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:

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.

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

>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

(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

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

- 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

- 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.

- 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).

- Penumbra: bulges out.

- Isodose distribution: 80 and 90% IDL shrink.

- X ray contamination increases with e- energy

- Oblique incidence: dmax shifts towards surface, depth of penetration decreases.

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

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

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

- In general is OK to abbut 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)

- 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:

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

KQ = Pgrad * kecal K'R50

(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.

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.

(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?

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).

(19) Superficial shielding calc given workload.

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

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

Xp = 1 mSv / year = 0.02 m Sv / week

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

For electrons is 0.6*R50 - 0.1

(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

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.

(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 <----?

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

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

(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.

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.

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%

(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?

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

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

Gamma emmiter sources calibrated in a well chamber.

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.

(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

- 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.

- NTCP: normal tissue complication probability

- 1-NTCP: normal tissue uncomplication probability

- TCP: Tumor control probability

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

- 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).

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

- Normal tissue alfa / beta = 3.0

- Tumor alfa / beta = 10

- 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

- 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:

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.

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

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.

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

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

(38) Calculate Eo given R50: Eo = 2.33 R50

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

Close collimators to a minimum to decrease scatter.

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

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

(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:

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?

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.

(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.

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.

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

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

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).

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)

{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}

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

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

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

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:

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).

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

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:

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.

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).

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

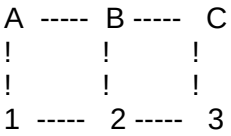
(9) SSD setup, find MU setting to deliver dose at SSD =125. PDD table at SSD = 100 cm given. This is simmilar to the problem we solved on bullet (3)

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.



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)

(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.

(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:

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.

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:

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

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

From 15 sources = 20.55 cGy/hr

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

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

(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

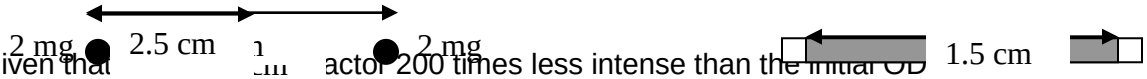
D = 1.44 * 59.6 * 5.24 * 24 (1 – exp (-ln2/ 59.6 * t))

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



(12) Given that [illegible] 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.

(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)

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:

CF = TMR (d, rd) / TMR (d+h, rd) , in this case h is negative, its SSD is 84 cm.

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' = 3 + 2 * 1.4 + 4 = 9.8 cm

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

CF = TAR (d', rd) / TAR (d, rd) = 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 %)

(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:

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

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.

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

Xp = 0.02 mSv/week = 0.002 R/week

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

B = 0.000089 -→ 2.7 mm of lead.

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

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

Remaining dose 6000 – 4500 = 1500

Fractions: 1500 / 200 = 7.5 fractions

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.

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

11 * 38 = 418 cGy.

Total to cord = 418 + 4028 = 4446 cGy.

(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

Xrate(30 cm) = Gamma Ir-192 * Activity in mCi / (30 cm)**2 * exp –(2.0 cm /0.3cm)

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

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.

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))

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.

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

(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?

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:

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.

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.

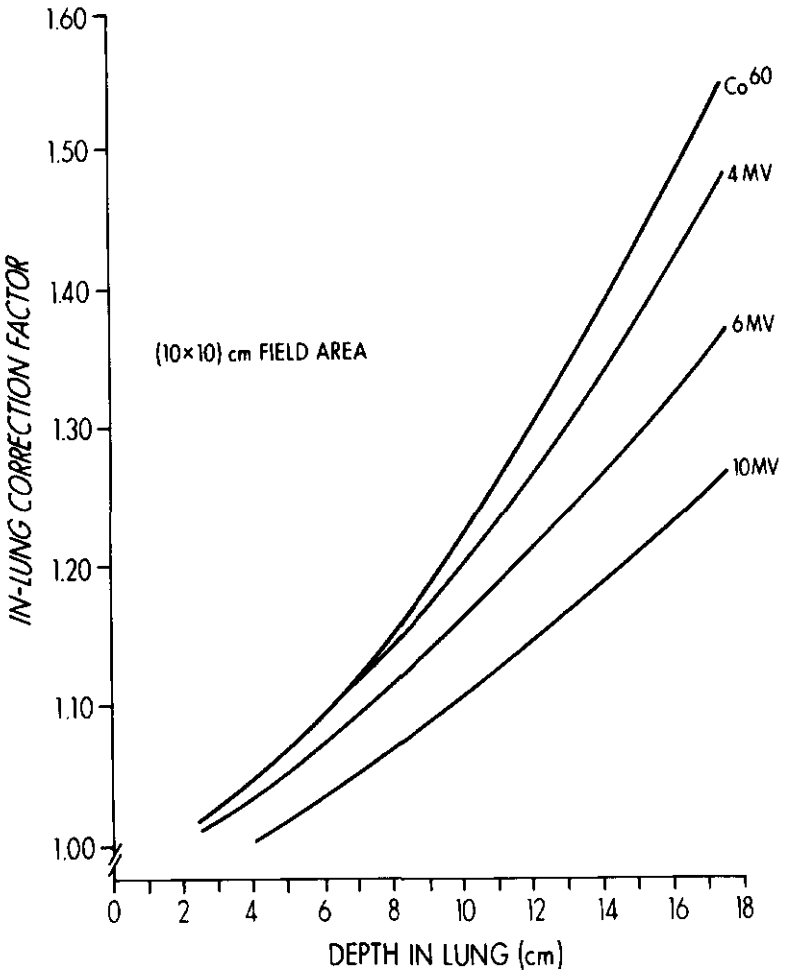


FIG. 5. In-lung correction factor as a function of depth in lung, and energy.

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:

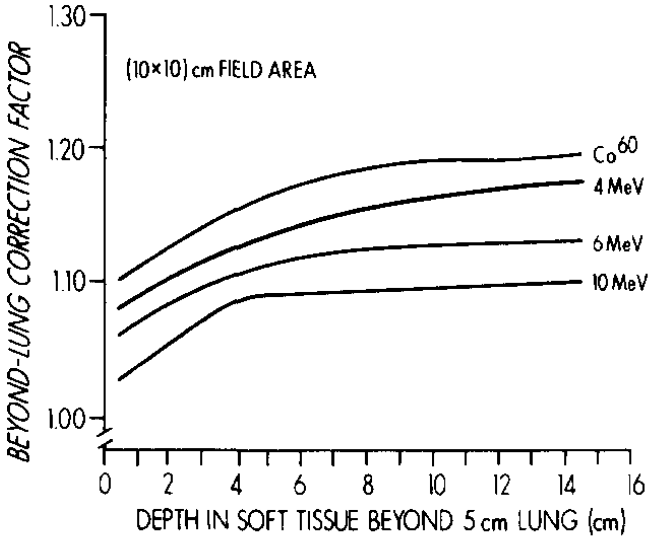


FIG. 3. Beyond-lung correction factors as a function of depth in soft tissue beyond 5 cm of lung, and energy.

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.

a) Using the effective depth method:

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

b)Using the Batho power law:

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

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

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

CF= TMR (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.

For remembering the Batho power law:

Three regions: d1, d2 (inhomogeneity, d3

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

2004 ABR Therapy Part 2, Written.

1. HDR, three dwell positions (1, 2 and 3 – 2 in middle) 1cm apart in single channel. Dose points A, B and C 1cm perpendicular to dwell positions 1,2 and 3 respectively. Dwell times in 1 and 3 are the same. What is the ratio of dwell times 1 to 2 to make dose A equal dose B.

A B C

1 ——— 2 ——— 3

[Solution]

DA = D1A + D2A + D3A
= DR* T1 + DR* T2/(1+1) + DR * T1 /(1+4)
= DR* T1* (1+ 1/5) + DR* T2/ (2)

DB = D1B+D2B+D3B
= DR* T1 / (1+1) + DR * T2 + DR * T1 / (1+1)
= DR * T1 + DR * T2

Given DA= DB

1.2 * T1 + 0.5* T2 = T1 + T2

0.2T1 = 0.5T2

T1/ T2 = 2.5

2. TG51 question (no TG21 in whole exam). Given Ppol, Pelec, T (deg C), P (mmHg), Vhigh = +300V, Vlow = +150V, 100mu Reading for Vh = 1.71 …., 100mu reading for Vl = 1.70…., given 60CoNdw Gy/C for chamber, given pdd photon, given kQ (not asked to do energy determination to find kQ) calc cGy/mu at dmax for photon beam. Answers approx 0.6% apart. (Also given plenty of irrelevant information such as TG51 electron beam parameters)

3. Simulator shielding question, NCRP 116 level to worker with office above simulator room. Occupation mentioned – I don't recall but was an allied health profession not related to radiation oncology/ radiology. Floor to floor = 12 ft, iso = 48" above floor, SAD = 100cm, given U=1/4. W=800mA.min/wk. Asked to work out the thickness of concrete shielding required. Answers about 4mm apart. Provided with a graph of R/(mA.min) at iso on vertical axis (log scale) vs concrete shielding thickness (cm) on horizontal scale – with the log scale, the plot was reasonably linear. Basically I think what you had to do was find allowed R/mA.min at point where person is sitting, then project back to iso to give your number for the Y axis then read across to get concrete thickness.

4. AP/PA doses given from each field to cord for 200 cGy to tumor. (62cGy, 150cGy respectively). Cord block put in PA, new cord dose is 18% of original. How many fractions need cord block to limit cord dose to 40Gy?

5. Counts given (cpm) for reference source with known activity (mCi). How many counts allowed to stay below wipe test leakage limit – limit not given (5nCi?).

6. 2cm diameter lead pig inside polyurethane foam inside 30cm diameter shipping drum. HVL Pb given. Exposure rate constant of 192 Ir given (but not the one I know!). Calc max activity to keep below 50mR/hr

on surface. Another variant of this question used 137Cs (again I didn't recognize the exposure rate constant provided), activity provided and asked to calc thickness of lead to reduce exposure rate to certain level (TVL given).

7. Parts definitely not included in EPID – options were ion chamber, CCCD camera, mirror, silicon screen, some other dose detection device.

8. TBI, diode reading 450cGy on surface, presc midline 600cGy POP laterals, 30cm separation. TMR's given, 350cmSSD. What is error in midline dose? Answers approx 5% apart, both + and -. I had to assume entry beam only, and diode reading relevant to dmax (not surface – no TMR at surface given) to get anything reasonable. 60cGy from each beam to be delivered to calc point. Post beams have 9cm lung, e density = 0.33, TMR's given at 3,6,9,12,15 cm. Ratio of mu's post to ant.

10. Several TMR and PDD questions that needed the 4A/P rule.

11.Extended SSD calc that needed the Mayneord F Factor. Was only given a graph of output vs field size ie could not separate Sc and Sp.

12. Ratio of dmax (25 MV)/ dmax (4mv) for same dose to midline using POP setup with SSD =100cm. PDD's given.

13. Neutron dose equivalent (mSv) outside field per photon Gy at isocenter.

14. Neutron dose equivalent ratio 18MV vs 15 MV. Answers were fairly widely separated ie 1, 2, 5, 10, 100.

15. Given distance iso to maze and maze length, neutron dose at iso (mSv) per photon cGy at iso, what is neutron dose (mSv) at door per photon cGy at iso. Told TVL of neutrons is 5m, but not where it applies. I applied kersey formula ie ISL iso to maze, then 5m TVL down maze to door.

16. Numerous questions of dose ratio where had to use TMR ratio and change of ISL.

17. Dual scattering foil in linac, when change to electron mode (from photon) what happens. A. gun current reduces substantially, B. Both scattering foils are in place C. other options that were way off.

Electron beam leaving the bend magnet is about 3mm in diameter. Scattering foils are used to spread the beam.
[Solution] A single high Z scatter is adequate for low energy electron up to 10MeV.
A dual-foil scattering system, with a few cm or more between two foils, improves beam flatness for E> 15MeV and field size > 15cm. The first high Z foil is selected to minimize energy loss for a given scattering distribution and the second scatter made of low z composite, thicker on axis, and functions more like a field flattering filter. The thicker portion of the second scatter may be in the form of high z button on a low z foil. Electron applicator in such system primarily serves to define the field size and only affect flatness secondly.

18. g(r) for 125I vs 103Pd. A. same at all depths, B. Pd exceeds I beyond 1cm, C Pd exceeds I beyond 4cm, D. I exceeds Pd beyond 1cm, E. Same at all depths.

19. No TG21 questions

20. No gamma knife questions

21. No ion chamber current from exposure rate or dose rate or in part 1 either.

22. TG 40 photon flatness spec.

23. TG40 field size spec A. 2mm/1%, B. 2mm/ 2% C others not 2mm

24. TG40 how often do you check well chamber leakage.A. 2 years, B. Every use, C….

25. TBI – what is not true – A. Dose Uniformity < 15% B. Tissue Equivalent compensators are used C. High SSD D. AP preferred over lateral.

26. Biggest impact on fetal dose according to TG36. A. Distance to fetus, B. energy C. Blocking, D. Depth below abdomen surface.
[solution]
The most important determinant of the peripheral dose is the distance from the radiation field edge, with the dose decreasing approximately exponentially with distance from the field edge. For a given depth and field size show that the peripheral dose for photons from 4 to 25 MV is the same order of magnitude and is qualitatively similar. In contrast, the peripheral dose from ^{60}Co at distances greater than 10 cm from the field edge is considerably higher because of a larger amount of head leakage. However, peripheral doses calculated by Keller et al.[5] show that the total dose outside the beam decreases as energy increases
Most published data[1,4,6] show that the change in the peripheral dose with depth is small.
The peripheral dose increases as field size increases; this effect is more pronounced closer to the beam edge and is due to the scatter within the patient from the treatment beam.

27. S/rho and rho given for lead. Calc MeV/cm then use to calc lead thickness needed to shield 18MeV beam.

28. HDR 192Ir. Patient treated with time XXX with Activity YYY on Aug 15th. Source replaced with activity ZZZ on Aug 17th. Treatment time on Aug 22nd is ? No 192Ir half life given.

29. Nothing on TBE lectron

30. 10MV through 6cm lung, dose actual vs dose without inhomogeneity. No other data given.

31. A question involving 10mg Ra – simple application of ΓxA/d2 – but needed to know (ie not given) exposure rate const. = 8.25 Rcm2/mg.hr

32. Shielding question. 36 in space available for needed 6 TVL (this information was given). Pb TVL given. Concrete TVL given. What is the minimum thickness of Pb needed.

33. How many TVL's in a linac head.

34. No MLC questions

35. **The only IMRT question:** In IMRT the physicist does not define: A. Beam Weights B. Field Sizes C. Gantry Angles
…..

36. Field size required at midplane is 25cm, maximum can open is 20cm. What is SSD? (separation = 22cm)

37. Sim film taken at 102cm SSD, SFD 140cm. Want to treat at 120cm SSD. What distance to film should be used when cutting blocks.

38. Standard question about the couch kick angle required to make inferior borders parallel on lateral brain fields.

39. Breast Tangent pair. Field widths at 100 SAD = 10.5 cm. LAO has gantry angle 45 degrees. What gantry angle does RPO have such that posterior borders will be parallel.

40. I'm vague on this one but I'll give it to you anyway. The question went like …. The simulator couch wouldn't go low enough, so the film was taken at X SSD, separation 25 cm, distance to film = 140 cm. Physician wants to treat at 132 SSD, simulator film needs to be placed at what distance to cut blocks.

41. No diagram with this one making it tough. Patient on simulator couch with isocenter 5cm right of midline. Wire placed on midline (didn't say A or P). R Lat film taken. Measured cord depth of 6.7cm, but therapist forgot to reset isocenter to midline. What is the true cord depth. If you think this is confusing, then I agree. Basically I think the depth was measured assuming isocenter at midline, then question was asking what is the true depth.

42. PDD for wedge increases over open field due to: A. Photon interactions in the wedge B,C,D,E….. other options that didn't look right.

43. Beam steering vs gantry angle in a linac. Signals to steer originate from ….. ion chamber …. various other options.

44. Considering a dual ion chamber scanning water tank, an error in the PDD (a shift up or down – I don't recall which) is **not** due to A. incorrect zero – ie set above water level B. RF interference C. water / air temperature differential D. Stepper motors not calibrated correctly.

45. No electron Arc questions, no gamma knife questions, no SRS questions.

46. Electron cutout changed from 6x6 to 4x4. What doesn't change, A. Bremstrahlung B. Output Factor, C. Depth of 80%, D. Surface Dose.

47. I50 ionization depth of an electron beam is 5.1 cm. The energy of the beam is …..

48. Saturation in an ionization chamber refers to ….A. voltage high enough to prevent recombination ….other options that were not correct.

49. A survey points a linac beam at a primary wall and measures 2mR/hr. Is this OK? There were various options in the answers, but this was the point of the question.

50. An ion chamber is used to perform a survey. You also need all of the following except: A. Dose rate of linac B. Sufficient buildup around the survey meter C… other options that looked to me like they were required.

51. SAR for this radial section: Diagram given, table of SARs given.
| | Block | |
0cm 6cm 9cm 10cm

52. Classic electron ISL calculation straight from Kahn, ie calculate the effective SSD, given energy, field size, dmax (2cm), given slope of (Io/Ig)1/2 = 0.0111.

53. Superficial question. Measurement at end of cone gives a reading of 150. Measurement at 10cm from the end of the cone gives a reading of 52.3. What is the effective SSD at the end of the cone.

54. No TG 61

55. Purpose of the guard ring in a plane parallel chamber is to? A. “Define the collection volume” appeared to me to be the only reasonable answer.

56. A question where you were given air kerma and had to calculate roentgens from this. I think you just divide by 0.876 rad/R – this gave one of the answers.

57. Dose to cord from AP/PA 100 SAD setup. 22cm separation, cord 4cm deep, 200cGy to isocenter. TMRs given.

58. Most radiation sensitive part of the eye is ….. lens

59. TVL is related to HVL by A: TVL = ln10/ln2 HVL, B… other impressive but erroneous relationships. This rule and it’s generalization can be used to speed up all sorts of calcs, not just in shielding but with regard to time as well – use it!

60. Film exposed for dosimetry. Given transmitted light is 200 times smaller than original, what is the dose? OD vs dose table provided that required interpolation.

61. Electrons at extended SSD, which is true?
A. Width of the 90% extends proportionately B. Penumbra increases C. Output follows ISL with 100 to source …

62. What happens when you change from 15cm field size to 20cm field size for electrons. No energy given. Various combinations of change in surface dose (increase / decrease) and change in dmax (increase/decrease). Only one option had no change in surface dose (which I chose)

63. Why does the equivalent square technique work? A. Because scatter doses are equal between square and rectangular fields, B.other options involved statement about collimators and scatter that sounded wrong
64. Scatter and leakage shielding thickness calculations are equal. The shielding that should then be used is: A TL + 1HVL, B other options including Ts + TL , Ts + 1TVL.

65. Order of materials in door for high energy linac – inside to outside.

66. Electron backscatter from internal shield versus Energy and Z – just had to know increase vs decrease.
67. Four field prostate treatment to 200cGy. What is the dose to anterior rectum. No other information was given, anterior was in bold. I answered 200cGy.

68. What should you check with each use of an ionization chamber / electrometer.

69. Classic isocentric POP where you had to calculate the maxdose / midplane dose ratio. Given TMR table, output factor as a function of field size graph (normalized to 1.000 for 10x10), cGy/mu at dmax for 100cm SSD and 10x10, no Sc or Sp given anywhere in the test.

70. A 60Co single field calc 100SSD, cGy/min at dmax given. PDD table given, BSF table given, TAR table given. Prescribed dose was 300cGy to 10cm deep. Had to use 4A/P to convert to square field (had to use 4A/P on numerous rectangular field questions.

71. Had to do single field 125 cm SSD calculation. 300cGy to 10cm deep. Given output factor as a function of field size graph (no Sc or Sp which in my opinion makes it impossible to do this question accurately),

given PDD table, TMR table, given output at dmax for a 10x10 at 100cm SSD. Answers all very close ie approx 1% apart.

72. Multiple beam plan. AP weighted to 100% at dmax, laterals weighted to 100% at dmax. 200 cGy delivered to 238% isodose line. Dose delivered by AP beam is ??? cGy.

73. Monte Carlo calculations require a random number generator and ….A. probability distributions, B,C,D,E other options that didn't look right.

74. Dose 10cm deep 5cm outside field is A. 1% B. 2% C. 3% D. 4% E. 5%

75. Γ factors given on several questions were not what I expected for the isotope in question. But I always used the one given.

76. Pacemaker dose limit.
(1) Pacemaker implanted patients should not be treated with a betatron.
(2) Pacemakers should not be placed in the direct (unshielded) therapy beam. Some accelerator beams can cause transient malfunction.
(3) The absorbed dose to be received by the pacemaker should be estimated before treatment. Estimation methods can be found in the literature.
(4) If the total estimated dose to the pacemaker might exceed 2 gray, the pacemaker function should be checked prior to therapy and possibly at the start of each following week of therapy. Since total and abrupt failure of pacemakers has been seen at cumulative doses between 10 and 30 gray and significant functional changes have been observed between 2 and 10 gray, early changes in pacemaker parameters could signal a failure in the 2-10 gray region.
(5) Although transient malfunction from electromagnetic interference is unlikely from contemporary therapy accelerators and cobalt irradiators, the patient should be closely observed during the first treatment with a linear accelerator and during subsequent treatments if magnetron or klystron misfiring (sparking) occurs.
(6) Studies to date have dealt with linear accelerators, betatrons, and cobalt irradiators only. Use of other radiation therapy machines should be evaluated on an individual basis and approached with caution.

77. Apparent mCi is less / more / same as mCi

78. No shielding questions were simple "plug in and solve for B". Every one required something "non-standard" or use data in a non-standard format.

79. TG40 photon flatness specification:A 1% B 2% C 3% D 4% E 5%.