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 metastaes

The NRC requires HDR shielding to be surveyed: daily, weekly, monthly, annually, after source change. quarterly ⇒ also check head leakage < 0.25 mR/hr @ 1m
also initially & 5 years

What detector is best for calibrating an Ir-192 IVRT source? (well chamber)? for γ-emitted source ^{192}Ir Re-entrant chamber (or free-space ion chamber
for β^- source ⇒ extrapolation ion chamber in water (r = 2mm, $\theta = \frac{\pi}{2}$)

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 $H = H_o \frac{S_o}{S} \frac{1}{d_1^2 10^{+d_2/5}}$ → TVL
TVD

$$\text{slope} = \frac{\sqrt{\frac{I_0}{I_g}} - \sqrt{\frac{I_0}{I_0}}}{\text{gap}}$$

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

$$\text{slope} = \frac{\sqrt{\frac{100}{44}} - \sqrt{\frac{100}{100}}}{20} = 0.0254$$

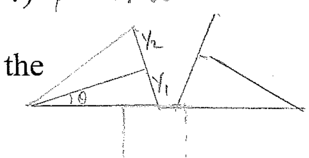
Electron virtual source- for linac with end of applicator at 100cm. ⇒ ⇒ $f = \frac{1}{\text{slope}} - d_m = \frac{1}{0.0254} - d_m = \boxed{39.4 - d_m}$
Given ion chamber readings at several distances, the virtual source position is __ cm.
At 100cm, 100; at 120cm, 44; at 140cm, 25. $\frac{I_0}{I_g} = \left(\frac{f+d_m+g}{f+d_m}\right)^2$ ⇒ $\frac{100}{44} = \left(\frac{f+d_m+20}{f+d_m}\right)^2$ $\frac{100}{25} = \left(\frac{f+d_m+40}{f+d_m}\right)^2$
⇒ $f + d_m$ = 39 cm

AAPM Report 54 (TG-42? SRS)- What is the max size of a scanning ion chamber for SRS beams? ⇒ for Linacs → ≤ 2mm for beam profiles (ion chamber, film, diode, TLD) ex. PPL PTW N23342
≤ 3mm for TMR & output factor (ion chamber) cyl. 0.07 cm^3
⇒ for Gamma knife → < 1mm × 1mm × 1mm

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-?) 4 photon: ^{60}Co ~ 50 MV

For a H&N case, calculate couch kick given the field sizes to match the inferior borders to an SCLAV field. $\theta = \tan^{-1}(Y_1/SAD)$

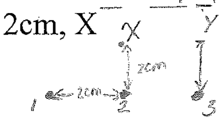


Calculate the gantry angle for a half-beam blocked medial breast tangent beam, given a bunch of geometrical distances.

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? Assume point source.
$D = \dot{D}_0 T_{avg} (1 - e^{-\lambda t})$ ⇒ $0.95 = (1 - e^{-\lambda t})$ ⇒ $0.95 = (1 - e^{-\frac{\ln 2}{59.4} \times t})$ ⇒ t = 257 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.



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

$$D_y = D_1 \cdot \left(\frac{1}{\sqrt{4^2+2^2}}\right)^2 + D_2 \left(\frac{1}{2\sqrt{2}}\right)^2 + \left(\frac{1}{2}\right)^2 \cdot D_3 = \frac{68}{160} D$$

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

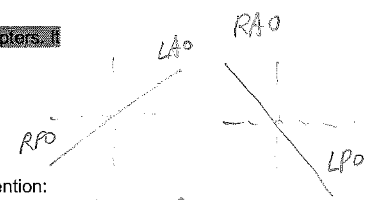
⇒ $\boxed{D_x/D_y = \frac{20}{17}}$

What is the range of a Sr-90 beta in air?
Strontium-90 β^- emission max energy → 0.5 MeV $T_{1/2}$ = 28 yr ⇒ range for 2 MeV β^- in air ≈ 10^3 cm – 10 m
↓ decay Avg energy → 0.02 MeV
Yetrium (Y^{90}) β^- max energy 2.3 MeV $T_{1/2}$ = 64 hr
Avg energy 0.97 MeV

2004 ABR Exam Questions

http://www-naweb.iaea.org/nahu/dmrp/syllabus.shtm. 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:

Angle of RPO = Angle of LAO + 180 - 2 * arctan(Width/(2 * 100))

If tangent fields are RAO and LPO and angle of RAO is given then:

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

Angle of LPO = Angle of RAO - 180 + 2 * arctan(Width/(2 * 100))

For Varian Convention:

Angle or RPO = Angle of LAO + 180 + 2 * arctan (Width/(2*100))

For Varian Convention:

Angle of LPO = Angle of RAO - 180 - 2 * arctan (Width/(2*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.

~~0.005 mCi~~ 0.005 μCi (5nCi)

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

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

>From there I obtain that the allowable cpm = efficiency * 5 E-09 = (X cpm / Y E -03 Ci) * 5.0 E-09 Ci = X cpm * 5 E-06

$$\text{allowable counts} = \frac{X\,cpm}{Y\,mCi} \times 0.005\,\mu Ci = (X/Y)(0.005)\times(0.001) = 5\times10^{-6}\,X/Y\,(cpm)$$

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

collimator angle = arctan (1/2 Lspinal/100)

table kick angle = arctan (1/2 Lcranial/100)

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

(4) Derive a relationship between HVL and TVL

HVL/ln2 = TVL/ln10

TVL ≈ 3HVL

$$(0.5)^{\frac{x}{HVL}} = (0.1)^{\frac{x}{TVL}}$$

$$\ln \Rightarrow \frac{x}{HVL}\ln 0.5 = \frac{x}{TVL}\ln 0.1$$

$$\frac{\ln 0.5}{HVL} = \frac{\ln 0.1}{TVL}$$

$$\frac{HVL}{TVL} = \frac{\ln 0.5}{\ln 0.1} = \frac{\ln 2}{\ln 10} = 0.303$$

↳ the relationship btw HVL. TVL (HVL < TVL)

$$(0.5)^{n_{HVL}} = (0.1)^{n_{TVL}}$$

$$\ln \Rightarrow N_{HVL}\ln 0.5 = N_{TVL}\ln 0.1$$

$$\frac{N_{HVL}}{N_{TVL}} = \frac{\ln 0.1}{\ln 0.5} = \frac{\ln 10}{\ln 2} \simeq 3.32$$

of (HVL)(TVL) to reach the equivalent shield ($n_{HVL} > n_{TVL}$)

$$\begin{cases} \frac{FVL}{\ln 5} = \frac{TVL}{\ln 10} = \frac{HVL}{\ln 2} \\ \Rightarrow \frac{n_{HVL}}{\ln 10} = \frac{n_{TVL}}{\ln 2} \\ n_{HVL} = \left(\frac{-\ln B}{\ln 2}\right) \end{cases}$$

$$n_{TVL} = -\log B = \left(\frac{-\ln B}{\ln 10}\right)$$

FVL/ln5 = TVL /ln10 = HVL / ln2

FVL would be the "five value layer".

1/ 2 **(x/HVL) = 1/10 ** (x/TVL)

x ln2 / HVL = x ln 10 / HVL

HVL/ln2 = TVL/ln10

(5) TG51 correction factors for photons and electrons:

Both:

Temperature and pressure correction factor: Ptp

Ion recombination correction: Pion = (1 - VH/VL) / (MrawH/MrawL - (VH/VL)

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

Electrometer correction factor: Pelec

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

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

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

Sqrt (Io/I) = g/(f + dmax) + 1

Slope = 1 / (f + dmax) from there f = 1/Slope - 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:

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 = Eo/2 → Rp

- Eo = 2.33 R50

- Ez = Eo (1-z/Rp) = 2.33R50 (1 - z/Rp)

- Depth Ionization curve is more upstream than Pdd curve (R50 > I50)

- R50 = 1.029 I50 - 0.06 → cm.

- Epo = c2 + c3 Rp + c4 Rp**2 / /Epo = 0.22 + 1.98 Rp + 0.0025 Rp**2

- Rp = Eo/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_{90} 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_{80}, 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.

ϕ of field = Rp

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

→ ICRU field size (eq.) $\geq R_p/2 \to r$
or field size > E(MeV)/2.5 → ϕ
$r \geq 0.88\sqrt{(E_p)_0}$

- Penumbra: bulges out.

- Isodose distribution: 80 and 90% IDL shrink.

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

- X ray contamination increases with e- energy

- Oblique incidence: dmax shifts towards surface, depth of penetration decreases. R_{80}↓

- 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 = Eo/2 + 1 for 12 MeV ⇒ 7mm

- Thickness of cerrobend for blocking electrons in mm = (Eo/2 + 1) * 1.2

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

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

- How to obtain PDD from Depth Ionization: PDD = (M * (L/ro)water to air * * Prepl) /(the same at dmax)
1 for PPL
$D_{med} = Q_{corr} \cdot P_{repl} \cdot (L/\rho)^{med}_{air} \cdot K$ → depth independent constant = cavity-gas calibration factor N_{gas}

$\%D(d) = \frac{D_{med}(d)}{D_{med}(d_{max})} \times 100\%$

- TG-51 for measuring the Depth Ionization curve place chamber at d + 0.5 Rcav. 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 Rcav upstream. From this curve obtain PDD with expresion given before.

- TG-51 for electrons: $D^Q_W = D^{60Co}_{D,W} \cdot K_{ecl} \cdot K'_{R50} \cdot M \cdot P_{grad}$

$M_{raw} \cdot P_{pol} \cdot P_{ion} \cdot P_{PE} \cdot P_{elec}$

Dw,Q = ND,W - Co60 * M * Pgrad * Kecal * K'R50

ND,w -Co60: given by ADCL

M corrected reading = Mraw * Ppol * Pion * Ptp * P elec

Pgrad = Mraw (dref+0.5 Rcav) / Mraw(dref)

Kecal from table

K'R50 from table K_{R50}

KQ = Pgrad * kecal K'R50

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

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

Ez = Eo (1 - z/Rp) <---- I think Rp should have been given also. If not I think we could use Rp = Eo/2.

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

Dose per beam 60 cGy at isocenter.

Post beams traverse 9 cm of lung. 15 cm is physical depth. Then radiological depth = 15 - 9 +9 * 0.33 = 8.97

TMR (10x10, 3)= 0.97, TMR (10x10,6)= 0.891, TMR(9)= 0.8, TMR (10x10, 12) = 0.719, TMR(10, 15) = 0.639

Determine the ratios MU AP / MU post.

MU AP = 60 / TMR (10x10,15) OF(10) = 60/ 0.639 = 94

MU RPO = 60 / TMR (10x10, 9) OF(10) = 60/0.8 = 75

Ratio MU AP / MU RPO = 94 / 75 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.

all in cm.

$\begin{cases} R_{50} = 1.029\, I_{50} - 0.06 \\ d_{ref} = 0.6\, R_{50} - 0.1 \end{cases}$

This problems are solved using similar triangles rules:

SSD1/SFD1 = SSD2/SFD2

SFD2 = SSD 2 SFD1/SSD1 = 110 * 140 / 102 = 151 cm.

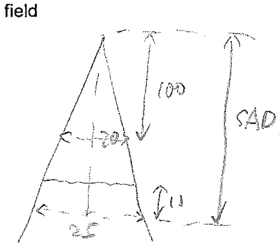
(17) A wedge has a field size limit of 20 cm. A patient is planned SAD with a FSize of 25 cm. Calc the SSD to be able to use the wedge (I noted that the separation is needed and the problem of Rosemark file 36 has it= 22 cm):

The wedge has a fsize 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:

(new SSD + dmplane) / 25 = 100 / 20

new SSD = 25 x 100 / 20 - 12 = 113, Which makes more sense.

11 for separation = 22 cm.



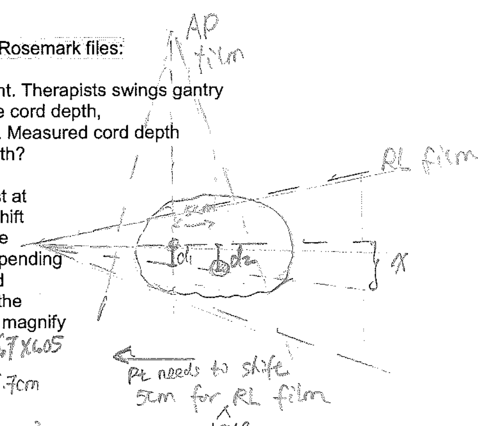
(18) This one I completed with question 41 from Rosemark files:

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)

$\begin{cases} mag = 105/SFD \\ mag' = 100/SFD \end{cases} \Rightarrow \begin{matrix} d_2 = 6.7 \times 1.05 \\ d_1 = 6.7 cm \end{matrix}$



Pt needs to shift 5cm for RL film true.

(19) Superficial shielding calc given workload.

B = Xp d**2 / (Workload * U * T) $B = \frac{Pd^2}{WUT}$

Xp = 50 mSv / year = 1 mSv / week ---> for radiation workers (0.1 rem per week)

↓ 0.1 mSv/wk → 0.01 R/wk

Xp = 1 mSv / year = 0.02 m Sv / week for public.

↓ 0.02 mSv/wk → 0.002 R/wk ✓

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

For electrons is 0.6*R50 - 0.1 $d_{ref} = 0.6 \times R_{50} - 0.1$ (cm) close to d_{max} if E<10MeV

(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 * rho of lead = S in MeV/cm. Then the required thickness will be: t = e- Energy/ S

(22) Radial Dose funtions of Pd-103 VS I-125 radial function g(r) → exclude IVS only account for attenuation 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 pentration and therefore the radial dose funtion 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:

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

Public: 1 mSv/year = 0.02 mSv/week = 0.002 rem/week and 2 mrem in any hour.

Patient in room contiguous a Cs-137 implant room: up to 6 mSv/week<----? 6mcGy/hr ⇐ 1mGy/admition.

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-cm**2/(mCi-h). For air kerma rate constant multiply 3.26 by 0.876 cGy/R $3.26 \times 0.876 \times 0.7 = 1.999$ cGy/mCi·h cm²

→ 0.96 cGy/R in tissue. according to McGinley

B = Xp d**2 / (WUT)

B = 1 / 2**n, where n is the number of HVL. n HVL = - ln B / ln 2 and the number of TVL's is n TVL = - log B

Two-source rule:
① if compable TVL_{max} + 1HVL
② if diff by more than 1 TVL use the larger of the TVL.

(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 RoseMark)

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. dmax = 100% 2Gy → 238% ⇒ dmax = 2/238% = 84cGy

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 200cGy → isocenter ; 200/3 = 67 cGy at iso 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 foild 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 criterium is the most important to the success/failulre of an IVBT Tx?

IVBT → reduce neointimal formation reduce rate of resterosis to below 10%,

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

temporary implant → 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 emmiter sources calibrated in a well chamber.

Target volume: 2~5cm in length of artery & 0.5~2mm in thickness of arterial wall

AAPM ⇒ depth of dose prescription for intracoronary irradition to be 2mm from center of the source and for the peripheral arteries 2mm beyond the average lumen radium. For each case, 3 dose planes ⊥ to catheter should be reported.

temporary implants: sealed source or liquid-filled ballons
permanent implants: radiactive stents

β source → higher specific activity, higher doserate (P^{32}, Sr^{90}/Y^{90}) } activity 30~40mCi
longer half-life: greater softy

γ source ⇒ more uniform target dose (Ir-192) better radial dose distribution } 1~4Ci

$\ln(a/b) = \ln a - \ln b$
$\ln(1/b) = \ln 1 - \ln b$
$= 0 - \ln b$
$= -\ln b$

Ho (Nutron dose equiv @1.4m from target per unit absorbed x-ray dose at iso)

Varian	Ho(mSv/Gy)	
10mv	0.04	⇒
15mv	0.79~1.3	⇒
18mv	1.02~1.6	⇒ (0.1%)

TVL = 3.32 HVL

$B = (0.5)^{N_{HVL}}$
$\ln B = N_{HVL} \cdot \ln 0.5$
$N_{HVL} = \left(\frac{\ln B}{-\ln 2}\right)$

$B = (0.1)^{N_{TVL}}$
$\log B = N_{TVL} \cdot \log(0.1)$
$N_{TVL} = (-\log B)$
or $\ln B = N_{TVL} \cdot \ln(0.1)$
$N_{TVL} = \left(\frac{\ln B}{-\ln 10}\right)$

NCRP 151 Page 30:
R neutron production coefficients (uSv cGy⁻¹ m⁻²) per x-ray cGy per beam area

	18mv	15mv	
R: (for lead)	19uSv/cGy/m²	3.5uSv/cGy/m²	⇒ 5.4 times

Varian	10MV	15MV	18MV
Q (10^{12}/Gy)	0.06	0.76	1.22

Neutron source strength (Q_n) (neutrons per gray) → Figure B.1 → From 10MeV-18MeV x10times~20times; 15MeV-18MeV x 2times~10time

Beta emmiter sources calibrated in plastic with extrapolation chamber at a depth of 2 mm.

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

(32) Not correct measurment 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 ⇒ define the volume ② minimize the charge leakage

(33) Purpose of the guard electrode in a paralell plate chamber?
To eliminate end effect of the electric field of the chamber and to define the measuring volume of the chamber. <----?

Purpose of the guard ring: attenuates the lateral inscattering of electrons into the chamber volume <----?

(34) Radiobiology question....

This is what I have collected regarding radiobiology:

- RBE = Dose at 250 kVp/ Dose test radiation ⇔ ORE

- RBE increases with incresing 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. um

- NTCP: normal tissue complication probability

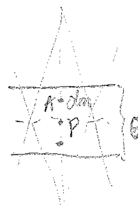
- 1-NTCP: normal tissue uncomplication probability

- TCP: Tumor control probability

- TCP * (1-NTCP) : Uncomplicated tumor control probability.

High LET > 30keV/um
Low LET < 2keV/um
clinical E beam 2MeV/cm in tissue
⇒ average LET 0.2~0.3keV/um
according to AAPM review course notes Page 21 of G.Luxton.

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



$$D_A = D_{dm}^{AP} + D_A^{PA} = \frac{\frac{1}{2} D_{mP}}{PDD(4MV, 0.5d)} + \frac{0.5 D_{mP}}{PDD(4MV, 0.5d)} \cdot PDD(4MV, d-d_m)$$

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).
⇒ check where is the max dose of combined AP/PA. @ dm

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 = ½ Dose MPlane / PDD (FS, sep/2, 4MV) + ½ Dose Mplane /PDD(FS, sep/2,4MV) * PDD(FS, sep – dmax,4MV)

Dose at Dmax 4MV = ½ Dose at MPlane /PDD (FS, sep/2, 4MV) (1+ PDD (FS, sep-dmax,4MV))

18 MV photons:

Dose at Dmax 18MV = ½ 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) Ir-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)

check {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}

$$50 mR/hr = (X mCi) \cdot 4.69 R cm^2/mCi\,hr \times 1000 (mR/R) \times e^{(-\frac{\ln 2}{0.25} \times 1)} \times (1/15cm)^2$$

X (15 cm, t=2.0 cm lead) = Xo exp (-ln2 * 1.0 / 0.25)

Xo= GammaIr-192 * Activity / (15)**2

$$\Rightarrow X = 38.4 mCi$$

50 E-03 R/h = 4.69 R cm2/(mCi -h) * Activity / (15.0**2) * 0.0625 ====>>> Activity = 50 E-03 * 15**2 /(4.69 * 0.0625) = 38.4 mCi (I was expecting something like 3.8 Ci or so).

(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

$$MU = \frac{D}{Output \cdot Sc(r) \, Sp(rd) \cdot BSF(r) \cdot PDD(r, d, SSD_{ex}) \cdot \left(\frac{SCP}{SSD+dm}\right)^2} \quad \text{if Output calib in air}$$

$$MU = \frac{D}{Output \cdot Sc(r) \, Sp(rd) \cdot PDD(r, d, SSD_{ex}) \cdot \left(\frac{SCP}{SSD+dm}\right)^2} \quad \text{if Output calib in water}$$

where $PDD(r, d, SSD_{ex}) = PDD(r, d, SSD_0) \cdot \left(\frac{f_2+dm}{f_1+dm}\right)^2 \left(\frac{f_1+d}{f_2+d}\right)^2$

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.

Time = Rx Dose/ (Output in cGy/min in Air(Fsize) * BSF(Fsize) * PDD(Fsize,depth)/100 * Trayfactor*Wedge factor * (SCD/(SSD + dmax) **2). (a)

Time = Rx Dose/ (Output in cGy/min in Water (Fsize)* PDD(Fsize,depth)/100 * Trayfactor*Wedge factor * (SCD/(SSD + dmax) **2). (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

MF = (SSD2 + dmax)**2 / (SSD1 + dmax)**2 * (SSD1 + d) ** 2 / (SSD2 + d)**2

New PDD at SSD2 = PDD at SSD1 * MF

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

Time = Rx Dose/ (OutPut in cGy/min in Water * New PDD at SSD2/100 * Trayfactor*Wedge factor * (SCD)**2/ (SSD2 + 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 F(size 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 expresion 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).

$$MU = \frac{D}{Output \cdot Sc \cdot Sp(rd) \cdot TAR(rd, d) \left(\frac{SCP}{f+d}\right)^2}$$

$$MU = \frac{D}{Output \cdot Sc \cdot Sp(rd) \cdot TMR(rd, d) \left(\frac{SCD}{f+d}\right)^2}$$

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:

Time = 200 /((130 cGy/min) * Sc(80/100*15=12x12) * Sp (15x15) * PDDatSSD=100(FS 15 x 15, d=8) * ((80+0.5)**2/(100+0.5)**2))

PPD2 = PDD1 * (100 + 0.5)**2/(80+0.5)**2 * (80+8)**2/(100+8)*82 = 66.5 * 1.0348 = 68.8

Time = 200/ (130 * 1.012 * 1.014 * 0.688 * 0.642) = 3.40 min.

- Using TMR:

Time = 200 / (130 * Sc(12x12) * Sp (15 * 108/100=16.2) * TMR (16.2,8) * (80.5)**2/(108**2) = 200 /(130 * 1.012 * 1.0175 * 0.7905 * 0.555) = 3.40 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:

Dose, water = M * kQ * N d,waterCo-60

M = Mraw * Ptp * Pion * Ppol * Pelec

Pion = 1 - VH/VL / (MrawH/MrawL - VH/VL)

Ppol = Abs ((Mraw+ - Mraw -) /2Mrawused)

kQ from tables given the Pdd(10)x

For electrons:

Dose to water = M * kQ * N d,waterCo60

kQ = Pgrad (=1 for plane paralells) * kecal * k'R50

From tables kecal and k'R50

R50 = 1.029 I50-0.06

dref= 0.5 R50 - 0.1 cm

0.6

$D_W^Q = D_{N,W}^{^{60}Co} \cdot K_Q \cdot M$

$M = M_{raw} \cdot P_{ion} \cdot P_{pol} \cdot P_{TP} \cdot P_{elec}$

$P_{ion} = \left(\frac{1 - V_H/V_L}{\frac{M_{raw}^H}{M_{raw}^L} - \frac{V_H}{V_L}} \right)$ or $\frac{1-\left(\frac{V_H}{V_L}\right)^2}{\frac{M_{raw}^H}{M_{raw}^L} - \left(\frac{V_H}{V_L}\right)^2}$

$P_{pol} = \frac{M_{raw}^{+} - M_{raw}^{-}}{2M_{raw}}$

$P_{TP} = \left(\frac{273.3+T}{273.3+22}\right) \cdot \left(\frac{760}{P}\right)$ or $\left(\frac{101.33}{P}\right)$

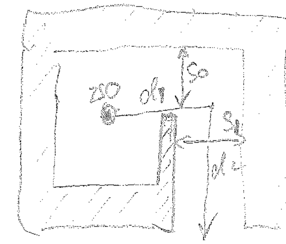
be careful of
{ dref
{ dcal

photon
① SSD=100, 10x10 → (%dd)x
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:
①. SSD=100, 15x15 → I_{50} → R_{50}
→ dref
② At dref, measure Mraw
③ dref → dmax use clinical PDD to correct.

Pgr = M(dref + 0.5 Rcav)/M(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/To)
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 NCRP151 (Pg 44)

$H_{n,D} = H_0 \cdot \left(\frac{S_0}{S_1}\right) \cdot \left(\frac{d_0}{d_1}\right)^2 10^{-\left(\frac{d_2}{5}\right)}$

↓ total n dose at d0 (1.41m)

H = Workload * Ho * (T/To) * (do/d1)**2 * 10 **(- d2 / 5 m)

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

$H_n = W_L \cdot H_{n,D}$

↳ leakage workload

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. → ?

Effective source distance = 1/slope - dmax

slope = (Sqrt (100/42) - Sqrt (100/100))/(10) = (1.54 - 1)/10 = 0.054

Effective source distance = 1/0.054 - 0.0 = 18.5 cm

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

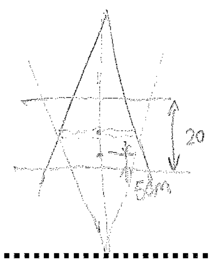
When usin TMR, Sc is at the field size defined at SAD = 100 cm = Nominal SSD, Sp is for the field at the depth of calc.

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

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

FS at SAD = 10 x 10, separation = 20 cm, 6 MV, depth of cord 15 cm.

Dose at isocentet = 200 cGy. Machine calibrated at isocenter (SAD = 100).



$$D_{cord} = \underbrace{\frac{1}{2} D_{mp} \cdot \frac{TMR(r_d = \frac{105}{100} \times 10, d=15) \left(\frac{SCD=100}{SAD=105}\right)^2}{TMR(r=10, d=10) \times \left(\frac{100}{100}\right)^2} \cdot \frac{S_p(r_d = \frac{105}{100} \times 10)}{S_p(r_d=10)}}_{AP} + \underbrace{\frac{1}{2} D_{mp} \cdot \frac{TMR(r_d = \frac{95}{100} \times 10, d=5) \times \left(\frac{100}{95}\right)^2}{TMR(r=10, d=10) \times \left(\frac{100}{100}\right)^2} \cdot \frac{S_p(r_d = \frac{95}{100} \times 10)}{S_p(r_d=10)}}_{PA}$$

....

The problem can be solved as in RAPHEX, there they don´t consider the Sp dependency with the field size:

Total Dose to Cord = ½ MPD /TMR(10,10) *[TMR(10*95/100,d=5)* (100/95)**2 + TMR(10*105/100,15) * (100/105)**2)]

Total Dose to Cord = 0.5 * 200 /0.77 * [0.9153 * 1.108 + 0.6425 * 0.9070] = 207 cGy

Bellow a general formula:

Dose from APto dx = [1/2 MPD / TMR(Fs at d,d)] * TMR(Fs at dx, dx) * (SCD)**2/(SSD+dx)**2

Dose from PA to dmax= [1/2 MPD/ TMR(Fs at d,d)] * TMR(Fs at dx from PA, dx from PA) * (SCD)**2/(SSD+ dx from PA)**2

Dose total = Dose from AP to dmax + Dose from PA to dmax

The term [ ] appears in both expressions:

Dose total = 1/2 MPD / TMR(Fs at d, d) * [TMR (Fs at dx, dx) * SCD**2/(SSD+dx)**2 + TMR (Fs at dx from PA, dx from PA) * (SCD**2/(SSD+dx from PA)**2]

....

Considering the Sp dependency with the field size:

First calc MU setting, just as an extra exercise:

MU = 100 / (TMR (10, 10) * Sc(10x10) * Sp(10x10) * 1) = 100 / (0.770 * 1.000 * 1.000 * 1.0)

MU = 129

Now for SAD calculation, in order to get the dose in one point when we now the dose at another one (for simplification along the central axis), we have:

Dose at isocenter/ (TMR (FS at isocenter, diso) * Sc(FS at iso) * Sp (FS at iso) * (SCD/SAD)**2) = Dose at depth d / (TMR (FS at depth d, d) * Sc(Fs at iso) * Sp(FS at d) * (SCD/SPD)**2)

In this problem it would be:

From AP beam:

Dose at depth d= 15 from AP = 100/ (0.770 * 1 * 1 * 1) * (TMR(10.5,15) Sc(10) Sp(10.5) (100/105)**2) = 129 * (0.6425 * 1 *1.0013 * 0.907) = 75.3 cGy

From PA beam:

Dose at depth d=5 from PA beam= 129 * (TMR (9.5,5) Sc(10) Sp(9.5) (100/95)**2) = 129 * (0.9153* 1.0 * 0.9985 * 1.108)= 130.6 cGy

Total dose at Cord = 130.6 + 75.3 = 206 cGy

....

In general this kind of problem can be solved using the relationship:

Dose at dx/(TMR(FS at dx, dx) * Sc(FSisocenter) * Sp(Fs at dx) * (SCD/SPD)**2) = Dose at dy/(TMR(FS at dy, dy) * Sc(FSisocenter) * Sp(Fs at dy) * (SCD/SPD)**2)

SCD can be SAD = 100 or SSD + dmax = 100 + dmax. SPD is SAD + dx and SAD + dy

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

(8-1): 6MV Xrays, 100 cGy at 9 cm depth. 12 x1 6 cm, at 100 cm SSD. Calib= 1 cGy/MU for 10 x 10 fsize at SCD = 100 + 1.5 cm. Calc MU setting:

MU = 100 / (PDD (13.7, 9)/100 * Sc(13.7) Sp(13.7) (101.5/101.5)**2) = 100/(0.7195 * 1.0* 1.01) = 137.6 = 138 MU's

(8-2) Tx conditions described in (8-1) changed to isocentric technique. FSize is 12 x 16 cm at isocenter, 9 cm depth. Calc MU setting:

MU = 100 / (TMR (13.7,9) * Sc (13.7) Sp(13.7) (101.5/100) **2)= 100/(0.817 * 1 * 1.01 * 1.03) = 118 MU's.

(8-3) Patient 22 cm thick in the AP direction and 32 cm thick in the LAT direction. 10 x 10 fields. SSD = 100 cm for all fields. 6 MV xrays. 4Field box setup. Rx Dose = 200 cGy. Equal doses to be delivered to the target point in the center. Calc "given" doses.

As every field delivers 50 cGy to the target:

For AP and PA fields, Given dose = Dmax = 50 / PDD (10, 11)/100 = 50 / 0.637 = 78.5 cGy

For RT and LT lats fields, Given dose = Dmax = 50 / PDD(10, 16)/100 = 50 / 0.488 = 102.5 cGy

(8-4) If equal "given" doses are to be delivered in the problem (8-3) what dose at the target point would be delivered from each field.

Dmax AP * PDD (10,11)/100 = TargetDoseAP

Dmax PA * PDD (10,11)/100 = TargetDosePA

Dmax RT * PDD (10,16)/100 = TargetDose RT

Dmax LT * PDD (10,16)/100 = TargetDose LT

From above problem 2* Dmax APPA * (PDD(10,11)/100 + 2 * Dmax Lats * (PDD (10,16)/100 = Target dose

Target dose = 2 * Dmax ((PDD(10,11)/100 + (PDD (10,16)/100) = 2 * Dmax (0.637 + 0.488)

Target dose = 200 cGy

Dmax = 200 /(2* (0.637 + 0.488)) = 88.9 cGy

(9) SSD setup, find MU setting to deliver dose at SSD =125. PDD table at SSD = 100 cm given. This is simmilar 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 = (SCD/New SSD + dmax)**2, SCD can be SSD + dmax (100 + dmax) 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.

```
A ----- B ----- C
!       !       !
!       !       !
1 ----- 2 ----- 3
```

DA = T1 / (1)**2 + T2 / (1**2+1**2) + T1 / (4 + 1) **2 = T1 + T2 / 2 + T1 / 5

DB = T1 / (1**2 + 1**2) + T2 + T1 / (1**2 + 1**2) = T1 + T2

DA = DB   T1 + T2 / 2 + T1 / 5 = T1 + T2 ----> T1 / 5 = T2 / 2

T2 = 2/5 T1

Another one similar from Hendee's book:

13-3 Two 2-mg radium needles [0.5-mm Pt(Ir)] 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 Pt(Ir). 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 to close for those line sources to be considered point sources.

```
A --2.5 cm--- B --2.5 cm--- C
!             !             !
2 cm          2 cm          2 cm
!             !             !
1 ---2.5 cm -- 2 --2.5 cm -- 3
```

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 = GammaRa * A1 / 2**2 + GammaRa * Ax / (2.5**2 +2.0**2) + + GammaRa * A2 / (5**2 + 2**2)

As A1 = A2 = 2 mg-Ra = A

DA = GammRa * A /(1/ 4 + 1/ 29) + GammaRa * Ax / (10.25)

DB = GammaRa * A / (10.25) + GammaRa* Ax / 4 + GammaRa * A / (10.25)

DB = GammaRa * A * 2 /(10.25) + GammaRa * Ax / 4

As DA = DB and same isotope then:

A (0.28445) + Ax * 0.097561 = A * 0.19512 + Ax * 0.25

A (0.08933) = Ax * 0.15244

Ax = 2.0 * 0.08933 / 0.15244)

Ax = 1.18 mg of Raeq.

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 formultation is the same as above but instead of GammRa * Ai we must use the value that the table gives us: Dose in cGy per mgRa*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 / mg-hr * 2.0 mg + 0.74 cGy/mg-hr * X mg Ra + 0.23 * 2 mg

DA = 3.7 cGy / hr + 0.74 cGy / mg-hr * X mgRa + 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)

$10\,mg \times 8.25\,R\,cm^2/mg \cdot hr \cdot \frac{1}{(20)^2} = 0.20625\,R/hr$ for 0.5 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/mg – 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.

$\Rightarrow (1.02)^x \quad (0.98)^x \qquad x = (t' - 0.5) \times 10$

(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

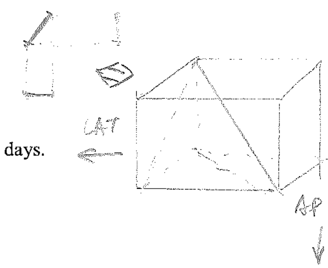
b) Dose rate as in a) but using across and along tables (13-3 page 299)

Dose rate (2 cm across and 0 cm along) = 1.866 cGy/mg – hr * 1 mg = 1.87 cGy/hr

Dose rate (5 cm across and 0 cm along) = 0.296 cGy/mg – 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:

$\Rightarrow$ Length = sqrt ((2.2/1.1)**2 + (0.8/1.2)**2) = 2.1 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
Xmg-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. R cm²/mCi-hr

Initial Dose rate at 1 cm from 1 source = 1 * 1.45 * 0.96 / 1cm2 = 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 / 1cm2 = 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 : 1mCi ^{125}I ⇒ 1.270 U
↑
1mCi → 1.45 R cm²/mCi hr
= 1.45 x 0.876 cGy/R
= 1.27 cGy·cm²/mCi hr

→ 0.965 per TG-43 ?

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

1.27 U ← 0.847 based on Hendee

Drate (1 cm, 90 deg) = 1.27 cGy cm2/hr * 0.847 cGy/hr – U * 1 * 1 * 1

Drate (1 cm, 90 deg) = ~~1.37~~ cGy / hr 1.076

From 15 sources = ~~20.55~~ cGy/hr 16.14

Total dose delivered = 1.44 * 59.6 * 24 * ~~20.55~~ 16.14 = 42328.4 cGy (using TG-43 approx) 33245 cGy

Ans: 33 303 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 cG 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 ** 2 = 0.115 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 according to Khan Page 421

< 5mCi TEDE to others

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

D = 1.44 * 59.6 * 24 * Initial dose rate

Initial dose rate = 10800 cGy / (1.44 * 59.6 * 24 hr) = 5.24 cGy/hr

To deliver 90 % of the dose

D = 1.44 * 59.6 * 5.24 * 24 (1 – exp (-ln2/ 59.6 * t))

D = 10800 * (1 – exp (- ln2 / 59.6 * t))

0.9 = (1- exp (-ln 2 / 59.6 * t)

ln (1 – 0.9) * 59.6 / (-ln 2)= t

t = 198 days

Given that a film shows a factor 200 times less intense than the initial OD. find the dose to a particular

2 mg ● 2.5 cm ● 2 mg 1.5 cm

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

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

⇒ For film:

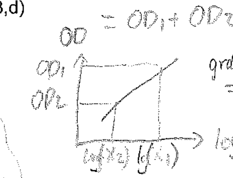
$OD = \log(^{I}/_{T})$

↑ optical density

↓ Transmission of Light 10%, 20% ↓ 0.5% in this question

two films:

$OD = \log\left(\frac{1}{T_1}\cdot\frac{1}{T_2}\right) = OD_1 + OD_2$



gradient $= \frac{OD_1 - OD_2}{\log X_1 - \log X_2}$

film speed/sensitivity $= \frac{1}{\text{Exp to produce } OD=1}$

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

Heterogeneity correction factors:

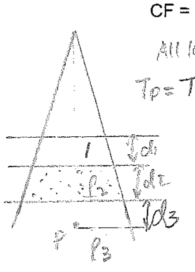
- Ratio of TAR (TMR also) method:

CF = TAR (d', rd) / TAR (d, rd) Where d' = d * relative electron density.

- Power Law method:

CF = TAR (d3, rd) ** (ro 3 – ro 2) / TAR (d2 + d3, rd) ** 1 – ro 2

CF = TAR (d3, rd)**ro 3 / TAR (d3, rd)**ro 2 * TAR (d2+d3,rd) ** rp 2 / TAR (d2+d3,d)



All layers of density = 1

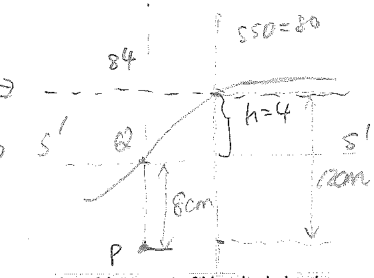
$T_P = T(d_1+d_2+d_3)^{\rho=1} \times CF(=1)$

Now remove layers d_2, d_3, replace with $\rho = \rho_2$

$T_P = T(d_1+d_2+d_3)^1 \cdot \underbrace{\frac{T(d_2+d_3)^{\rho_2}}{T(d_2+d_3)^1}}_{CF}$

Now replace d_3 with $\rho = \rho_3$

$T_P = \frac{T(d_2+d_3)^{\rho_2}}{T(d_2+d_3)^1} \cdot \frac{T(d_3)^{\rho_3}}{T(d_3)^{\rho_2}} = \frac{T(d_2+d_3)^{\rho_2-1}}{T(d_3)^{\rho_2-\rho_3}} = \frac{T(d_3)^{\rho_3-\rho_2}}{T(d_2+d_3)^{1-\rho_2}}$



TMR ⇒

PDD ⇒

PDD(80, 8, 9.9) = 0.745

$CF = \left(\frac{SSD+dm}{SSD+dm+h}\right)^2 = \left(\frac{80+1.5}{80+1.5+4}\right)^2 = 0.9086$

$\%P' = 0.745 \times 0.9086 = 0.677$

$D_P = 0.677 \times 1.006 = 0.681$

4 problems out of Hendee's book:

8-5: Obliquely incident beam of 6MV xrays. FSize= 8 x 13 cm, SSD = 80 cm. Dose rate at dm = 1.006 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:

Dose rate = Dose Rate at Dmax * PDD (8, 8 x 13, 8)/100 = 1.006 * PDD (8, 9.9)/100 = 1.006 * 0.745 = 0.7495 cGy/MU

(a) Using the effective SSD method:

CF = (SSD + dm – h) ** 2 / (SSD + dm) **2 = (80 + 1.5 - 4.0) ** 2 / (80 + 1.5) ** 2

CF = 0.9042

Dose rate at target = 0.7495 * 0.9042 = 0.677 cGy/MU (Hendee's answer is = 0.694 cGy/MU) ?

(b) Using the ratio of TAR method: ⇒ PDD(80, 12, 9.9) = 0.605

$CF = \frac{TMR(8, rd)}{TMR(12, rd)} = \frac{0.837}{0.7255} = 1.154$

CF = TMR (d, rd) / TMR (d+h, rd) , in this case h is negative, its SSD is 84 cm. $D_P = 0.605 \times 1.154 \times 1.006 = 0.702$?

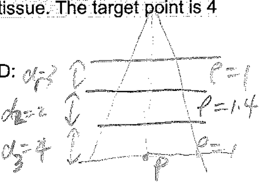
FSize at depth of target, 8 cm from isocenter = 8x13/(8 + 13) * 2 * 88/80 = 10.9 x 10.9
Depth of target point 8 + 4 cm = 12 cm.

CF = TMR (12, 10.9) / TMR (12-4, 10.9) = 0.7255/0.837 = 0.8668

Dose rate at target = 0.7495 * 0.8668 = 0.6496 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 e = 1.4. 6MV, FS=6x6 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 cm $d_1 = 3+2+4$
d' = 3 + 2 * 1.4 + 4 = 9.8 cm $d_2 = 3+2\times1.4+4$

FS at d = 6 * 109/100 = 6.5 cm

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

PDD (9, 6) = 68.6 % --> Corrected PDD = 0.9569 * 68.6 = 66.38 % (Hendee's answer = 66.2 %)

PDD ↓

power law

$CF = \frac{T(2+4)^{1.4-1}}{T(4)^{1.4-1}}$

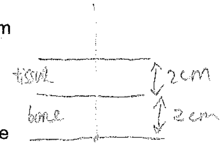
$T(3+2+4)^1 \cdot \underbrace{\frac{T(2+4)^{1.4}}{T(2+4)^1} \cdot \frac{T(4)^1}{T(4)^{1.4}}}_{CF} \Rightarrow \frac{T(2+4)^{1.4-1}}{T(4)^{1.4-1}}$

(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

Corrected PDD = 68.6 * 0.9727 = 66.72 % (Hendee's answer is = 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: $d_{eff} = d - z(1-CET)$

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

2cm

1.65 bone

0.5 lung

deff = 4 – 2 (1 – 1.65) = 5.3 cm. (Hendee's answer is 5.3 cm)

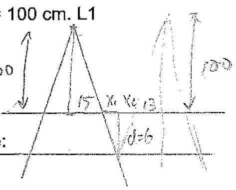
8-8: Two high energy photon beams abutted to treat spinal axis field. SSD = 100 cm. L1 = 30 cm and L2 = 26 cm. d = 6 cm. Calculate the GAP

$x_1 = \frac{15}{100} \times 6$

$x_2 = \frac{13}{100} \times 6$

$x_1 + x_2 = 1.68cm$

GAP = ½ (L1/100 + L2/100) * depth = 1.68 cm



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

OD = log 1/T, where T 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 = ¼, 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.

1 ft = 0.305 m.

d = 3.7 – 1.22 + 1.0 = 3.48 m

B = Xp * d**2 / (W U T)

Xp = 0.02 mSv/week = 0.002 R/week

B = 0.002 R/week * (3.48) **2 / (800 mA-min /week * 0.25 * 1)

B = 1.21 E -04 R –m2 /mA -m

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 casette at a distance of 6 feet from the x-ray tube if an office with uncontrolled access is behind the casette.

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 accoun 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

= 1

= 1

Xp = 0.02 mSv/week = 0.002 R/week

1R/min

Assume

(dose rate 1R/min @ 1m from x-ray tube per 1 mA ?)

B = 0.002 R/week * 1.83**2 / (750 mA - min/week) * 1 * 1)

B = 0.000089 → 2.7 mm of lead.

0.000089 R/mA·min

Or if Hendee uses Xp = 0.1 mSv/week then

B = 0.01 * 1.83**2 / (750 mA - min/week * 1 *1)

B = 0.000045 → 2.9 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 cGy ✓

New cord dose 0.18 * 212 = 38 cGy ✓

$38 \cdot x + (30 - x) \cdot 212 < 4500$

$\Rightarrow 38x - 212x + 30 \times 212 < 4500$

4500 / 212 = 21 fractions if new dose 0. But new dose is 38 cGy.

$-174x < -1860$

Remaining dose 6000 – 4500 = 1500

$x > 10.68$

Fractions: 1500 / 200 = 7.5 fractions

$= 11$ fx.

7.5 x 38 = 285 cGy more.

So 21 * 212 + 285 = 4737, more than 4500 therefore reduce to:

19 fractions without PA block = 3800 cGy to tumor and

19 x 212 = 4028 cGy to cord.

11 fractions with PA cord block.

if we don't know 200cGy per fx or 30 fx total, we only know total 6000 cGy

$\begin{cases} 38 \cdot x + 212 \cdot y = 4500 \\ D_0 \cdot (x+y) = 6000 \end{cases}$

⇒ can't solve the problem

have to know D_0 = 200 cGy

$450 = \frac{1}{2} Dmp / 0.729 \times [1.078 \times (\frac{365}{351.5})^2 + 0.4 \times (\frac{365}{378.5})^2]$

$450 = \frac{1}{2} Dmp / 0.729 \times [1.1624 + 0.3720]$

$450 = \frac{1}{2} Dmp / 0.729 \times 1.534$

11 * 200 = 2200 (2200 + 3800 = 6000 cGy to tumor)

11 * 38 = 418 cGy. $Dmp = 450 / 1.534 \times 0.729 \times 2$

Total to cord = 418 + 4028 = 4446 cGy. $Dmp = 427$

(15) 2 cm diameter lead pig inside polyurethane foam inside 30 cm diameter shipping drum. HVL Pb given for Ir-192 (3.0 mm Hendee's book). Exposure rate constant for Ir-192 = 4.69 R cm2/ hr mCi.
Calc max activity that can be transported in the room to keep level at surface less than 50 mR/hr

$X (mCi) \cdot 4.69\ R \cdot cm^2/hr \cdot mCi \cdot e^{-\frac{\ln 2}{3.0} \times 10} \cdot (\frac{1}{30 cm})^2 = 50\ mR/hr$

Xrate(30 cm) = Gamma Ir-192 * Activity in mCi / (30 cm)**2 * exp -(2.0 cm /0.3cm) 15 $\Rightarrow X = 96.5$ mCi

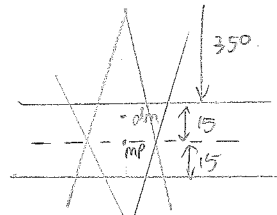
Activity = 50 E-03 R/hr / ((4.69 R -cm2/hr mCi)/ 30 ** 2 cm2 * exp -(ln 2 * 1/0.3))

Activity = 96.7 mCi

(16) Parts definitely not in a EPID device:

Electronic Portal Imaging Device

In recent years, Electronic Portal Imaging Device (EPID) technology has greatly improved. EPIDs are used to produce images using the high-energy x-rays produced in the LINAC. They allow the real-time verification of patient positioning in the treatment room. Real-time meaning that the images are processed immediately with no actual films to be developed. In the past EPIDs were not clinically accepted as the image contrast was generally poor. The new generation of devices has improved the contrast issue and are gaining clinical acceptance. The contrast in the images produced by EPIDs are still much less than that in images produced using diagnostic x-rays as can be seen in Fig. 7, however for positioning purposes using implanted markers the contrast is adequate.
EPIDs use digital imaging technology to measure the intensity of photons incident on the detector. Digital imaging utilizes arrays of photodiodes, which absorb incident photons and convert them into electrical signals. Each electrical signal is proportional to the energy of the incident photon producing it. The photodiodes used in EPIDs require photons with wavelengths in the visible spectrum. A thin layer of scintillation material is used to convert the x-ray photons to visible wavelength photons. A scintillator is a material that absorbs light of one wavelength and re-emits it at another wavelength. Scintillation materials are available for a range of absorption and emission values. The scintillation material used in the EPID at UCSF absorbs incident x-ray photons and visible light is emitted, which is then absorbed by the photodiodes. The photodiodes convert the visible wavelength photons into electrical signals, which are then read out and stored. This method of detection is referred to as indirect, as the x-ray photons are indirectly detected having first been converted to visible wavelength photons. Viewed in its entirety the array of photodiodes produces a digital x-ray image.
UCSF currently uses an amorphous silicon photodiode array deposited on a glass substrate with a scintillation coating. The array is 41x41 cm^2 with 25 pixels per cm. The



$\frac{1}{2} Dmp = D_R \cdot Sc\, Sp\, TMR(30 \times \frac{350+15}{100}, d=15)\, (\frac{100}{350+15})^2$

$Ddm = D_R \cdot Sc\, Sp \cdot TMR(30 \times \frac{351.5}{100}, d=1.5) \cdot (\frac{100}{351.5})^2 + D_R \cdot Sc\, Sp \cdot TMR(30 \times \frac{378.5}{100}, d=28.5) \cdot (\frac{100}{378.5})^2$

EPID is attached to the LINAC on a retractable mechanical mount. The gantry and the EPID can rotate around the patient to image from zero to 120 degrees.

(16) TBI, diode reading 450 cGy on surface. Prescription midplane 600 cGy, POP laterals, 30 cm separation. TMR's given, 350 cm SSD What is error in midline dose.

$Dm = \frac{1}{2} Dmp / TMR(30 \times \frac{350+15}{100}, d=15) \times [TMR(30 \times \frac{351.5}{100}, d=1.5) \cdot (\frac{365}{351.5})^2 + TMR(30 \times \frac{378.5}{100}, d=28.5) \cdot (\frac{365}{378.5})^2]$

Fsize = 30 x 30 cm2 at nominal isocenter, Energy 6 MV.

Total Dose = ½ DMP/(TMR(30* (350+15)/100), d = 15 cm) * [TMR(30 * 331.5/100, dmax))(365/351.5)**2+ TMR (30* (350+28.5)/100,d=28.5) * (365/(350+28.5)**2)]

Total dose = ½ 600 cGy / TMR (109.5x109.5, d=15 cm)(1 * 1.078 + TMR (113.5x113.5, d= 28.5) * (0.93)) 0.4

Total dose = ½ 600 / 0.729 * [1 * 1.078 + 0.4 * 0.93]

Total dose to a point in dmax = 596.7 cGy

The above result is obtained if the diode also measures (AP+PA)

If only the entrance dose is measured then,

Dmax dose = 300 * 1.078 / 0.729 = 443.6 cGy

Error = 450 cGy / 443.6 cGy = 1.014 → + 1.4%

(17) HDR Ir – 192. Patient treated with time 630 seconds and Sk = 12 000 U on August 15th. Source replaced with activity of Sk = 40 000 U on August 17th. Determine Tx time on August 22nd.

Sk(Aug 15) t (Aug15) = Sk(Aug 22) (t Aug 22)

Sk (Aug 22) = Sk (Aug 17) * exp –(ln2 5/73.83) = 40 000 * 0.954 = 38166 U

T (Aug 22) = 12 000 / 38166 * 630 seconds = 198 seconds.

(18) How many TVL's in a linac head:

If leakage has to be reduced to 0.1 %, then:

1/1000 = 1 / 10 n

n = 3 TVL's

? (19) A survey meter points at a primary wall and measures 2 mR/hr. Is this OK?

I think yes, because in the case that the linac operates continuously still one has to divide that number by 4, the use factor of a primary barrier is 1/4.

?

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/slope – dmax = 1/0.0111 – 2.0 = 88.1 cm

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

Leakage for linacs: Bl = 1000 x Xp * d**2 / W T

Leakage for Xray units: Bl = 600 I * Xp * d** 2 / W T

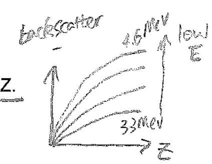
In this equation W is given in mA-min/week, I is the max current in mA, Xp should be in R / week

Scatter for linacs: Bs = Xp do**2 d1**2 *400 / (a W T F). a is usually 0.001

Scatter when primary hits a barrier: Bsp = Xp dsca**2 dsec**2 / alpha * A * W U 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 in air: (cGy in air/min * BSF = cGy in water / min) * PDD /100 = cGy in water at Dmax * Dwate at d / Dwater at dmax.

Calibration at 80.5 cm in water: cGy in water/min * PDD //// No use of BSF is required.

Calibration at 80.0 cm in air: (cGy in air/min at dmax * TAR) = cGy in air /min at dmax* Dose in water /dose in air at dmax //// No use of BSF is required.

Calibration at 80.0 cm in water: cGy in water/ min at dmax * TAR / BSF = cGy in water/min at dmax * (Dose in water at d/ dose in air at dmax) / (Dose in water at dmax / Dose in air at dmax) = cGy in water / min at dmax * Dose water at d / Dose water at dmax.

TAR(FS at d, d) / BSF(Fs at d, dmax) = TMR (Fs at d, d)

Relationship between PDD and TMR:

TMR (Fs at d, d) = PDD (Fs at surface, d, SSD) * (SSD + d) **2/ (SSD + dmax) **2 * Sp (Fs at surface) / Sp (Fs at d)

This relationship comes from:

TMR (Fs at d, d) * Sp (Fs at d) (SCD)**2 / (SSD + d)**2 = PDD (Fs at surface, d, SSD) * Sp(Fs at surface) (SCD)**2 / (SSD + dmax)**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 cGy → 100%

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

200 / 3 = 66.7 cGy is 79.3 %, then Dmax = 66.7 / 0.793 = 84.0 cGy.

(26) Dose 10 cm deep 5 cm outside field is: 1~2%

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.   ? <0.25mR/hr @ 1m   ? < 3 mR/hr @ 0.2m.

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 inhomegeneity.

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.

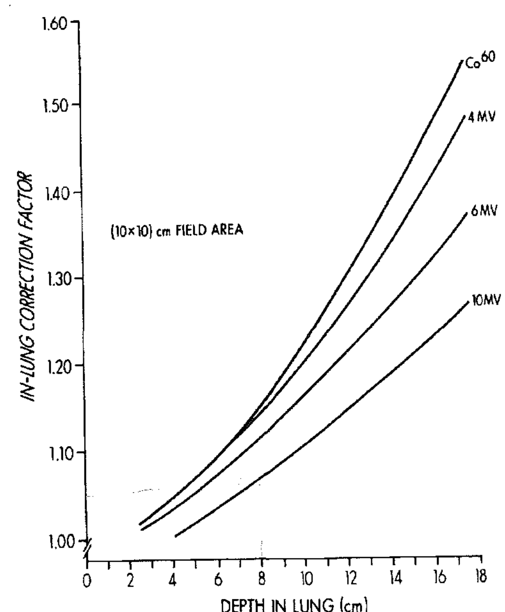


FIG. 5. In-lung correction factor as a function of depth in lung, and energy.

For the in-lung correction we see that for 10 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 10 %.

For the after lung correction factor see next figure:

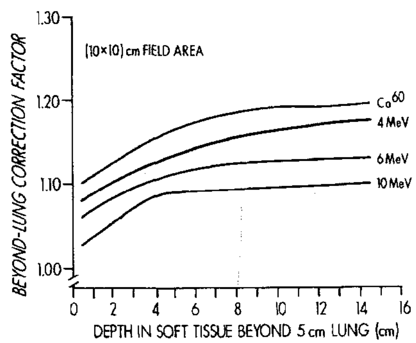


FIG. 3. Beyond-lung correction factors as a function of depth in soft tissue beyond 5 cm of lung, and energy.

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.

<u>a) Using the effective depth method:</u>

deff = d1 + d2 ro elec + d3

For 10 MV and 10 x 10 cm2

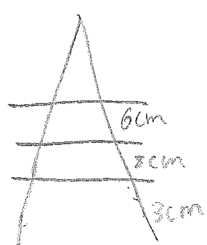
CF = TMR (10x10, deff)/ TMR (10x10, d) = TMR (10x10, 6+0.25* 8 + 3) / TMR(10x10, 17) = 0.814 / 0.680 = 1.19

<u>b)Using the Batho power law:</u>

CF= TMR (10x10, 3) **(ro 3 – ro 2) / TMR (10x10, 8+3) ** (1-ro2)
CF= 1 ** (1-0.25) / 0.814 ** (1 – 0.25) = 1.17

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

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



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

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

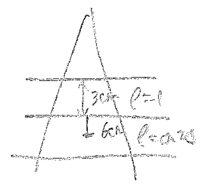
CF= TMR (10x10, d2)** (ro2-ro1)/TMR(10x10,d1+d2)**1-ro1 = TMR (10x10, 6) **(0.25-1) / 1
CF = 0.939 ** -0.75 = 1.048.

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

<u>For remembering the Batho power law:</u>

Three regions: d1, d2 (inhomogeneity), d3

CF= TMR (Fs at d3, d3)** ro3 – ro2 / TMR (FS at d3, d2+d3)**(1-ro2)



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

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

- Normal tissue alfa / beta = 3.0

- Tumor alfa / beta = 10

$S = \exp(-\alpha D - \beta D^2)$

- Linear-quadratic model for the survival fraction of cellsl: S = exp (- alfa D - beta D**2)

- Survival curve with LET: higher LET decreases surivival faster

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

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

Raphex 2009 T.48

- 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. Whe LET increases, the direct effects increases. Oxygen is an indirect effect.

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

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

- Dq quaisthreshold dose, dose to which if straight portion of survival curve is extrapolated, gives like a threshold for an only exponential curve. Mesure 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 / (alfa/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 treatmen duration has to be decreased or done faster. Example: or tumor

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

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 alfa/beta = 3.0 for normal tissue.

BED = 60 cGy (1 + 2 / 3) = 100 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 / (alfa/beta)) = 25 * d (1 + d / 3) = 100 cGy

Solving for d we obtain:

4 - d - d**2/3 = 0 ----> 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 curses of Tx are equivalent.

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

NCRP 151. Page 100

① head leakage → film wrapped to locate hot spots
integrating type survey meter ② appropriate d in the patient plane

② Voids, cracks → sensitive photon rate meter with fast response time
(G-M, scintillator meter
calibrated ion-chamber used to determine exposure rate or integrated dose equivalent (H)

(36) Question regarding survey around an accelerator vault for crack detection:

③ measurement outside each barrier ⇒ portable ion-chamber (both rate and integrate) up 50mGy/hr

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 → 0.1%. every use how to ?

(38) Calculate Eo given R50: Eo = 2.33 R50 $E_0 = 2.8 R_{80}$ $E_0 = 3.2 R_{90}$

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

Close collimators to a minimum to decrease scatter. rotate gantry to different angles
use higher ratio grid

(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 phenomenum that happens in the wedge itself as the person is trying to suggest in the answers. WF ↓ with depth↑, field size ↑

(41) Electron oblique incidency on a surface:

Out Khan's book, page 319:

Electron beam obliquity tends:

- Increase side scatter at depth of dmax
- shifts dmax 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 funtion 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 mucosas, 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:
or wax
Electrons, back-scattered from the shielding, may deliver an inadvertently high dose to

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? TG 36.

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

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

0.5mSv x 10 = 5mSv total
↓
same as infrequent public.

scatter from collimator
scatter within patient.
head leakage

total
50mSv / 50 = 1mSv

(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 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 R50<8.5 cm ~E <20 MeV!, the field size is >10X10 cm2 at the phantom surface and for higher-energy beams it is >20x20 cm2.

(47) Typical neutron dose in photon beams: Approx 0.1 % per cGy of dose from photons. H10 in Table B1. in NCRP 151 1.41m from 150

Φ neutron source strength @ 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%

A. 300 – 400
B. 100 – 200
C. 20 – 80
D. 2 – 4
E. 0.05 – 0.1

TG36 Table III

	Point A Top	Point B middle	Point C bottom of fetus
Distance	15.5	28.5	41.5
dose	42cGy	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 toráxicos.

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 is estimated that the total dose to pacemaker implanted in a radiation therapy patient will excede xxxxx cGy over the entire treatment

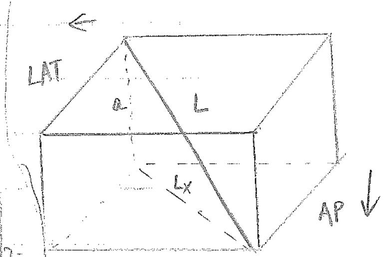
A. 5
B. 50
C. 100
D. 200
E. 1000

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

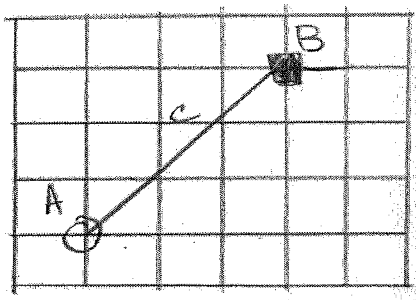
200 cGy

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).

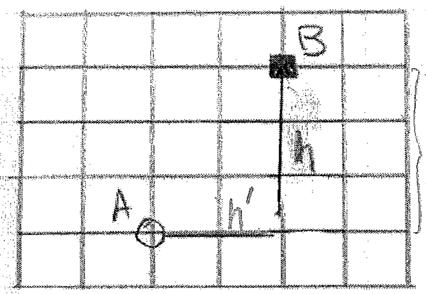


$L^2 = \sqrt{Lx^2 + a^2}$



AP

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



LAT

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

$\cancel{AB^{3D} = \sqrt{(AB^{AP})^2+(AB^{LAT})^2} = \sqrt{3^2+3^2+2^2+3^2} \approx 5.6}$

using Kahn's method pg 380 3RD edition

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

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

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

$a = h = 3$ wrong 2

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

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

so

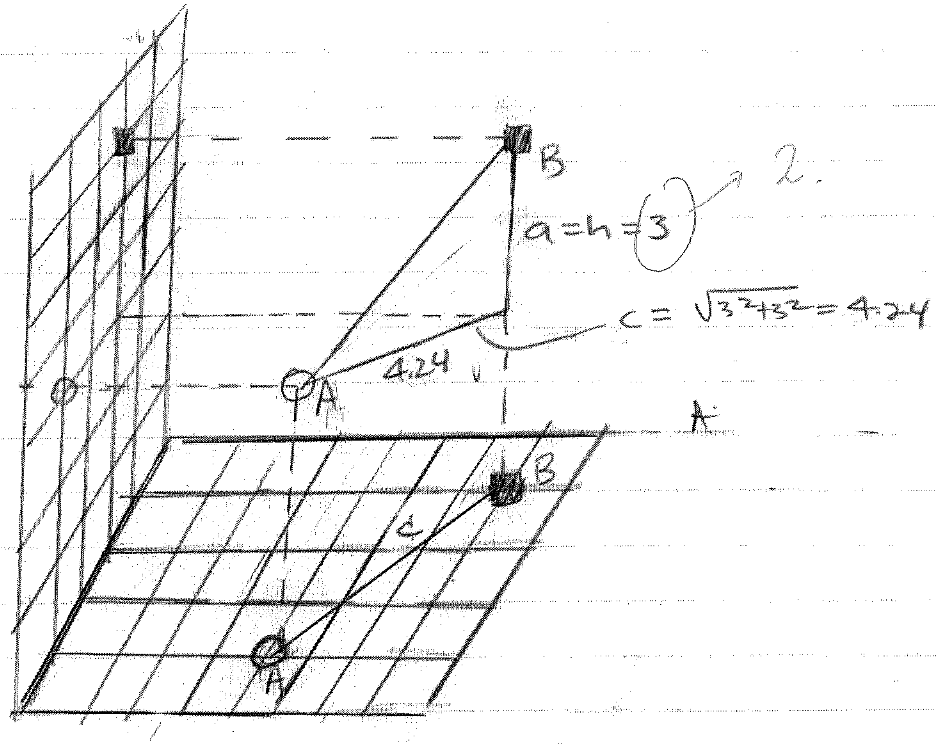
$AB = \sqrt{c^2 + h'^2}$

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

$= 4.69$

2005 Part 2 TX

1. continued



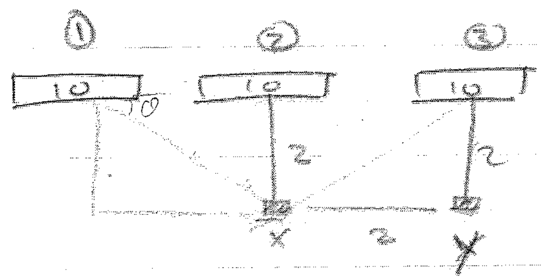
$AB = \sqrt{a^2+c^2} = \sqrt{3^2+4.24^2} = 5.2$

2005 Tx Part 2

2\. 'Given 3 linear sources as in figure, determine the ratios of the dose at point Y with respect to point X

$$D = \frac{I \times Act. \times \cancel{time}}{d^2}$$

I, act., + time constant for all sources



Dose X ≈ $\frac{1}{\ }$ + $\frac{1}{\ }$ + $\frac{1}{\ }$ ...

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

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

$$\text{Dose } y \approx \frac{1}{(\sqrt{(4)^2+(2)^2})^2} + \frac{1}{(\sqrt{2^2+2^2})^2} + \frac{1}{2^2}$$

$$\approx \frac{1}{20} + \frac{1}{8} + \frac{1}{4} = 0.425$$

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

can we use TG-43 formula? $\overset{?}{\Rightarrow}$ If dose $\propto \frac{1}{r}$ (because distance is not 2 x Source length)

except for contribution of Source ① to y which is 4.47 cm away

β 2cm

1.4cm

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

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

$\theta = 90^\circ$ $\sin\theta = 1$

$r = 2cm$

$L = 1.4cm$

$\beta = \tan^{-1}\left(\frac{0.7}{2}\right) \times 2$

$= 38.6^\circ$

$= 0.673$ rad.

if

$r = 0.5$ cm

$L = 1.4cm$

$\beta = \tan^{-1}\left(\frac{0.7}{0.5}\right) \times 2$

$= 108.9^\circ$

$= 1.90$

$$G(r_0, \theta_0) = \frac{\beta}{1.4 \times 1 \times 1} = \frac{\tan^{-1}\left(\frac{0.7}{1}\right) \times 2}{1.4 \times 1 \times 1} = \frac{1.221}{1.4} = 0.87. \Rightarrow \frac{G(r,\theta)}{G(r_0,\theta_0)} = \frac{0.24}{0.87} = 0.275$$

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

2005 Part 2 TX

2. (cont.)

$$\text{Dose } x = \overset{②}{\frac{1}{2}} + \overset{①}{\frac{1}{2.828}} + \overset{③}{\frac{1}{2.828}} = 1.2072$$

$\frac{1}{r} \to 2$ $\quad \frac{1}{r} \to 2.828$ $\quad \frac{1}{r} \to 2.828$

$$\text{Dose } y = \overset{③}{\frac{1}{2}} + \overset{②}{\frac{1}{(2.828)}} + \frac{1}{20} = 0.9036$$

$\frac{1}{r} \to 2$ $\quad \frac{1}{r} \to (2.828)$ $\quad \frac{1}{r^2}$

$$\frac{\text{Dose } y}{\text{Dose } x} = \frac{0.9036}{1.2072} = \underline{\underline{0.75}}$$

3. practice Raphex mu calcs.

4. A shielding problem 36 inches space available

Concrete required = 66 inches TVL = 13.6 inches
TVL steel = 3.8 inches - determine
the amount of steel

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

② set up simultaneous equations to optimize steel + concrete

Ⓐ $X_{\text{TVL concrete}} + y_{\text{TVL steel}} = 4.853$

Ⓑ $13.6X + 3.8y = 36$ inches

- from Ⓐ $x = 4.853 - y$

So: Ⓑ $= 13.6(4.853-y) + 3.8y = 36$

$= 66 - 13.6y + 3.8y = 36$

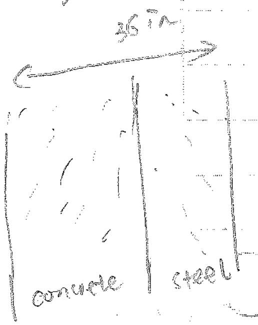
$30 = 9.8y \rightarrow y = \frac{30}{9.8} = 3.06$

$X = 4.853 - 3.06 = 1.79$

$13.6(1.79) = 24.36''$ concrete $3.8(3.06) = 11.628''$ Pb

$\frac{66}{13.6} = \frac{36}{13.6} + \frac{\text{Steel}}{3.8}$

Steel =



$$\begin{cases} 13.6x + 3.8y = 36 \\ x + y = \frac{66}{13.6} \end{cases}$$

$\Rightarrow x = 1.79$
$y = 3.06$

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 ISO = 6000 cGy, total dose to cord = 212 cGy/fraction. Cord dose constraint = 4500 cGy

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

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

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

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

$$6360 - 212y + 38.16y = 4500$$

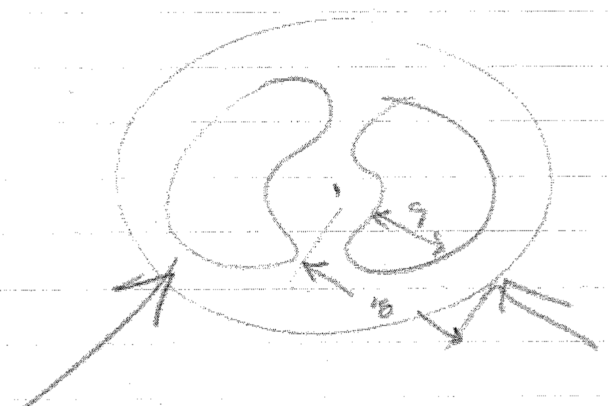
$$1860 = 173.84y$$

$$y = 10.699$$

$$x = 30 - 10.699 = 19.301$$

TOTAL fractions $= x + y = 10.699 + 19.301 = 30$ fx

6 9cm lung, Post. obliques, 150 depth = 18cm
given TMR for 3, 5, 9, 12, 18



9cm eq to $9 \times 0.33 =$ 3 cm

$$\text{use } d_{eff} = \frac{(18-9)}{2}^{?} + \overset{0.25 \text{ to } 0.33}{3} = 12$$

Say 180 cGy to 150, e.g., 15x15

$$\frac{180\ cGy}{1\frac{cGy}{mu} \times TMR(d\ 12,\ 15\times15)}$$

7. Thickness of compensator − missing tissue
= 5cm $\rho_{water} = \frac{1g}{cm^3}$, $\rho_{comp} =$

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

use $t_{thick\ comp} = T_{issue\ Deficit} \left(\frac{I_{ratio}}{\rho_c}\right) \longrightarrow$ density of compensator

$= 5cm \left(\frac{0.7 \leftarrow \text{common value for } \tau}{\frac{1g}{cm^3}}\right) = 5(0.7) = 3.5cm$

$$t_c = t' \left(\frac{\tau}{\rho_c}\right)$$

$\tau \rightarrow 0.7$

$\rho_c \longrightarrow$ density of compensator

$t' \rightarrow$ tissue missing

$t_c \rightarrow$ thickness of compensator

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

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

- D_n measured over n dose segments.

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

2005 Part 2 TX

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

(see IAEA hand book page 178).

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

time error

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.

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

$D_1' = (125\ cGy/min)(T + \frac{0.02}{60})$

$\Rightarrow D_1'/D_1 < 1.01$

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

$T > 0.033$ 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%

$$\frac{\sigma_{SD}}{R_{ate}} = 0.01$$

In this case 1 SD = the 68% confidence level. Let R = 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 $\frac{\sigma}{D_{rate}} = 0.01$ $\quad \sigma = 0.01\left(125\frac{cGy}{min}\right)$

$= 1.25$ min

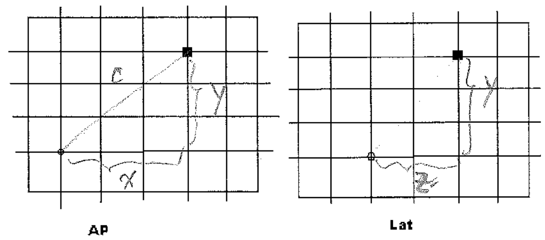
$\sigma = \sqrt{\frac{D_{rate}}{t}} = 1.25\ \frac{cGy}{min} \rightarrow t = \frac{125}{(1.25)^2} = 80$ min

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

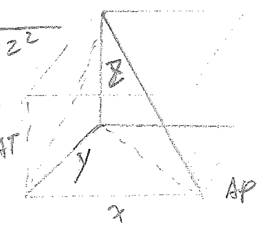
1.- Given the grid in which every line intersection is at 1 cm. Determine the distance between the source (black dot) and the point of interest (white dot).



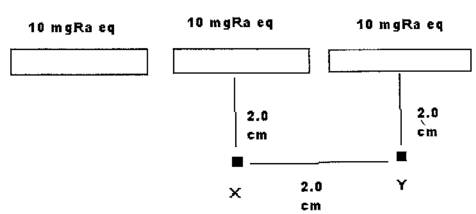
$d = \sqrt{c^2 + z^2}$

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

$= 4.69$ cm.



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



3- 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 enegies, 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 refers 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 (cGy/R)	^{125}I	^{192}Ir	^{103}Pd
water	0.88	0.97	0.89
muscle	0.92	0.965	0.92
bone	4.44	0.93	4.3

For all ^{226}Ra substitutes ($E > 200$ keV),
$f_{med} = 0.974$ for water
$= 0.966$ for muscle per Perez's textbook.

$$\begin{cases} x + y = \frac{66}{13.6} \\ 13.6x + 3.8y = 36 \end{cases} \Rightarrow \begin{cases} x = 1.79 \\ y = 3.06 \end{cases} \quad \text{Steel} = 3.06 \times 3.8 = 11.628 \text{ in}$$

4.- 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).

5.- 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:
eq 1: x Dose to cord + y * 0.18 * Dose to cord = 4500 (Dose to cord 212 cGy/fraction)
eq 2: x Dose to iso + y Dose to iso = 6000 (Dose to iso = 200 cGy/ fraction)

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

7.- 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.

8.- 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).

check RAPHAX.

9.- 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.

$\dot{D} = \Gamma_\delta (A) \cdot f \cdot \left(\frac{1}{d}\right)^2$

$(10 \times 10^3 \text{ mCi}) \times$
$(4.69 \text{ R cm}^2/\text{mCi}\cdot\text{hr}) \times$
$(0.96 \text{ cGy/R}) \times \left(\frac{1}{3\text{cm}}\right)^2$
$= 5003$ cGy/hr

$T = \frac{340}{5003} = 0.068$ hr
$= 245$ sec

10.- 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.

11.- 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. ?

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

or:

$\dot{D} = S_K \cdot \Lambda \cdot G(r,\theta)\, g(r) \cdot F(r,\theta)$

$\underbrace{G(r,\theta)}_{(1/r)^2}$ for point source and high E source

$= X \cdot \left(\frac{\bar{W}}{e}\right) \cdot l^2 \cdot \Lambda$

$= (4.69 \text{ R/hr}) \cdot (0.876 \text{ cGy/hr}) \cdot (1 \text{ cm}^2) \cdot (1.11 \text{ cGy/hr/U}) \cdot \left(\frac{1}{3\text{cm}}\right)^2$

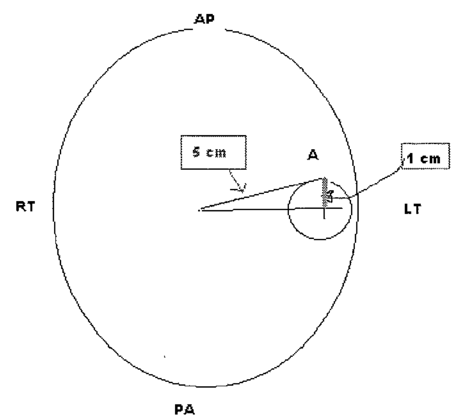
$= 5067$ cGy/hr

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 it 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.

$(1/180)\cdot\pi\cdot R = \frac{\pi}{180}\times 5cm = 0.087cm$

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. (mgRa eq for the source were given, 8.25 R-cm2/(mCi – hr) one had to know, I think f 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 or MU ?

Dose: 1 : 2 (wedge vs open)

MU: 1 : 1

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.

Dose weighting for open field: W_o, wedged: W_w

$W_o + W_w = 1$

$\Rightarrow W_w = \frac{\tan\theta_{eff}}{\tan\theta}$

For example: $\theta = 60°$, $\theta_{eff} = 30°$, $W_w = 0.333$, $W_o = 0.667$

So dose from wedge is 2 times of open field

In term of MUs:

$MU_w = \frac{W_w \cdot Dose}{Sc\cdot Sp\cdot TMR\cdot(WF)\cdot WHF}$

$MU_o = \frac{W_o\cdot Dose}{Sc\cdot Sp\cdot TMR}$

$\Rightarrow \frac{MU_w}{MU_o} = \frac{W_w/(WF)}{W_o} = \frac{0.333/0.5}{0.667} = \boxed{\frac{1}{1}}$

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.

0.38 MeV TVL = 5.8 in concrete.

TVL: 5.8 in concrete

HDR shielding
occupation: 50 mSv/yr → 1 mSv/wk or < 2 mR/hr
public → 5 mSv/yr → 0.1 mSv/wk (infrequent) ⇓ 0.01 R/wk

$B = \frac{(0.01 R/wk)\cdot(2m)^2}{(10Ci)\cdot(1000mCi)\cdot 4.69 (R\cdot cm^2/mCi\cdot hr)\cdot(100 min/wk)}$

$= \frac{0.01 R/wk\cdot(200)^2}{(10.000 mCi)\times 4.69 R\cdot cm^2/mCi\cdot hr\cdot(\frac{100}{60})/hr} = 0.0029$

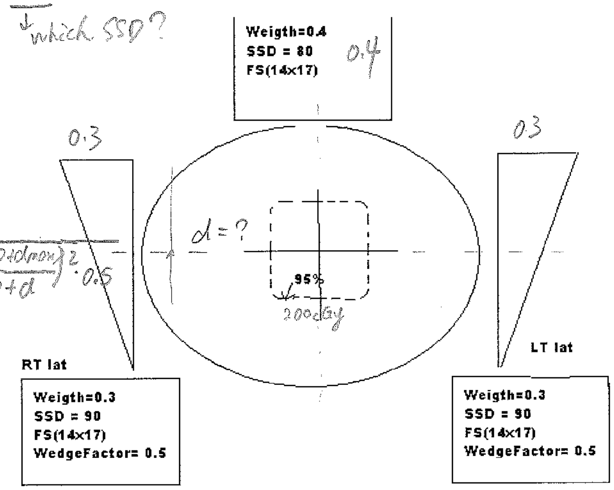
$n = 2.29 TVL$

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.

which SSD?

$eq = \frac{2\times 14\times 17}{14+17} = 15.35$

$MU = \frac{200\times 0.3/0.95}{Sc(15)\cdot Sp(15)\cdot TMR(15,d)\cdot(\frac{SSD+d_{max}}{90+d})^2\cdot 0.5}$



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.

$\dot{D} = S_k\cdot\Lambda\cdot g(r=2)\times G(r=2)\times\phi(r,\theta) = (0.868 cGy/hr/U)\cdot(2.5U)\cdot g(2cm)\cdot(\frac{1}{4})\cdot 0.939$

assume point source

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.

$\frac{I_0}{I_g} = (\frac{f+d_m}{f+d_m+h})^2 \Rightarrow \frac{44}{100} = (\frac{f}{f+20})^2$

$f' = 39$

20.- A geometry problem:

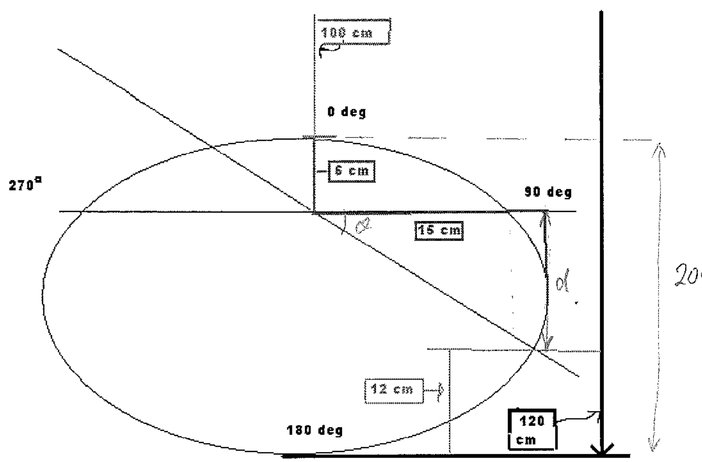
Determine the angle, following the IEC convention of angles, of the medial field, given the dimensions in the figure:

$WF_{eff} = W_o(1) + W_w\cdot WF$
$= (1-W_w) + W_w\cdot WF$
$= 1-(1-WF)W_w$
$= 1-(1-WF)\cdot\frac{W_w}{W_o\cdot WF + W_w}$
$= \boxed{\frac{WF}{W_o\cdot WF+W_w}}$

$d = 20-12-6 = 2cm$

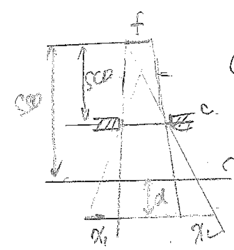
$\theta = \arctan(\frac{2}{15}) = 7.6^\circ$

$\theta_{med} = 90 + 7.6 = 97.6^\circ$



$f/\alpha_1 = \frac{SCD}{SSD+d-SCD} \Rightarrow \alpha_1 = (\frac{SSD+d-SCD}{SCD}) \cdot f$

electron: primary collimator → scattering filter → ion chamber → secondary colli → electron cone



30.- Main difference between Magnetron and Klystron. Hint: Klystron is not a microwave generator. (amplifier)

31.- Select proper order of parts in a LINAC. Different orders of parts were given. Hendee's and Khan's book.
photon: x-ray target → primary coll → flattening filter → ion chamber → second. coll.

32.- Main n contribution to dose behind LINAC. Select among neutrons, scatter from patient, scatter from walls, leakage from LINAC head.

33.- Penumbra calculation from LINAC given target surface distance, target block distance, depth in patient and target dimensions. → $P = \frac{f(SSD+d-SCD)}{SCD}$

34.- Radionuclide and energy emission from Sr-90 eye applicator.
$Sr^{90} - Y^{90}$ Sr^{90} $\beta_{max} \to 0.5MeV$ (0.02MeV) Avg ; Y^{90} $\beta_{max} \to 2.3MeV$ (max) 0.97MeV (Avg)
⇓ low Z material to shield β source, high Z ⇒ bremsstrahlung

35.- The only factor less than 1 in TG-51. Select from Ptp, Pelec, Ppol, Pgrad.
Pgrad always less than 1 if $d_{ref} > (d_{most} + 0.5r)$

36.- Flatness and symmetry tolerance figure according to TG-40
photon: 2%, 3% electron: 3%, 3%

37.- What percent of a batch of seeds has to be checked in a prostate seed implant procedure. 10% or 2 ribbons

38.- Tolerance for deviation between light and radiation field according to TG-40.
2mm or 1% on a side.

39.- Necessary thickness of lead for 6MeV electron cut-off (6/2mm + 1mm) = 4mm
↓ safety

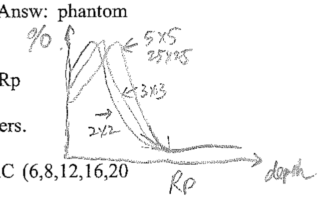
40.- Which components of a LINAC are pulsed after Thyratron is fired?
electron gun & microwave power generator (klystron + magtron)

41.- A tumor is reduced because of its higher mitotic activity, was my answer.

42.- PET cant bring information about (metabolism, metastasis, pathology, TX follow up, tumor) can not

43.- An error of 2 mm in MLC opening causes an error of xx % in 2cm radiation field ?

44.- What condition is not required for collimator output factor Sc. Answ: phantom measurements.



45.- What doesn't change by reducing field size in electron beam. Answ: Rp

46.- ~~TVL~~ TVD for neutron attenuation in maze according to ?? is: Answ: 5 meters.

47.- Energy at which theoretically can be produced a neutron in LINAC (6,8,12,16,20 MV): Answ: 8 MV.
neutron binding energy of roughly 8 MeV for most nuclides
only become significant when E exceed 10MV

$0.6\% \times 760 mmHg \doteq 5mmHg$

21.- What is the change expected in mmHg when reading at 50 meters of altitude from the airport level. 0.6~0.7% per 50mm $P = P_0 \cdot e^{-0.000125\Delta h}$ ⇒

$X = \frac{Q}{m}$

$V = \frac{Q}{C}$

22.- Given the density of air 0.001293 g/cc, chamber with 0.19 cc, given 1 R = 2.58 e -04 C/kg. Calculate the approximate exposure calibration factor of the chamber in R/C. ?

$= \frac{X(R) \cdot 2.58\times10^{-4} \times \rho \cdot V}{C}$

23.- Three or four problems that are solved using equivalent triangles rules for field sizes transferred from SAD setups to SSD setups.

$= \frac{X(R) \times 2.58\times10^{-4} \times 0.001293 \times 0.19}{C}$

24.- A DVH was shown. What is true from it?

25.- A graph of raw (not shifted) PDD's VS depth shown. Diameter of chamber 0.6 ~~mm~~ cm. Determine the PDD(10 cm). shift 0.6r upstream photon . 0.5r electron
$0.6 \times 0.6 \times \frac{1}{2} = 0.18cm$

$= \frac{X(R) \cdot 6.338\times10^{-11}}{C}$

26.- What percent higher/lower difference is expected when going from TG21 to TG51
1% higher photon ; 2% e^-.

27.- What is the meaning of D90 = 110 Gy?
90% of volume covered by dose > 110Gy

⇒ $\frac{V(voltage)}{X(R)} = \frac{6.338\times10^{-11}}{C}$

28.- Scatter transmission factor B given distance to patient 1 m, distance to secondary barrier 5 m, field size 20 x 20, alpha= 0.001, W = 500 Gy/week, Xp = 0.02 mSv/week.
400

29.- A simulator shielding problem. Exposure rate at 1 m was given= 0.01 R/ mAs at 1 m. Workload = 600 mA-hour / week. U = 1/4, d = 3 meters. Xp = 0.01 R/week. Determine how many TVL's given the exposure rate limit.

$X = \frac{Q(C)}{m(kg)}$

$X(R) \times 2.58\times10^{-4} = \frac{Q(C)}{m(kg)}$

$\frac{X(R)}{Q(C)} = \frac{1}{m(kg) \times 2.58\times10^{-4}}$

$= \frac{1}{0.001293 \times 0.19 \times 10^{-3} (kg) \times 2.58\times10^{-4} (C/kg)}$

$= \frac{1}{6.34\times10^{-11}}$

Assumed (20x20)

$B = \frac{P \cdot d_{sca}^2 \cdot d_{sec}^2 \cdot 400}{\alpha W T F}$

$= \frac{(0.02mSv/wk) \cdot 1^2 \cdot 5^2 \cdot 400}{0.001 \cdot (500\times10^3 mGy) \cdot 1 \cdot (20\times20)}$

$= 0.001$

$B = \frac{Pd^2}{TKN}$

$= \frac{Pd^2}{T \cdot W U}$

$= \frac{(0.01R/wk) \cdot 3^2}{(T=1)(1/4) \cdot (600mA \cdot hr)/wk}$

$= \frac{0.01 \times 3^2}{1 \times 0.25 \times (600mA(3600s) \times 0.01)R}$
↓ Exp rate given

$= 1.67 \times 10^{-5}$

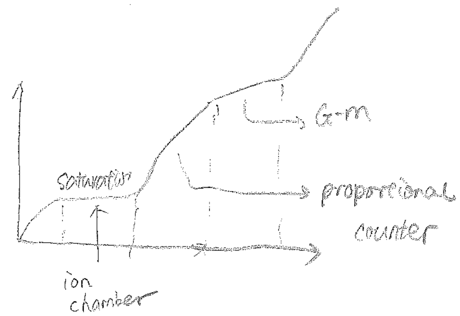
or

X(R)/min

⇒ $X(R)/min \cdot (2.58\times10^{-4} C/kg/R) \cdot 0.001293g/cc \times 0.19cc$

⇒ $X(R)/min \cdot (2.58\times10^{-4} C/kg R) \cdot 0.00024567g \times 10^{-3} kg/g$

⇒ $6.338\times10^{-11} \cdot X(C/min) = 0.106\times10^{-11} X(\AA)$



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

$(1 - e^{-\frac{\ln 2 \cdot t}{59.4}}) = 0.95 \Rightarrow t = 256.7$ days

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

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. → wrong.

53.- Detector resolution required for SRS field profile is (less than 1mm, 2mm, 3mm, etc) ⇒ Linac base <2mm <3mm for outpt / TMR.
Gammaknife <1mm.

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

The simulation starts from the plane of phase-space file, the particle being tracked through particular beam-defining device

55.- Sliding window in IMRT means A, B, C, D, etc?

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.

-1000 -700 0 50 200

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 ? → assure enough dose to shallow tissue of target

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

3% - 16MeV
5% - 20MeV
} varian machine

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

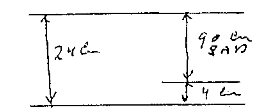
5mSv 1mSv

usuall 6MV 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

Given



3. Many questions in TG 41.
4. Some TG 30 questions. → TSKE
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 A1 needed to compensate for missing tissue. Factors given. ⇒.
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 polly on outside, → polyethylene what is the energy of the gamma coming off polly? 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.
    a. Both 6 and 18 photon
    b. 18 photon and all electrons
    c. 18 photon and 20 electrons
    d. 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 Do= 8cGy 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.

$D = \dot{D}\cdot T_{avg}\left(1-e^{-\frac{\ln 2}{T_{1/2}}t}\right)$

$= 8\,cGy/hr\cdot(73.8\times 24)\times\left(1-e^{-\frac{\ln 2}{73.8}\cdot 45}\right)$

$=$

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 mr/hr (similar to questions on previous exam).
26. What is allowable dose to frequently exposed member of public? infrequent - 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) T
29. Target of therapy x-ray unit not transmission type (T-F). F
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) F → generate radioactive airborne particles
35. Linac jaw are made from natural uranium? (T-F) F
36. Natural uranium is commonly used as jaw material for linacs. (T-F) F depleted uranium contains ^{235}U with a concentration lower than 0.711% occurring in nature
37. What provides the greatest contribution to the dose from I-125 implant.
    a. gamma rays ✓
    b. fluorescent photons EC → γ emission
    c. auger electrons EC 100% 0.035 MeV
    d. beta rays
    e. internal conversion electrons
38. When commissioning a set of new wedges. which of the following must be measured?
    a. wedge factor vs. Depth
    b. wedge factor vs. Field size ✓
    c. wedge factor vs. Off access
    d. 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 ½ 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