each source exchange for the after-loading device:

1. The licensee shall perform radiation surveys of the following locations:

a. The after-loading device source housing, with the source in the shielded position. The maximum radiation level at 20 centimeters from the surface of the source housing shall not exceed 3 milliroentgens per hour.

$$0.25 \text{ mR/hr} @ 1 \text{ m} \\ \rightarrow 3 \text{ mR/hr} @ 0.2 \text{ m.}$$

b. All areas adjacent to the treatment room with the source in the exposed position. The survey shall clearly establish:

i. That radiation levels in restricted areas are not likely to cause personnel exposure in excess of

the limits specified in R12-1-408 and R12-1-414.

ii. That radiation levels in unrestricted areas do not exceed the limits specified in R12-1-416.

iii. The activity of the source, using an Agency approved procedure and a calibrated Farmer chamber, or equivalent.

2. The licensee shall retain records of the radiation surveys for three years for inspection by the Agency.

G. A person shall not perform the following work without written authorization by the Agency:

1. Installation and replacement of sources contained in an after-loading irradiation device; or
2. Any maintenance or repair operation on the after-loading irradiation device involving work on the source driving unit, or other mechanism that could expose the source, reduce the shielding around the source, or compromise the safety of the unit and result in increased radiation levels.

H. Before making any changes to treatment room shielding, treatment room location, or use of the after-loading irradiation device which could result in an increase in radiation levels in unrestricted areas outside the treatment room, the licensee shall perform a radiation survey according to subsection (F)(1). A report describing each change, and giving the results of each survey shall be sent to the Agency.

(28) 10 MV thru 8 cm lung, dose actual VS dose without inhomogeneity.

In the paper cited by Khan, McDonalds et al.:

Method for calculating dose when lung tissue lies in the treatment field

Stanley C. McDonald, Bowen E. Keller, and Philip Rubin
Division of Radiation Oncology, Strong Memorial Hospital, University of Rochester Cancer Center, Rochester, New York 14642
(Received 31 March 1975)

Medical Physics, Vol. 3, No. 4, Jul./Aug. 1976

In-lung correction factor.

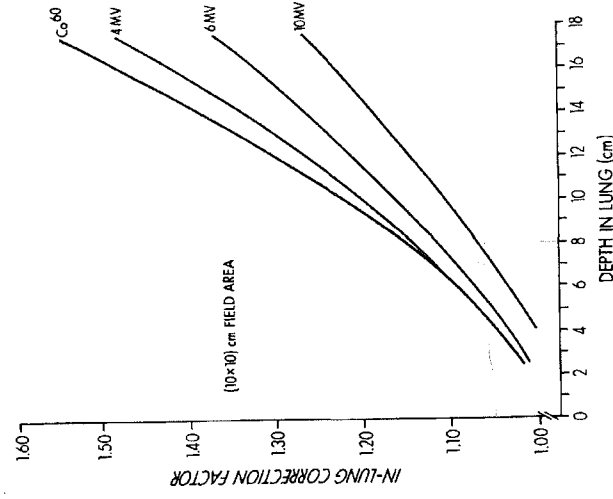


FIG. 5 In-lung correction factor as a function of depth in lung, and energy.

For the in-lung correction we see that for 40-MV at 8 cm in lung, the correction is approx. 1.05, or 5%. For 6 MV it is more, 1.07 (7%) and for 4 MV even more 1.10.

For the after lung correction factor see next figure:

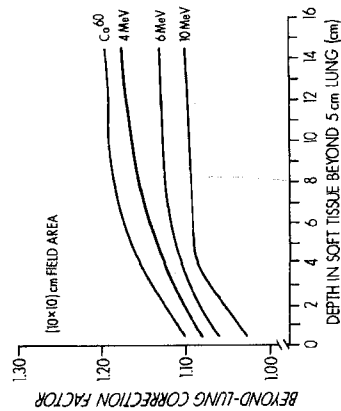


FIG. 3. Beyond-lung correction factors as a function of depth in soft tissue beyond 5 cm of lung, and energy.

Khan also offers: Increase in dose to healthy tissue after lung:

- Co-60 +4 % / cm lung
- 4 MV Xrays + 3 % / cm lung
- 10 MV Xrays + 2 % / cm lung
- 20 MV Xrays + 1 % / cm lung

So after 8 cm lung in tissue for 10 MV correction: $1.02^{**}(8) = 1.17$. 17%. Doesn't agree with the above figure. The values obtained by Khan are for 6 cm tissue, 8 cm lung and 3 cm tissue.

a) Using the effective depth method:

$$d_{eff} = d1 + d2 \text{ ro elec} + d3$$

For 10 MV and 10 x 10 cm²

$$CF = TMR(10 \times 10, d_{eff}) / TMR(10 \times 10, d) = TMR(10 \times 10, 6 + 0.25 \times 8 + 3) / TMR(10 \times 10, 17) = 0.814 / 0.680 = 1.19$$

b) Using the Batho power law:

$$CF = TMR(10 \times 10, 3)^{**} (ro3 - ro2) / TMR(10 \times 10, 8 + 3)^{**} (1 - ro2)$$

$$CF = 1^{**} (1 - 0.25) / 0.814^{**} (1 - 0.25) = 1.17$$

$$CF = \frac{T(11)^{0.3}}{T(11)^1} \cdot \frac{T(3)^1}{T(3)^{0.3}}$$

$$= \frac{T(3)^{1-0.3}}{T(1)^{1-0.3}}$$

This value agrees with what is predicted by the rule of thumb above.

c) Using the Batho power law for a point at 6 cm inside the lung:

$$CF = TMR(10 \times 10, d2)^{**} (ro2 - ro1) / TMR(10 \times 10, d1 + d2)^{**} (1 - ro1) = TMR(10 \times 10, 6)^{**} (0.25 - 1) / 1$$

$$CF = 0.939^{**} -0.75 = 1.048.$$

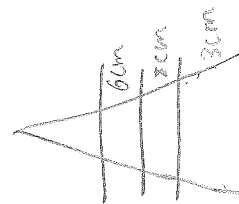
From the very first figure the value is around 3 % so it agrees well.

For remembering the Batho power law:

Three regions: d1, d2 (inhomogeneity), d3

$$CF = TMR(Fs \text{ at } d3, d3)^{**} ro3 - ro2 / TMR(Fs \text{ at } d3, d2 + d3)^{**} (1 - ro2)$$

$$CF = \frac{TMR(6)^{0.25}}{TMR(6)^1} = TMR(6)^{-0.75}$$



NCRP 151. Page 100

- ① head leakage → film wrapped to locate hot spots
integrating type survey meter @ appropriate d in the posterior plane
- ② Voids cracks → sensitive photon rate meter with full response time
(GM semiconductor meter)
calibrated ion-chamber equivalent (14)

(36) Question regarding survey around an accelerator vault for crack detection:
③ measurement outside each barrier → portable ion-chamber (both rate and integrate)
I would have chosen the GM counter for its sensitivity in detecting small changes in dose. But ion chamber for radiation survey and NRC report around vault.
neutron survey meter

(37) As per the TG-40 the leakage of a chamber should be checked at what frequency?
Every use of the chamber. Table X of TG-40 page 602.

http://www.aapm.org/pubs/reports/public/rpt_46.PDF

(38) Calculate E_0 given R50: $E_0 = (2.33)R50$ $E_0 = 2.8 R50$ $E_0 = 3.2 R50$

(39) A colpostat didn't show up on a film. What do you need to do?

Close collimators to a minimum to decrease scatter.

(40) Why does the wedge factor changes with field size?

I think is due to the fact that the chamber placed at 10 cm in the waterphantom is getting more scatter because the field size is increased. I don't think is because of any other phenomenon that happens in the wedge itself as the person is trying to suggest in the answers.
wfd with depth, field size?

(41) Electron oblique incidence on a surface:

Out Khan's book, page 319:

Electron beam obliquity tends:

- Increase side scatter at depth of d_{max}
- shifts d_{max} towards the surface. The larger the angle, the shallower is d_{max} and the larger is the dose at d_{max} (beam output).
- decreases the depth of penetration, decreases d80%.

(42) Amount of X ray contamination as a function of electron energy:

4-12 MeV = 0.5 to 1 %

12 - 15 MeV = 1 to 2 %

15 - 20 MeV = 2 to 5 %

(42.1) Shielding electrons to spare mucosae, etc.

Shield thickness in mm of lead: $(E/2 + 1)$ and for cerrobend shield $(E/2 + 1) * 1.2$.
Then add 1 mm of AL around so:

Electrons, back-scattered from the shielding, may deliver an inadvertently high dose to

- Tumor response = acute or early effects and normal tissue response = late effects

- Normal tissue $\alpha/\beta = 3.0$

- Tumor $\alpha/\beta = 10$

- Linear-quadratic model for the survival fraction of cells: $S = \exp(-\alpha D - \beta D^2)$

- Survival curve with LET: higher LET decreases survival faster

- Survival curve with dose rate: higher dose rate decreases survival faster

- Survival curve with oxygen effect: higher oxygen content (higher oxygen content) decreases survival faster

- Survival with dose fractionation: higher fractions SLOWER decreasing in the survival curve for normal tissue (this is good). What happens to tumor survival curve?

- Oxygen enhancement effect decreases with increasing LET. When LET increases, the direct effects increases. Oxygen is an indirect effect.

- Bigger α produces curves like the one for tumors, more curvilinear. Smaller α produces curves more flat, like puer exponentials.

- Do lethal dose, dose to decrease cell population in e times = 0.37

- Dq threshold dose, dose to which if straight portion of survival curve is extrapolated, gives like a threshold for an only exponential curve. Measure of shoulder thickness. n: extrapolation number: number of targets to be inactivated to kill the cell.

- BED: biological equivalent dose. $BED = N d (1 + d / (\alpha/\beta))$ allows to calculate the new dose per fraction for a new number of fractions (known) to have the same BED to, for example normal tissue if the treatment duration has to be decreased or done faster. Example: $n = 4$ fractions

Calculate the new dose per fraction if the new Tx schedule will have to be done in 25 fractions for a BED equal for normal tissue. Original Tx was to deliver 60 cGy at 2 Gy/fraction. Assume $\alpha/\beta = 3.0$ for normal tissue.

$BED = 60 \text{ cGy} (1 + 2/3) = 100 \text{ cGy}$ The original Tx has a BED of 100 cGy. To have a new Tx schedule that has the same BED in 25 fractions we have

$BED = N d (1 + d / (\alpha/\beta)) = 25 * d (1 + d / 3) = 100 \text{ cGy}$

Solving for d we obtain:

$4 - d - d^2/3 = 0 \rightarrow 12 - 3d - d^2 = 0$, the solution is 2.27 cGy per fraction during 25 fractions gives a BED of 100 cGy. So the two courses of Tx are equivalent.

(35) In IMRT the physicist sets all the parameters listed except beam weights. In fact that is the aim of the inverse planning, to obtain the beam weights for each beamlet.

Radex
2009
T. 48

$$BED = n \cdot d \cdot (1 + \frac{d}{\alpha/\beta})$$

healthy tissue in contact with the shield. This dose enhancement can be appreciable and may reach levels of 30 to 70% but it drops off exponentially with distance from the interface on the entrance side of the beam. • Aluminum or acrylic have been used around lead shields to absorb the back-scattered electrons. Often, these shields are dipped in wax to form a 1 mm or 2 mm coating around the lead. This not only protects the patient from the toxic effects of lead, but also absorbs any scattered electrons which are usually low in energy.

The above rules of thumb give around only a 5% transmission of electrons.

(42.2) Extending the SSD to treat with electrons:

- Extending the SSD typically produces a large change in output, a minimal change in PDD and a significant change in beam penumbra.
- The beam penumbra can be restored by placing collimation on the skin surface. The inside edge of the skin collimation has to be well within the penumbra cast by the normal treatment collimator.

(43) Define GTV, CTV, PTV, TV.

- "The Gross Tumour Volume (GTV) is the gross palpable or visible/demonstrable extent and location of malignant growth" (ICRU 50).
- "The clinical target volume (CTV) is the tissue volume that contains a demonstrable GTV and/or sub-clinical microscopic malignant disease, which has to be eliminated. This volume thus has to be treated adequately in order to achieve the aim of therapy, cure or palliation" (ICRU 50).
- "The planning target volume is a geometrical concept, and it is defined to select appropriate beam arrangements, taking into consideration the net effect of all possible geometrical variations, in order to ensure that the prescribed dose is actually absorbed in the CTV" (ICRU 50).

The PTV depends on the precision of such tools as immobilization devices and lasers, but does NOT include a margin for dosimetric characteristics of the radiation beam (i.e., penumbral areas and build-up region) as these will require an additional margin during treatment planning and shielding design.

Treated volume: additional margins provided around the PTV to ensure correct coverage and the limitations (penumbra, etc.) of the beam.

Irradiated volume: the one receiving more than 50% of the dose.

(44) What is the most important factor concerning dose to the fetus? 7836

Distance from fetus to bottom of field. There was also beam energy, but the distance is the one that sounds more logical to me.

Effective dose equivalent allowable for the fetus (pregnant woman): 0.5 mSv per month, once pregnancy is known for a radiation worker woman.

$$0.5 \text{ mSv} \times 10 = 5 \text{ mSv total}$$

same as frequent public.

Scatter from collimator -
scatter within patients -
head leakage

(45) A physicist does 50 seeds cases per year. What is the max dose equivalent in mSv he can get per case handling the seeds.

Ht to the hands is: 500 mSv/year then $500 / 50 = 10 \text{ mSv per case}$.

Ht to lens of the eye is 150 mSv/year. To the rest of the organs 500 mSv/year.

(46) The cone size specified by TG-51 for electrons is:

For beams with $R_{50} < 8.5 \text{ cm}$ $\sim E < 20 \text{ MeV}$, the field size is $> 10 \times 10 \text{ cm}^2$ at the phantom surface and for higher-energy beams it is $> 20 \times 20 \text{ cm}^2$.

(47) Typical neutron dose in photon beams: Approx 0.1% per cGy of dose from photons.

Φ neutron source strength @ 100 Hz in Table B1 in NCRP 151 1.41 m from 150

T49 A pregnant woman is treated for Hodgkins disease with AP/PA 6 MV mantle fields, to a total dose of 4000 cGy. Without supplementary shielding, the maximum dose to the fetus would be approximately xxxx cGy.

0.5%

TG36 Table III		
Point A T _{0.9}	Point B middle	Point C bottom of fetus
Distance 15.5	28.5	41.5
Dose 42 cGy	14 cGy	6 cGy

Respuesta del RAPHEX: C. The dose to the fetus depends on its distance from the edge, but from 10 to 20 cm the dose at 10cm depth is between about 2% and 0.6% of the dose on the beam axis. (ref: AAPM Report No. 50, "Fetal Dose from Radiotherapy with Photon Beams", AAPM TG #36). The dose is made up of patient scatter, head leakage, and radiation scattered from collimators and blocking tray.

Resumiendo voy a recordar 1% de dosis al feto, en campos torácicos.

Algo interesante tambien de RAPHEX es la dosis que debe limitarse a marcapaso. Te transcribo pregunta y respuesta al problema T62 del RAPES del año 2000.

T62 Special measures should be taken if it is estimated that the total dose to pacemaker implanted in a radiation therapy patient will exceed xxxxx cGy over the entire treatment

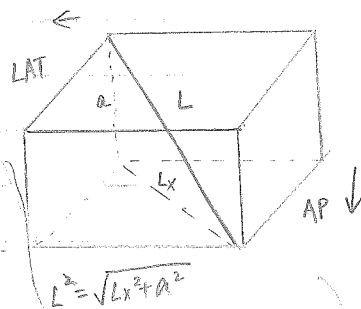
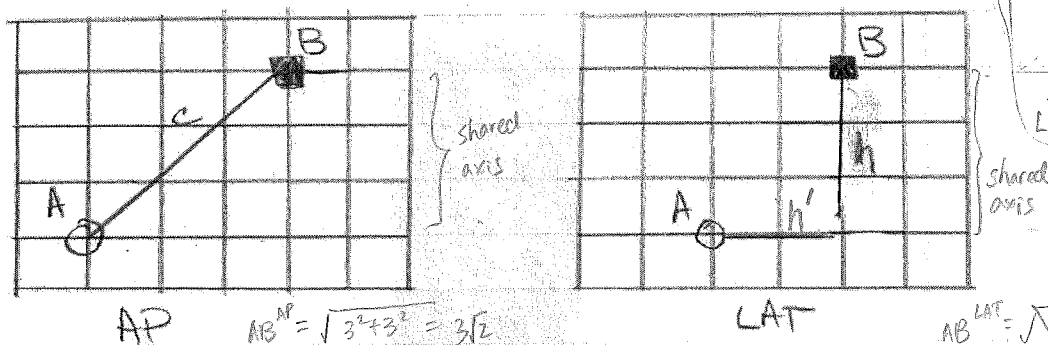
- A. 5
- B. 50
- C. 100
- D. 200
- E. 1000

Respuesta del RAPHEX. D. The report of the AAPM TG 34 recommends checking pacemaker function prior to radiotherapy and possibly weekly thereafter.

Significant functional 2000 cGy

2005 Part 2 TX

1. Given the grid in which every line is at 1 cm. Determine the distance between the source (black dot) and the point of interest (white dot).



using Kahn's method pg 360 3PD edition

$$AB = \sqrt{a^2 + c^2}, \quad a = \text{length of image on one of the radiographs}$$

$$c = \text{projection of AB to baseline}$$

~~$AB^{LAT} = \sqrt{2^2 + 3^2} = \sqrt{13}$ wrong!~~

~~$AB^{3D} = \sqrt{(AB^{AP})^2 + (AB^{LAT})^2}$~~

~~$= \sqrt{3^2 + 3^2 + 2^2 + 3^2}$~~

~~≈ 5.6~~

In this case let c = the AP projection to baseline + a = the height of the distance between A + B = h

$$c = \sqrt{3^2 + 3^2} = \sqrt{9 + 9} = \sqrt{18} = 4.24$$

$a = h = 3$ wrong

$$AB = \sqrt{a^2 + c^2} = \sqrt{3^2 + 4.24^2} = 5.2$$

For AP, LAT films, there must be a shared axis.

so

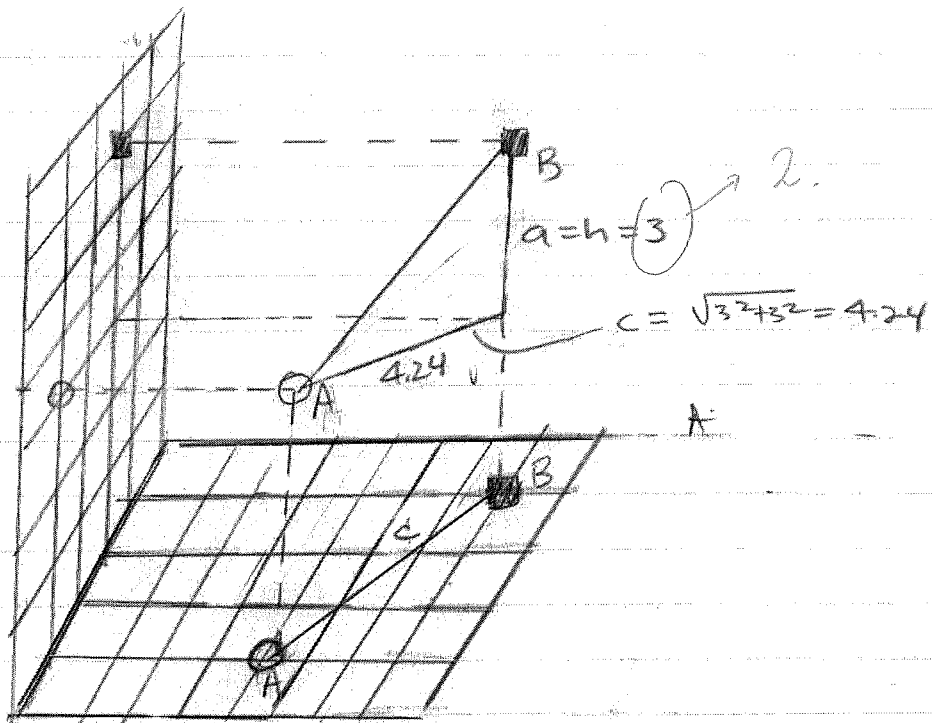
$$AB = \sqrt{c^2 + h^2}$$

$$= \sqrt{3^2 + 3^2 + 2^2 + 3^2}$$

$$= 4.69$$

2005 Part 2 TX

1. continued

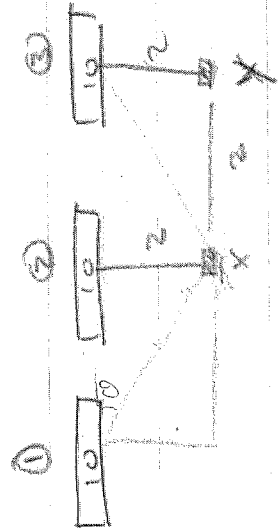


$$AB = \sqrt{a^2 + c^2} = \sqrt{3^2 + 4^2} = 5.2$$

205 TX Part 2

- Given 3 linear sources as in figure 1, determine the ratios of the dose at point X with respect to point Y

$$D = \frac{I \times \text{Act.} \times \text{time}}{d^2} \quad T, \text{ act.}, + \text{time constant for all sources}$$



$$\text{Dose at X} = \frac{1}{10^2} + \frac{1}{10^2} + \frac{1}{10^2}$$

$$(\sqrt{2^2+2^2})^2 = 2^2 + (\sqrt{2^2+2^2})^2$$

$$\approx 2\left(\frac{1}{8}\right) + \frac{1}{4} = 0.5$$

$$\begin{aligned} \text{Dose } \gamma &\approx \frac{1}{(\sqrt{4^2+(2)^2})^2} + \frac{1}{(\sqrt{2^2+2^2})^2} + \frac{1}{2^2} \\ &\approx \frac{1}{20} + \frac{1}{8} + \frac{1}{4} = 0.425 \end{aligned}$$

$$\frac{\text{Dose } \gamma}{\text{Dose } x} = \frac{0.425}{0.5} = 0.85$$

If dose $\propto \frac{1}{r}$ (because distance is not $2 \times$ source length)

except for contribution of source ① to γ which is 4.47 cm away

$$\begin{aligned} \frac{1}{r} &= \frac{1}{4.47} \times 2 = \frac{1.221}{1.4} = 0.87 \Rightarrow \frac{G(r, \theta)}{G(r_0, \theta_0)} = \frac{0.24}{0.87} = 0.275 \end{aligned}$$

$$\frac{\beta}{G(r_0, \theta_0)} = \frac{\beta}{1.4 \times 1 \times 1}$$

$$G = \frac{1.90}{1.4 \times 0.5 \times 1} = 2.71$$

$$G = \frac{1}{r^2} = \frac{1}{4} = 0.25$$

$$G = \frac{\beta}{Lr^2\theta} = \frac{0.673}{1.4 \times 2 \times 1} = 0.240$$

$$\begin{aligned} \text{if } r &= 0.5 \text{ cm} \\ L &= 1.4 \text{ cm} \\ \beta &= \tan^{-1}\left(\frac{0.7}{0.5}\right) \times 2 \\ &= 108.9^\circ \\ &= 1.90 \end{aligned}$$

$$\begin{aligned} \theta &= 90^\circ - 0 = 1 \\ r &= 2 \text{ cm} \\ L &= 1.4 \text{ cm} \\ \beta &= \tan^{-1}\left(\frac{0.7}{2}\right) \times 2 \\ &= 36.6^\circ \\ &= 0.673 \text{ rad.} \end{aligned}$$

can we use TG-43 formula?

$$\frac{\beta}{G} = \frac{1}{r^2} = \frac{1}{4}$$

ZSS Part 2 TX

2. (cont.)
$$\text{Dose } x = \frac{1}{\frac{1}{2} \rightarrow 2} + \frac{1}{1 \rightarrow 2.828} + \frac{1}{1 \rightarrow 2.828} + \frac{1}{1 \rightarrow 2.828} = 1.2072$$

$$\text{Dose } y = \frac{1}{\frac{1}{2} \rightarrow 2} + \frac{1}{1 \rightarrow (2.828)} + \frac{1}{1 \rightarrow 2} = 0.9034$$

$$\frac{\text{Dose } y}{\text{Dose } x} = \frac{0.9034}{1.2072} = 0.75$$

3. practice Rephrase mu calcs.

4. A Shidding problem 36 inches ^{space} available

concrete required = $\frac{66}{13.6}$ inches $VL = 3.6$ inches
 VL steel = 3.8 inches - determine
the amount of steel

① # of VLs needed = $\frac{66}{13.6} = 4.853$

② set up simultaneous equations to optimize
steel & concrete

① $X_{VL \text{ concrete}} + Y_{VL \text{ steel}} = 4.853$

② $13.6X + 3.8Y = (36)$ inches

- from ① $X = 4.853 - Y$

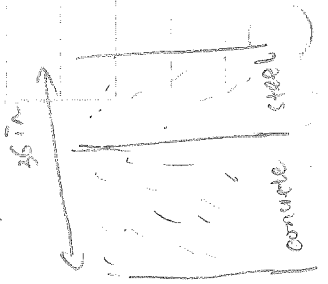
So: ② $13.6(4.853 - Y) + 3.8Y = 36$

$= 66 - 13.6Y + 3.8Y = 36$
 $30 = 9.8Y \rightarrow Y = \frac{30}{9.8} = 3.06$

$X = 4.853 - 3.06 = 1.79$

$13.6(1.79) = 24.36$ concrete $3.8(3.06) = 11.628$ PD

$\frac{66}{13.6} = \frac{36}{3.8} + \frac{3.8}{3.8}$
 $\frac{66}{13.6} = \frac{36}{3.8} + 1$



$\begin{cases} 13.6X + 3.8Y = 36 \\ X + Y = \frac{66}{13.6} \end{cases}$

$\Rightarrow X = 1.79$
 $Y = 3.06$

Steel: $3.8 \times 3.06 = 11.628$

2005 TX Part 2

5. How many fractions with a PA cord block if after the block is added the dose to the cord is reduced to 18% of what was being given without it. TOTAL dose to 150 = 6000 cGy, total dose to cord = 212 cGy/fraction. Cord dose constraint = 4500 cGy.

$$x(212) + y(0.18)(212) = 4500$$

$$x(200) + y(200) = 6000$$

$$x = \frac{(6000 - 200y)}{200} = 30 - y$$

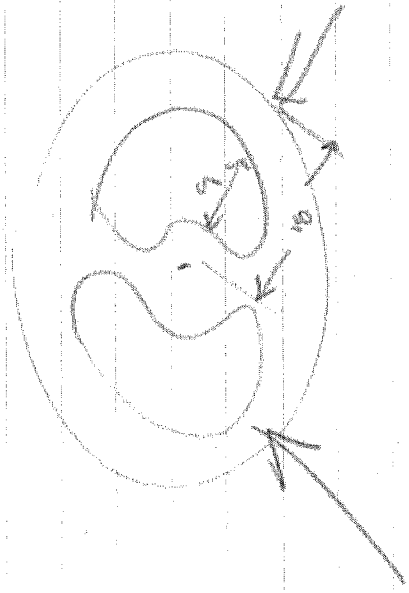
$$(30 - y)212 + y(38.16) = 4500$$

$$\begin{aligned} 6360 - 212y + 38.16y &= 4500 \\ 1860 &= 173.84y \\ y &= 10.699 \end{aligned}$$

$$x = 30 - 10.699 = 19.301$$

$$\text{TOTAL fractions} = x + y = 10.699 + 19.301 = 30 \text{ fx}$$

6) 9cm lung, Post. oblique, 150 depth = 18cm
 given DR for 3, 5, 9, 12, 16



acm eq to $9 \times 0.33 = 3 \text{ cm}$

0.25 to 0.33

$$\text{use } d_{\text{eff}} = (10-9) + 3 = 12$$

Say 100 cGy to 150, e.g., 15x5

100 cGy

$$\frac{1 \text{ cGy}}{\text{min}} \times \text{Time} (12, 15 \times 5)$$

7) Thickness of compensator - missing tissue

$$= 5 \text{ cm} \quad \rho_{\text{water}} = \frac{19}{\text{cm}^3} \quad \rho_{\text{comp}} =$$

don't need 5cm - need less because of scatter loss at depth due to compensator

$$\text{use } t_{\text{tissue comp}} = T_{\text{issue}} D_{\text{ref}} \left(\frac{Z_{\text{ratio}}}{\rho_c} \right) \rightarrow \text{density of compensator}$$

$$= 5 \text{ cm} \left(\frac{0.7}{\frac{19}{\text{cm}^3}} \right) = 5(0.7) = 3.5 \text{ cm}$$

0.7

$$t_c = t' \left(\frac{Z}{\rho_c} \right) \rightarrow \text{density of compensator}$$

tissue missing

thickness of compensator

- D_1 measured with relative long exposure T containing one end-effect

$$D_1 = \dot{D}(T + \epsilon)$$

- D_n measured over n dose segments

$$D_n = \dot{D}(T + n\epsilon)$$

$$\Rightarrow \dot{D} = \frac{D_1}{T + \epsilon} = \frac{D_n}{T + n\epsilon}$$

$$\Rightarrow T = \frac{(D_n - D_1)T}{nD_1 - D_n}$$

time error

2005 Part 2 TX

(see IAEA hand book

page 178)

11. Error on orthov. unit = 0.02 seconds, ?
 125 cGy/min, PDD = 60%, what is max
 dose delivered w/ < 1% error not
 taking into account the 0.02 seconds.

$$\Rightarrow D_1 = (125 \text{ cGy/min}) \cdot T$$

$$D'_1 = (125 \text{ cGy/min}) \left(T + \frac{0.02}{60}\right)$$

$$\Rightarrow D'_1/D_1 < 1.01$$

$$\Rightarrow \frac{T + 0.02/60}{T} < 1.01$$

$$T > 0.033 \text{ min}$$

?? Please give me your answer !!

What about this approach: This is like a counting statistics + timer problem. You have a certain rate, R , have to count for a certain time, t , to get the error down to, say, 1%

$$\frac{\sigma}{\text{Rate}} = 0.01$$

Rate

In this case 1 SD = the 68% Confidence level. $L \cdot T \cdot R = \text{Dose rate}$

??

Can I assume if I count for a certain time t , that the 0.02 seconds error doesn't matter? (I DON'T KNOW so give me your input.)

anyway $\frac{\sigma}{\text{Rate}} = 0.01 \quad \sigma = 0.01 \left(\frac{125 \text{ cGy}}{\text{min}} \right)$

$$= 1.25 \text{ min}$$

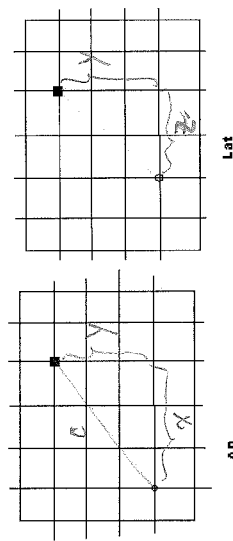
$$\sigma = \sqrt{\frac{\text{Rate}}{t}} = 1.25 \frac{\text{cGy}}{\text{min}} \rightarrow t = \frac{125}{(1.25)^2} = 80 \text{ min}$$

$$80 \text{ min} \times 125 \frac{\text{cGy}}{\text{min}} = 10,000 \text{ cGy} \quad \text{PDD } 60\% = 10,000(0.6) = 6,000 \text{ cGy}?$$

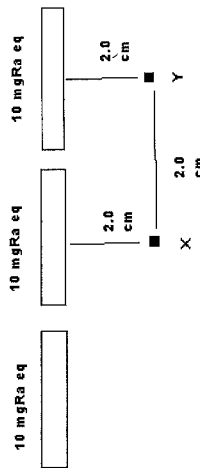
What I remember from ABR Exam 2005 PART II

Disclaimer: This is only what I remember, the problems can be poorly formulated. I am not responsible for misunderstandings.

- Given the grid in which every line intersection is at 1 cm. Determine the distance between the source (black dot) and the point of interest (white dot).



- Given three linear sources as in the figure, determine the ratios of the dose at point Y respect to point X.



- Tables of 4 MV and 6 MV PDD and TMR VS field size were given in two sheets of paper. At the very bottom of the PDD tables for both energies, a column with the BSF for every field was given. BSF, not Normalized Peak Scatter Factors were given. The calculations were to obtain MU settings for different field sizes:

-In general: most of the time the calibrations were at SSD + dmax.
 -In some problems the Sc,p was not given. Even the whole exam doesn't refer to this magnitude like that (in some other problems OF was given, which is Sc,p)
 -Use of SAD and SSD setups, change in SSD's (to require one to use the Mayneord factor to get the new PDD at a different SSD).
 -Calculate the dose to cord at 4 cm, given every thing needed for a SAD setup.

f-factor	10^3	10^2	10^1	10^0
water	0.88	0.97	0.99	0.99
muscle	0.92	0.965	0.98	0.98
bone	0.94	0.98	0.99	0.99

For all Ra substitutes (E > 200 keV),
 f-mu = 0.974 for water per Pere's textbook
 = 0.966 for muscle

$$\begin{cases} N + 1 = \frac{66}{13.6} \\ 13.6 \times 3.8 = 36 \end{cases} \Rightarrow \begin{cases} \lambda = 1.79 \\ \gamma = 3.06 \end{cases} \quad \begin{cases} \text{Steel} = 3.06 \times 3.8 \\ = 11.628 \text{ in} \end{cases}$$

- A shielding problem like: Available space 36 inches. Required thickness of concrete was 66 inches. TVL for concrete = 13.6 inches. TVL for steel 3.8 inches. Determine how much of steel has to be in the 36 inches wall for the shielding to work out.

Hint: develop a system of two equations and two unknowns (X, Y being the thicknesses of concrete and steel).

- The same method (a system of two eq. and two unknowns) can be used to quickly solve for problems like: How many fractions with a PA cord block if after the block is added the dose to cord is reduced to 18% of what was being given without it. Total of dose to isocenter 6000 cGy, total dose to cord 212 cGy per fraction. Constrain: cord dose can not be more than 4500 cGy

Hint:

$$\begin{aligned} \text{eq 1: } x \text{ Dose to cord} + y \cdot 0.18 \cdot \text{Dose to cord} &= 4500 \quad (\text{Dose to cord } 212 \text{ cGy/fraction}) \\ \text{eq 2: } x \text{ Dose to iso} + y \text{ Dose to iso} &= 6000 \quad (\text{Dose to iso} = 200 \text{ cGy/fraction}) \end{aligned}$$

- Again a problem in which two post oblique fields traverse 9 cm of lung. Depth of isocenter from the two posteriors is 18 cm. TMR given for 3, 5, 9, 12 and 18. (Better formulated in previous years).

- A problem in which you had to calculate the thickness of a compensator, given the missing tissue = 5 cm. Density of compensator material and electronic densities of water and compensator material.

- A problem in which the transmission factor B had to be calculated given everything you needed. In ALL the radiation protection problems the Xp (effective dose limits were given, so there were no ambiguities in this regard).

- Two problems like the ones that appeared in previous years regarding transferring a patient to a Co-60 unit after being simulated and treated in a SAD = 100 cm setup in linac. The treatment in Co-60 had to be done with SSD setup. Thickness of patient given.

- HDR scenario: Given activity of Ir-192 source 10 Ci (quickly convert it to mCi's), the exposure rate constant of Ir-192 was not given here, I used 4.6 R-cm²/(mCi-hr), then you had to know the f factor also for Ir-192. Balloon with 4 cm diameter. Calculate the approx. time to deliver 340 cGy's (at 1 cm from the surface of balloon).

- A problem in which the timer error of a orthovoltage unit was + 0.02 secs. The dose rate was 125 cGy/min in water. PDD was 60% at 2 cm. Determine what is the maximum dose that can be delivered with less than 1% error without having to take into account the + 0.02 secs.

- Another problem in which the leakage transmission factor B had to be calculated. Basically you only had to know that there is a factor of 1000 (1/0.1%) for leakage.

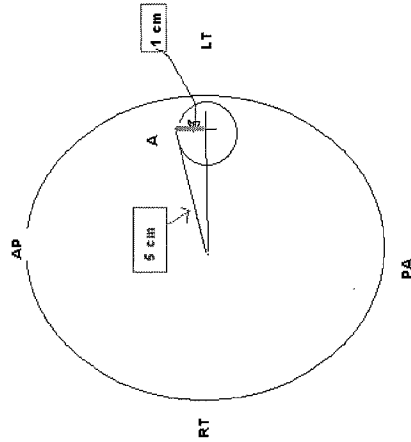
$$\begin{aligned} \dot{D} &= S_k \cdot A_s \cdot G(r, \theta) \cdot g(r) \cdot F(r, \theta) \\ &= X \cdot \left(\frac{r}{r_0}\right)^2 \cdot \Delta \\ &= (4.69 \text{ R/hr}) \cdot (10.376 \text{ cm/hr}) \cdot (10 \text{ cm})^2 \cdot (1.11 \text{ cGy/hr/13}) \cdot \left(\frac{1}{30 \text{ cm}}\right)^2 \\ &= 5.67 \text{ cGy/hr} \end{aligned}$$

In general, and it is very fair, all the time the T, U and W was given. It is better to leave the decision of selection for an oral test scenario.

13.- Stereotactic radiosurgery scenario: Given a CT image with the rest of the info as given in the picture that follows. How much and in what direction (either one of four choices AP-PA, PA-AP or RT-LT LT to RT) will move if the patient head (or AP beam I don't recall it) is tilted 1 degree.

$$\frac{1}{100} \cdot \pi \cdot R = \frac{\pi}{180} \times 50 \text{ cm} = 0.87 \text{ cm}$$

Here I don't remember if the isocenter was centered on the circle or at the origin from where the 5 cm are measured. This is a key issue for solving the problem.



14.- Another problem with a 1 cm grid superimposed on a AP and Lateral Fletcher applicator. Essentially like problem 1. Determine the distance from one of the ovoids to a point. And calculate the dose rate to the point due to that source in that ovoid only. (mgKa eq for the source were given, 8.25 R-cm²/(mCi-hr) one had to know, I think factor also was not given (source was Cs-137).

15.- Given a universal wedge with Wedge Factor = 0.5. Calculate the ratio of wedged / open field to make the wedge a 30 degree wedge. *Dose; 1:2 (wedge vs open)*

Hint: use Tatcher relationship: new Wedge angle = (1-F) Universal wedge angle, and take into account the with a WF = 0.5, twice the mu's has to be given for the same dose.

16.- Shielding calculation for a HDR room (Ir-192 source 10 Ci, exposure rate constant of Ir-192 given, weekly limit given (0.01 R/week), T = 1 given. And workload W = 100 min/week given. Distance 2.0 meters. Determine B. T_{1/2} = 58 in concrete.

HDR shielding

occupational: 50mSv/yr → 10mSv/yr or <2mSv/yr

public: 5mSv/yr → 0.1mSv/yr

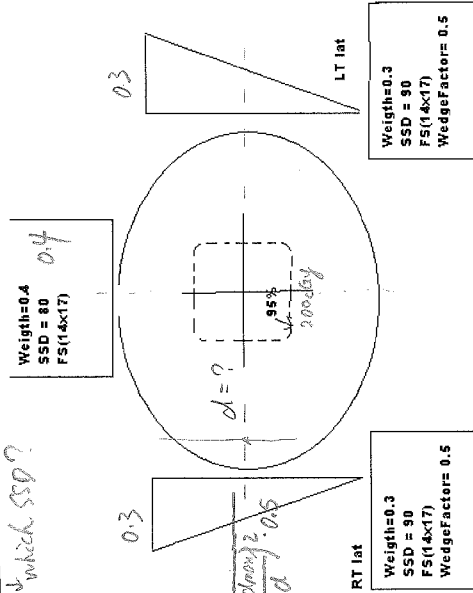
(infrequent) → 0.01 R/week

$$B = \frac{(0.01 \text{ R/week}) \cdot (100 \text{ min/week}) \cdot (100 \text{ min/week})}{(100) \cdot (10000 \text{ Ci}) \cdot (0.01 \text{ R/week}) \cdot (100 \text{ min/week})} = 0.005$$

$$= \frac{0.01 \text{ R/week} \cdot (100 \text{ min/week}) \cdot (100 \text{ min/week})}{(10.000 \text{ mCi}) \cdot (0.01 \text{ R/week}) \cdot (100 \text{ min/week})} = 0.0029$$

$$= \frac{0.01 \text{ R/week} \cdot (100 \text{ min/week}) \cdot (100 \text{ min/week})}{(10.000 \text{ mCi}) \cdot (0.01 \text{ R/week}) \cdot (100 \text{ min/week})} = 0.0029$$

17. What is the ratio of MU's given the weights of AP = 0.4, RT lat and LT lat = 0.3 to deliver 200 cGy to 95 % Isodose line. Fsize for every was given. WFactor for lat. Fields given. SSD for every field given. Table with TMR's (FS, depth). Calibration 1cGy/ MU at SSD + dmax.



18.- Total dose at 2 cm from one seed of Pd-103 given its dose rate constant (0.868 cGy/hr), g(2cm) was given, Sk for the source was given= 2.5 U. Phi (anisotropy) = 0.939.

19.- Determine the Effective SSD for 6 MeV electrons. Io = 100, at 20 cm gap reading was 44, and at 40 cm gap reading was 25, dmax for 6 MeV electrons not given.

20.- A geometry problem: Determine the angle, following the IFC convention of angles, of the medial field, given the dimensions in the figure:

21.- A geometry problem: Determine the angle, following the IFC convention of angles, of the medial field, given the dimensions in the figure:

22.- A geometry problem: Determine the angle, following the IFC convention of angles, of the medial field, given the dimensions in the figure:

23.- A geometry problem: Determine the angle, following the IFC convention of angles, of the medial field, given the dimensions in the figure:

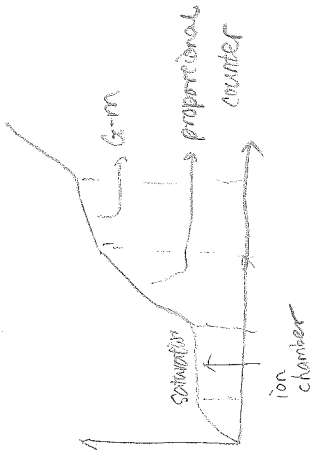
24.- A geometry problem: Determine the angle, following the IFC convention of angles, of the medial field, given the dimensions in the figure:

25.- A geometry problem: Determine the angle, following the IFC convention of angles, of the medial field, given the dimensions in the figure:

26.- A geometry problem: Determine the angle, following the IFC convention of angles, of the medial field, given the dimensions in the figure:

27.- A geometry problem: Determine the angle, following the IFC convention of angles, of the medial field, given the dimensions in the figure:

28.- A geometry problem: Determine the angle, following the IFC convention of angles, of the medial field, given the dimensions in the figure:



48.- Given a graph of ionization current vs polarization voltage with different areas marked select which detector works at specific area

49.- Measurement of the crack in a LINAC vault with high volume IC. Chamber over the crack measures 1 mR/h and far from the crack 0.5 mR/h. Estimate what would be the actual exposure rate (less than 0.5, 1, more than 1, etc).

50.- Calculate the time required to achieved 95% of the total dose for a I-125 permanent implant

$$(1 - e^{-\frac{\ln 2}{57.4}}) = 0.95 \Rightarrow t = 256.7 \text{ days}$$

51.- Permanent implant of Pd-103. Activity was given. Calculate total dose delivered $\Rightarrow D = \dot{D} \cdot 1.44 \cdot T_{1/2} = (S_k \cdot \Lambda) \cdot (1.44 T_{1/2})$

52.- What can be said about TBI. (compensators can be used, requires long treatment distance, lateral irradiation brings higher inhomogeneity that AP irradiation, 5% dose homogeneity could be achieved for all distances). See RAPHEX for a better questions. \rightarrow wrong.

53.- Detector resolution required for SRS field profile is (less than 1mm, 2mm, 3mm, etc)

\Rightarrow Linac beam $< 2\text{mm}$ $< 3\text{mm}$ for overlap / TMR.

54.- What is the meaning of a phase-space file in Monte Carlo calculations?

Scantknife $< 1\text{mm}$.

55.- Sliding window in IMRT means A, B, C, D, etc? \rightarrow The simulation starts from the plane of phase-space file, the particle being tracked through particular beam-defining device

56.- A set of CT numbers was given -1000, -100, 0, 100, 1000. Select proper order of tissues that correspond with the order of these CT numbers. Air, lung, water, soft tissue, bone were in all possible answer in different orders. \rightarrow 1000 - 700 0 50

57.- A DVH graph was given. A point on the DVH curve was marked. Select proper meaning of this point from different enunciations.

58.- For what purpose a beam spoiler for 10MV breast treatment is used?

\rightarrow Assume enough dose to shallow tissue of target

59.- Amount of X-ray contamination for a 18 MeV beam is around % 3-5%.

3% - 16 MeV } various
5% - 70 MeV } machine

60.- Dose limits for the public for frequent and infrequent exposure is

5mSv 1mSv

usual 6mSv

is enough to

achieve adequate

dose uniformity & skin-sparing

For large breast, high E beams are

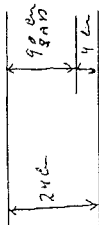
needed to produce adequate

dose uniformity

1. Several questions concerning the NRC regulations. (see below)

2. Calc. dose to cord

Gr. ve



3. Many questions in TG 41.
4. Some TG 30 questions. \rightarrow TSEE
5. also TG?? On electrons.
6. Dose to patient on Linac x3 } Needed to interpret charts, Inv sq.
7. Dose to patient on Co. } Eq. Sq. Calc. etc.
8. All data was given when isotopes were involved i.e. T1/2, HVL, Γ factor etc.
9. TMR calculations
10. Given dose to an isodose line i.e. 200 cGy to the 105 % isodose line what is given dose for 100% to field #1.

11. Follow up to above lat field had a wedge and asked to calc given attenuation of wedge and asked to calc given dose use data from above.

12. F factor calc. given μ/ρ H2O and muscle etc.

13. Thickness of Al needed to compensate for missing tissue. Factors given. \rightarrow

14. Sc and Sp calc. given TMR. Collimator open 40x40 blocked to 8x8. Calc. Mu for midline dose.

15. Neutron questions width of maze effect on scatter energy at end if maze. T-F A wider maze will give less scatter at the door than a thinner maze.

16. Given a 20 MeV neutrons and the door mounted backwards i.e. Borated poly on outside, what is the energy of the gamma coming off poly? Given choice of answers 10 KeV neutrons, 10 KeV photons, 5 MeV photons, 100 KeV photons and 10 MeV photons.

17. questions on acceptance checks for wedge factor. See below

18. In commissioning a new linac with 6 and 18 photons and electron up to 20 MeV you should determine neutron dose from which selection of beams.

- Both 6 and 18 photon
- 18 photon and all electrons
- 18 photon and 20 electrons
- 18 photon only

19. Gap calc.

20. Manard's F calculations.

21. Many brachy question all factors given Γ and T1/2 etc.

22. Calc dose from Ir after 45 days. Given $D_0 = 8 \text{ cGy hr}$ T1/2 must convert days to hours etc.

23. Could not remember any HDR or stereo questions.

24. Many WF questions. ie wedges from fields 90 and 220 and 180 apart, in plane cross plane diff FS, depth doses, dynamic wedge.

25. Dose outside of Rm need for additional shielding or if it meets NCRP standards. T1/4 U1/4, and W, given instantaneous dose rate. Reduce to 2 m/hr (similar to questions on previous exam).

26. What is allowable dose to frequently exposed member of public? *independent = 0.5 rem. 0.1 rem = frequent*
27. Dose at 2 cm depth on field prescribed to 6 cm depth with cobalt 60 and 9 MeV electron, electron %DD curve given. 5Gy electron and 40 Gy at 6 cm depth with cobalt 60 no cobalt 60 data given.

28. Target angle of therapy x-ray unit greater than diagnostic unit. (T-F) \checkmark
29. Target of therapy x-ray unit not transmission type (T-F). \checkmark

30. Skin dose from superficial unit greater than electron. (T-F)

31. Many simulator questions, can't remember exact questions.

32. Some radio biology questions.

33. The NRC requires a wipe test on linac collimators made of depleted uranium. (T-F)

34. You can drill/screw into a depleted uranium collimator? (T-F) \checkmark *radiation*

35. Linac jaw are made from natural uranium? (T-F) \checkmark *depleted uranium contains*

36. Natural uranium is commonly used as jaw material for linacs. (T-F) \checkmark *with a concentration*

37. What provides the greatest contribution to the dose from I-125 implant.

- gamma rays \checkmark
- fluorescent photons
- auger electrons
- beta rays
- internal conversion electrons

38. When commissioning a set of new wedges, which of the following must be measured?

- wedge factor vs. Depth
- wedge factor vs. Field size \checkmark
- wedge factor vs. Off axis
- wedge factor for the average chamber reading with gantry at 0 and 180 degrees.

Can not attest to exact format on wording of questions but the idea of what they were looking for is stated. I felt it was a fair test and had many appropriate questions asked. I finished with 1/2 hour to spare. One unique screw up on exam. 2 of the 15 point questions had the correct answer marked in the text booklet, they were marked with a *

Good Luck

$$D = D_0 \cdot T_{\text{avg}} \left(1 - e^{-\frac{1.44}{T_{1/2}} \cdot t} \right) = 8.66 \text{ cGy/hr} \cdot (73.8 \times 24) \times \left(1 - e^{-\frac{1.44}{73.8} \cdot 45} \right)$$