

## 2011 Recall

80 Q, 53 easy (1 point) and 27 (3 points) and total 4 hours;

1. 6x, 10 x 10 cm<sup>2</sup> field, 100 SSD, treatment depth at 1 cm, which following change will make the dose uncertainty < 2 %
  - (a). Changing collimator field size to 12 x 12 cm<sup>2</sup>
  - (b). Changing the treatment depth to 12 cm
  - (c). Changing the SSD to 101.5 cm
  - (d) Put 1 cm tray block
  - (e). Using 4 x 4 cm<sup>2</sup> field

2. What is the difference between the conventional CT and MV CT

- (a) In the curve of HU vs. electron density, MVCT shows slow slope in the low electron density region than the high electron density region
- (b) From the curve of HU vs. electron density, the region between air and bone is more linear.

3. In Monte Carlo Treatment Planning Algorithms, what is the cutoff energy under which the path a particle will no longer be mapped discretely, and instead it will be lumped in with a general energy distribution function.

1 keV, 10 keV, 500 keV, 1 MeV, 2 MeV

*Used in Aerasys & B for electrons  
Photon, 1 keV*

4. From NCRP116, what is the dose limit for unrestricted area per week? 0.02 mSv/wk

5. For 6x 5x5 cm<sup>2</sup> at dmax, Monte Carlo simulation, the voxel size is 0.5 x 0.5 x 0.5 cm<sup>3</sup>, if we want the dose uncertainty is 2%, how many photon tracking history needs to be done? Assuming there is no photon getting outside the field.

- (a)  $2.5 \times 10^3$
- (b)  $1 \times 10^5$
- (c)  $2.5 \times 10^5$
- (d)  $1 \times 10^7$

$$\frac{1}{\sqrt{25 \times 10^3}} = \frac{1}{5 \times 10}$$

$$\sqrt{\frac{x}{1000}} = 2\%$$

$$\sqrt{\frac{x}{1000}} = 50$$

$$x = 2500 \times 1000$$

6. If we use portal image, which soft tissue can be readily seen?

- (a). Optical chiasm, (b). Carina, (c). Esophagus, (d). Plexus (e). Sella turcica

7. For an adult received 500 mSv whole body dose, what the probability is to get fatal cancer? = 0.25 million

- (a) 2.5% (b) 5% (c) 10% (d) 20% (e) 0.1 %

$$5\% / 500$$

8. Where is the effective measurement point for parallel plate chamber?

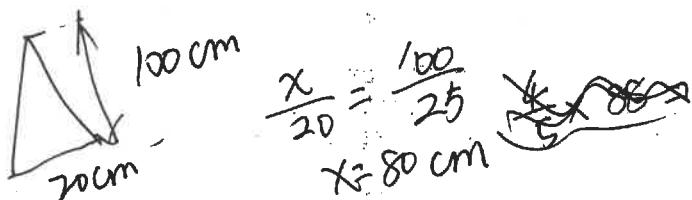
9. According to TG51, how much we need to shift the cylindrical chamber for PDD?

10. what is gamma index ?

$$\Gamma = \sqrt{\frac{r^2}{\Delta r^2} + \frac{s^2}{\Delta s^2}} = \sqrt{\frac{9^2}{3^2} + \left(\frac{6\%}{3\%}\right)^2} = \sqrt{9+9} =$$

11. Problem about gamma index that measured closest location to the calculated point is 6% dose difference and 9 mm away. What is the value of gamma if using a tolerance of 3% and 3mm?

12. Questions giving the value of 2 random error and 3 systematic error for prostate therapy, and according to Van Herk criteria ( $2.5\Sigma + 0.7\sigma$ ), what is the treatment margin from CTV to PTV?



13. A setup calls for a 25 cm field length at 100 SAD. The SSD is 88 cm. However, the field requires a wedge that has a field size limit of 20 cm at isocenter. What must the new SSD be in order to accommodate the wedge?

depth = 12cm;  $20/25 = \text{SPD}/100 \rightarrow \text{SPD} = 80 \rightarrow \text{SPD} = 80 - 12 = 68\text{cm}$ , SPD source to the treatment point

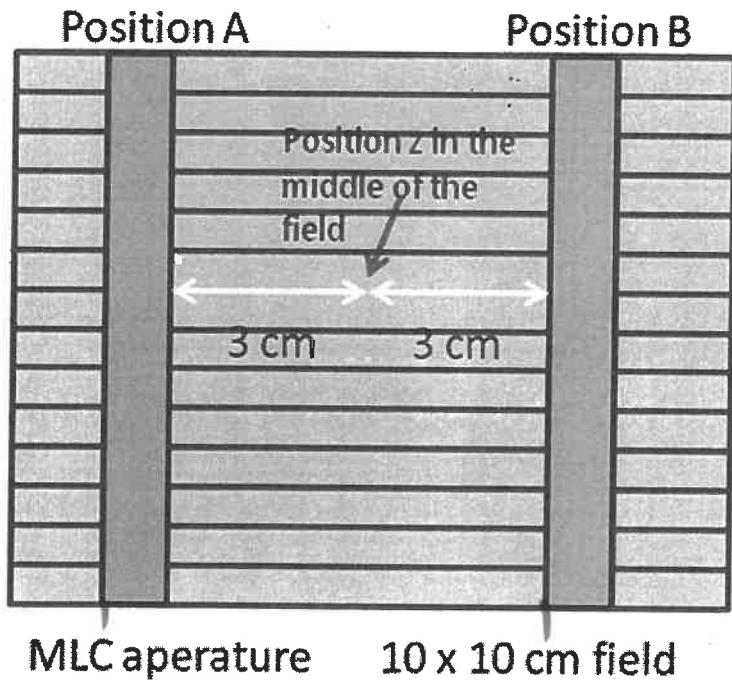
14. TG51 regular photon calculation and calculate the dose at d<sub>max</sub> with SSD setup

15. TG51 regular photon calculation at a point in water, but ask what the dose is at the same depth within muscle?

16. For a TPS, it uses equivalent path length for heterogeneity calculation. If it use relative mass density for bone instead of relative electron density, how much percentage the dose calculation will change?

17. Using 120 kVp for a regular CT scan, and the HU is measured as 1200 (electron density 1.7). Now someone by accident changes the voltage to 140 kVp, and get the HU measured as 1065. If we use the new HU for bone for treatment planning, how much percentage change for 6x passing the bone?

18. A 1 cm wide and 8 cm long MLC aperture sweeping through a 6 cm field (dynamic window) as shown below. The point z measures 5 cGy/s and 0.2 cGy/s when it is exposed to MLC aperture or closing, respectively. The MLC movement is 0.5 cm/s. What is the dose measured at point z after the MLC moving from position A to position B? (a) 15.5 cGy (b) 14.4 cGy (c) 13.5 cGy (d) 12.4 cGy



19. For a 4 slice CT scanner with a slice thickness of 1mm a pitch 1.5 and a gantry rotation of 0.5 sec, how long will it take to scan 100mm?

Pitch is defined as table travel per rotation divided by the collimation of x-ray beam. However, more intuitive way to define pitch is table travel per rotation divided by the effective detector raw thickness. (Radiology, 233, 323-327 (2004))

Table speed = beam collimation (effective detector raw thickness) x pitch x gantry rotation per sec  
 $= 4 \times 1 \text{ mm} \times 1.5 \times (1/0.5) = 12$

$100/12 = 8.3 \text{ s (KW)}$

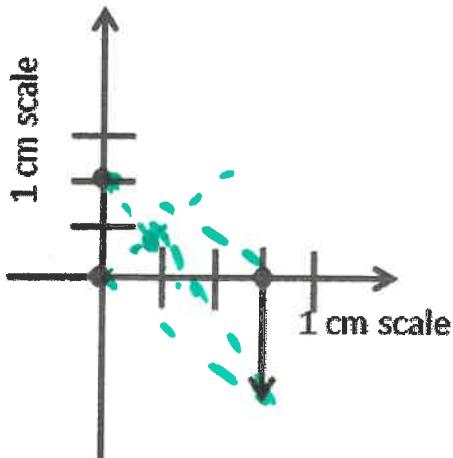
20. Another very similar question but asking helical tomotherapy with pitch

21. A well-chamber is calculated in national lab, and a calibration factor S (U/nA) is given. Now you use this chamber measure a Ir-192 source under the condition of 720 mmHg and 19 degree, and the measurement value is x (nA), asking what the source strength is?
22. Giving TAR, SAR, Output factor, Inverse square factor, tray factor, and 100 MU, and ask the dose under an irregular block (the key is using TAR or SAR? I used TAR)
23. What is the difference between transit electron equilibrium and electron equilibrium? (a) lateral scatter (b) photon attenuation (TG65)
24. Electron dose calculation 9 MeV, 100 SSD, and the calibration is done at dmax, effective SSD and virtual SSD are given. Now ask, if we want to prescribe the dose 200 cGy at 90% iso dose line with SSD 100? What the MU is?

25. Giving the definition of HI (heterogeneity index) = max dose/prescribed dose. For a treatment 200 cGy is prescribed to 70% iso dose line and the maximum dose is 105%, what is the HI? (I calculated as 1.5)

26. TG51 parallel plate chamber cross calibration

27. According to SRS, the isocenter is usually set as the center of mass of the fiducial markers. If we have fiducial markers set as the following orientation, and if we have a fiducial marker with 2 cm margin as indicated in the arrow, what the systematic uncertainty relative to the isocenter?  
 (a) 0.5 cm (b) 0.7 cm (c) 1.2 cm (d) 3 cm



28. Prescription is 60 Gy 30 fx delivered by parallel opposed, equally weighted beams. They say they gave 147 MU per beam, but after 10 fx, the monitor unit setting was found out with wedge factor of 0.8 omitted. What is the MU required (per beam) for the remaining 20 treatments in order to deliver the prescribed dose for the entire course of treatment? (a) 147 MU (b) 175 MU (c) 202 MU (d) 265 MU (all the answer is larger than 147 MU)

$$0 \times \frac{1}{3} = 3 \text{ cm} . \quad 3\% \text{ cu} \times 3 = 9\% .$$

29. If a photon beam penetrating 3 cm of healthy tissue then 9 cm in the lung then 4 cm of tumor what the dose difference between the algorithm with heterogeneity correction and without correction?  $9\% \times 3\% = 27\% .$   
 (a) 25% (b) 15%

30. Sim film taken at 102cm SSD, SFD 140cm. Want to treat at 120cm SSD. What distance to film should be used when cutting blocks.  $102/140 = 120/X \rightarrow X=164.7$

40  $\sqrt{2}$

31. Shielding: We have 40 x 40 cm field at 1 m, and the collimator angle can rotate to +/- 165 degree if our primary wall is at 5.3 cm, what is the primary barrier width should be?  $40 \times \sqrt{2} \times 5.3 + 60 = 360$  cm ?

32. 1 U = ? uGy m^2 /h

33. 1 U of Ir-192 = ? cGy cm^2 /h Not sure why they ask the similar question but just changing choice

34. Giving mass attention coefficient and density of lead, ask what the TVL is?

35. Brachtherapy question, giving the dose at 500cGy at 2 cm, and giving the g(2 cm), anisotropy factor is 1, asking how long it will take to receive that 500 cGy, maybe Pd-103?

36. Another brachytherapy, 1 mg-Ra asking if we want to have 30 mR what is the distance it should be?

37. Shielding calculation, 3Gy/pt, 25/pt per week, distance from iso to the point is 7.9 cm, U = 0.25, T = 0.25, what is the primary wall thickness, the dose limit is 0.02 mSv/wk?

38. Where dose parotid locate? Posterior to the mandible

39. Have a normal distribution, where you have 50% of the rate of occurrence. Answers: different factors multiply the standard derivation 1.786

40. Calibration of parallel plate chamber calculation – TG51

41. Given the Pion of Co-60 and 10MV x-ray, the reason that Pion for 10MV is lower than Co-60?  
Answers: A. Different energy B. continuous beam and pulse beam...

42. Input A + Bsin(2pi\*f\*l) and output is A + B\*exp(?) \* sin^2(2pi\*f\*l) what is MTF (modulated transfer function ) value?

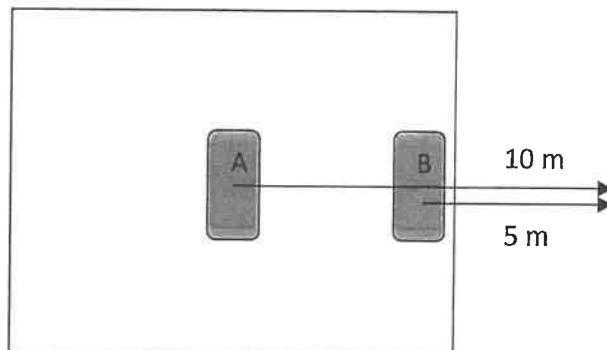
43. Electron energy 18MeV what's the energy after passing 5 mm lead, 8 MeV

44. Given electron mean energy E0, depth d and the energy at depth Ez asking the practical range?  
Using the formula  $Ez = E0(1 - d/Rp)$

**Complex:**

1-Shielding: Brachytherapy source was at 10 m distance from protection point, and then moved to 5m. Dose rate at 10m distance was given (2mR/h). Treatment time is 15 min. How many patients can be treated in position B before exceeding the 0.1 mSv in any one hour limit?

- 0
- 1
- 2
- 3
- 4



$$2 \text{ mR/hr} \rightarrow 8 \text{ mR/hr}$$

$$0.1 \text{ mSv/hr}$$

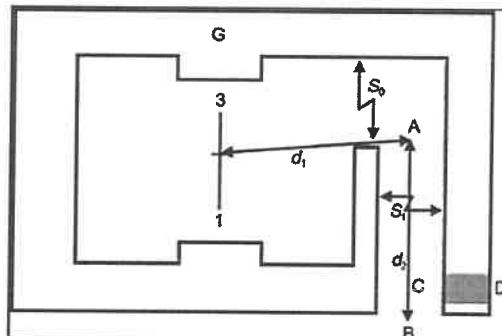
$$10 \text{ mR/hr}$$

4

2-Neutron shielding: Kersey's formula given. Find the Neutron load at the door and use the logB formula to find #TVLs.

$S_0, S_1, d_0, d_1, d_2$  were given

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



3-SSD calibrated machine (1cGy/MU at 100SSD, 10by10 field.) SSD setup, a table of TMRs given (instead of PDD). What is the dose at 10 cm depth?

4-Pd-103 and I-125 brachy: How much dose difference if physicist wrongly used half-life of Pd instead of I? (85 Gy prescription in 110 min) Assume initial "strengths" are the same.

$$\frac{P_{ion}}{P_{ion}} = \frac{\frac{M_H}{M_L}}{\frac{V_H}{V_L}} - \frac{\frac{V_H}{V_L}}{\frac{M_H}{M_L}}$$

5-TG51: some terms given. Need to find  $P_{ion}$ ,  $P_{TP}$  and used PDD to find dose per MU.

6- Standard shielding calc: distance given form iso not target. U, T, W, P, TVL<sub>1</sub>, and TVL<sub>e</sub> all are given.

7- TBI: midplane dose at umbilicus is 150 cGy, and at femur is 200 cGy. How many 2-mm-thick lead sheets do we need to attenuate the beam within 3% of the umbilicus (HVL given)? 3

$$\left(\frac{1}{2}\right)^x = \frac{3}{4}$$

8-Electron: MU needed to treat 90% at 4 cm depth?

9-Electron: Thickness of lead to shield beyond a 1cm thick lip using 6 MeV electron beam? 2mm

$$2^x = \frac{4}{3}$$

$$x = \log \frac{4}{3}$$

$$= 0.29$$

$$70 \times \left(1 + \frac{2}{10}\right) = 40 \times \left(1 + \frac{2}{10}\right) + 10 \times \left(1 + \frac{x}{10}\right)$$

10- BED calc: given initial fractionation scheme. Original prescription 70 Gy in 35 fractions. After 20 fx pt couldn't tolerate and physician wants to reduce the remaining # of fxs to 10. What is the dose per fx?

13- Find  $\Gamma$  for a table of measurements using 2mm resolution? (given 2%/2mm criterion)

- <1
- =1
- >1

$$30 \times 1.2 = 10x + x^2$$

$$x^2 + 10x - 36 = 0$$

14-Ratio of max dose if we use 4 or 24 MV in a parallel opposed fields? Thickness of the pt given (25 cm). PDDs given.

Depth (cm)	PDD (%)	
	4 MV	24 MV
1	100	xx
4	xx	100
5	xx	xx
10	xx	xx
12.5	yy	yy
15	xx	xx
20	xx	xx
21	xx	xx
24	xx	xx

$$\Delta = 3 \text{ Gy/fx}$$



15-Gamma knife: Output factor for two cone sizes, calibrated (18) and non-calibrated (8 or 4), are given. After 60 days how much dose delivered in 10 min using the non-calibrated cone size?

16- HD curve slope of a film is 1.5. Optical density of two different beams are 1 and 0.55. What is the ratio of transmission? 3:1 (HD curve given, slope of the curve was 1.5)

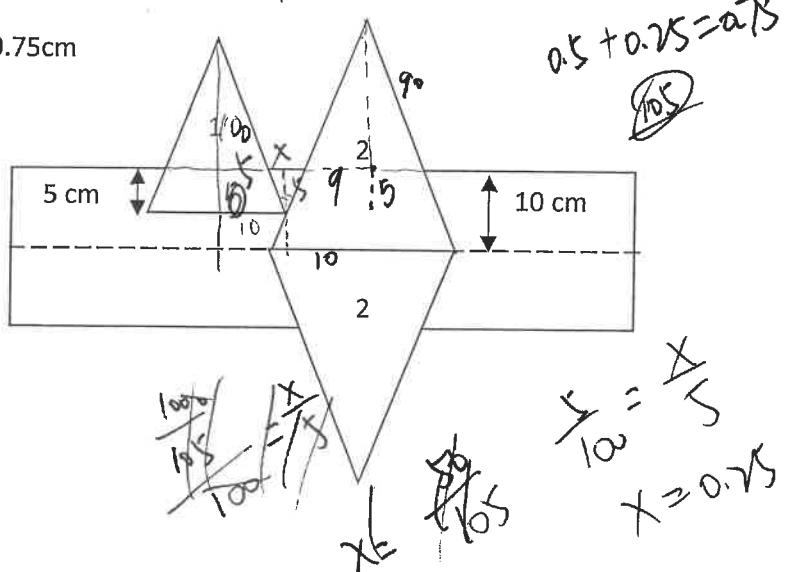
17-Neck and shoulder thickness is given. Cord dose is 2Gy when beam goes through the shoulders. What is the cord dose when beam goes through neck only? (TMRs given)

18-Electron effective SSD: Outputs (cGy/MU) at two gaps given, one where the cone is touching the phantom and one with 10 cm gap. No Dmax (or maybe 2.2 cm). Energy was 16.

19-Find gap at skin to match 5 cm in depth? 0.75cm

Beam 1: SSD setup, field size (10x10)

Beam 2: SAD setup. Field size (20x20)



20-Find minimum activity injected to patient in order to be able to release the patient. A formula was given. Needed to know the release criteria.

***Not sure complex or simple:***

1-Linac calibrated at sea level, it moved to a cancer center at xxx m elevation. Drop of pressure per yy altitude increase was given. What is the reading?

2-If in KV CT, absorption coefficient of a medium is twice that of water. What is its water equivalent thickness of 5 cm slab at 18 MV? (graph given, need to find electron density and scale based on that)

3-Find the collimator rotation in a CSI.

4-SBRT: isodose volumes of 24 and 12 Gy given. Asked to find gradient?

5-Calculate source strength in units of U?

**Simple:**

1-TG43: what does  $\Lambda$  do?

2- How many TVLs are in the linac head? Type 3 ✓

3-TG100: Find RPN. Occurrence, severity, can be detected and can't be detected values are given. Need to know that Delectability is actually not being detectable.

4-Detector with BF3 is good for what? Nuetron detection ✓

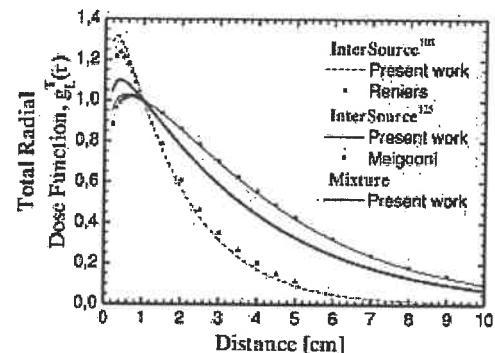
5-Entrance dose of monoenergetic proton vs. electron. Which one is higher? ✓

6-In order to make SOBP in double scattering what material is used? Combination of low and high Z. ✓

7-TG40 tolerance for HDR positioning accuracy is 1 mm.

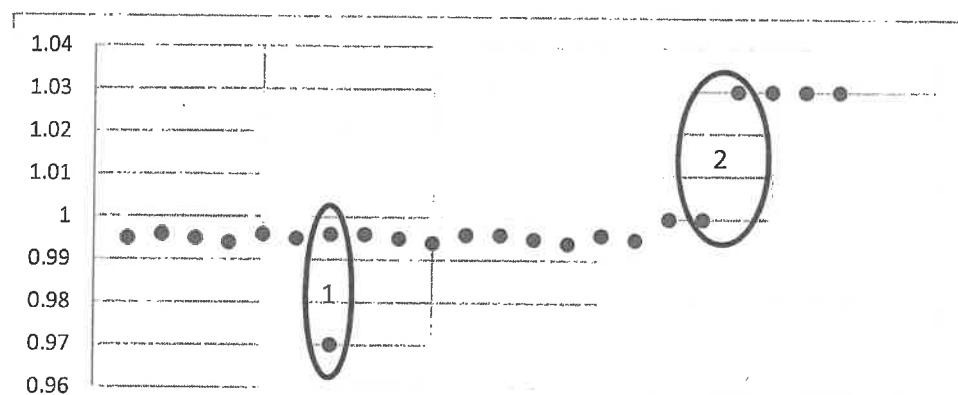
8-Graphs of  $g(r)$  is given vs. distance and asked us to label the isotopes for each: Cs, I, Pd

[something similar to this graph but for Cs, I, Pd]



9-Daily QA is systematically off (close to but less than 3% high)? What do you need to investigate?

Region 1 or 2 (graph similar to this)



10-Used a cutout for electron, what doesn't change? Range/energy/PDD/..

11-Electron output is off in consecutive days, what parts need attention? Ion Chamber

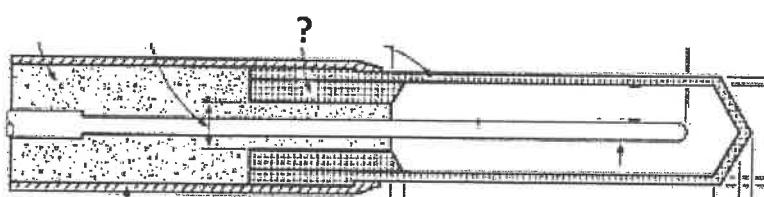
12-Image of a vaginal cylinder with artifact give, asked what the artifact is? Motion, photon starvation, ring,

13-Image of T&O with asymmetric ovoids given. Asked where points A are defined with respect to what line.

u<sub>c</sub> G<sub>y</sub>.

14-Pt had 25 fxs of CBCT (360 degree). Estimate the pacemaker dose that was in the field from imaging.  
1Gy

15-Farmer chamber picture given, what is that material? Graphite

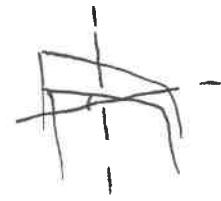


16-What is the new use factor if CT scan is replaced by a PET/CT? 1

17-How wedge angle is defined? With respect to a perpendicular line to CAX.

18-Why we need MLC position accuracy.

19-CT#s of -50,0,50, what are the materials: fat, water, muscle.



20-Breast tangent isodose lines change due to? Wedge angle, energy,..

21-What is source of differentiation in cell killing for tumor vs. normal cells? Oxygenation, mitosis rate,

...

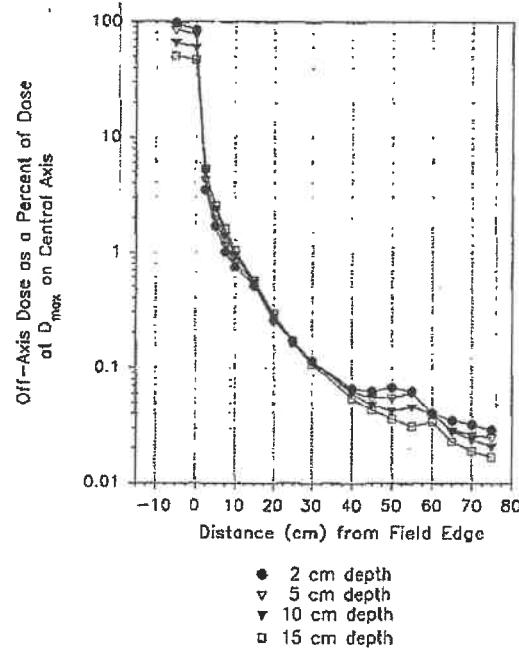
22-OARs are segmented. What DICOM have them? Structure set

23-Pregnant worker need to do first? Written declaration, blood test, ...

24-Dose to fetus? The total dose at CAX given.

Distance from edge of the field given (about 22 cm).

Graph of off-axis dose given.



25-Left OSLD in vault 1 m away from gantry. Delivered 8Gy. What is the extra dose to OSLD?

26-Ion chamber region in ionization curve? Region 2

27-What to use to measure dynamic wedge profile? Diode array and film (both)

28-Prostate vol 45 cc. D100=93%. What is the volume of prostate that didn't receive the prescribed dose.

29-DVH is given. Asked to interpret.

30-TG51: At what depth is the photon beam quality defined? 10cm

31-Which survey meter should be used for shielding? Large vol. IC, GM, ...

32-4DCT included. Calculate the load. Simple multiplication.

33-Two axial pet scans are shown of the same place. Asked why they differ? Attenuation correction, inverse grayscale,...

34-TG51: Electron cross cal for pp done for highest electron energy.

35-What is the danger in installing research software on a clinical machine? Mistakenly used for patients.

36-Dose limit to public?

37-In vivo dosimetry with diode: entrance and exit doses are different, why? Energy dependency, SNR,...

38-What is the SNR in penumbra? 1:1, 10:1, 100:1, 1000:1

39-What is the HDR output constancy? 3%, 5%, ...

40-DVH was given, asked what is D<sub>100</sub>? Or so!

41-Pion limit is 5%.

5% for Pion is the limit.

## Part II Note:

1. Yahoo downloaded therapeutic study guide included
2. 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010 recall included
3. Raphex 2006, 2007, 2008, 2009, 2010, 2011 included

1. Treatment related: (review+ 3)
2. Brachytherapy (+ 3)
3. TBI: (+ 3)
4. QA: (+ .3)
5. Shielding: (+ 3)
6. Radiation safety: (+ 3)
7. Dose/MU Calc: (+ 3)
8. TG51: (+ 3)
9. SRS: (+ 3)
10. LINAC(+ 3)
11. Beam Data/Measurements: (+ 3)
12. IMRT(+ 3)
13. Atom and radioactive decay: (+ 3)
14. Imaging: (+ 3)
15. Tissue inhomogeneities: (+ 3)
16. Electron dosimetry: (+ 3)
17. Dose calculation: (+ 3)
18. Radiobiology: (+ 3)
19. Others: (+ 3)

### Treatment related:

All of the following procedures are commonly used for pre-treatment setup verification. For an IMRT prostate treatment, all of the following would be acceptable methods of verifying the prostate position, except:

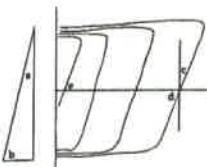
- A. Orthogonal kV images of gold seeds implanted in the prostate.
- B. Orthogonal kV images of bony anatomy.
- C. Cone beam CT.
- D. Imaging the prostate with ultrasound.
- E. Imaging implanted RF transponders.

B

Bony anatomy is not a good surrogate to be used in patient setup because it does not follow the motion of the prostate, which can be influenced by adjacent bladder and rectal filling. A system of markers which can be followed during treatment would be the best surrogate for prostate position assessment.

In the diagram below, the wedge angle is \_\_\_\_\_.

- A.
- B.
- C.
- D.
- E.



For a 10x10 cm photon field, the TMR and FDD (fractional depth dose = PDD/100) are both 1.0 at depth  $d_{max}$ . At depth  $d=10$  cm, the TMR is larger than the FDD. This is because:

- A. TMRs do not account for attenuation.
- B. FDDs contain an inverse square component.

B

TMR represents the attenuation of  $d$ -cm of tissue, while FDD represents attenuation and inverse square falloff between  $d_{max}$  and depth  $d$ .

The depth of maximum dose for a photon beam is approximately equal to:

- A. The depth at which dose and kerma are equal.
- B. The maximum range of the secondary electrons.
- C. The depth at which electronic equilibrium occurs.
- D. All of the above.

D

Suppose that a photon undergoes a Compton interaction in which the backscattered photon has the minimum energy. At what angle is the Compton electron emitted relative to the direction of the initial photon?

- A. Cannot be determined from the information given.
- B. 0°

B

The minimum energy for a backscattered photon always occurs at 180° to its original direction. When this happens, due to conservation of momentum, the Compton electron must go off in the direction exactly opposite to the backscattered photon: 0° relative to the direction of the initial photon.

All of the following are properties of electromagnetic radiation, except:

- A. Obey the inverse square law for point source.
- B. Travels at a constant velocity in a vacuum.
- C. Can be deflected by a magnetic field.
- D. Is exponentially attenuated by a medium.
- E. Is composed of perpendicular electric and magnetic fields.

C

Only charged particles are deflected by a magnetic field, not electromagnetic radiation.

When a therapy beam of nominal energy 23 MV interacts with soft tissue, which of the following is true?

- A. Pair production predominates.
- B. Pair production and Compton are about equally probable.
- C. Photoneuclear disintegration predominates
- D. Compton predominates.

We use 23MV because it's in the Compton range!, actually Compton is from 25kV to 25 MeV. The 23 MV is the nominal highest energy, the peak energy is around 23/3 or 23/4. So it is with Compton range.

The approximate maximum dose to a patient's contralateral breast from tangential breast fields treated with conventional wedges, and delivering a total dose of 3000 cGy is of the order of:

- A. 2500 cGy.
- B. 250 cGy.

Parallel-opposed 18 MV photon beams ( $d_{max} = 3.5$  cm) are used to treat an area which includes nodes at a minimum depth of 2.0 cm. If the nodes are to receive at least 90% of the midplane dose:

- A. 3.5 cm bolus is needed.
- B. More than 3.5 cm bolus is needed.
- C. Between 2 and 3.5 cm bolus is needed.
- D. Bolus is not needed.

Each field contributes about 2.5% of the prescribed dose: the lateral field contributes internal scatter, and the medial field contributes dose from the physical wedge. If a dynamic wedge is used, this will reduce the contralateral breast dose by almost one-half.

In the treatment of Hodgkin's disease with a mantle field on a linac, patients may experience a skin reaction in the neck region. This could be due to which of the following?

- A. Smaller thickness of tissue at neck than on the central beam axis.
- B. Oblique incidence at sides of neck reduces skin sparing.
- C. Use of a blocking tray and large field size tend to increase skin dose.
- D. All of the above.

13. Patient was treated with 100 cm SAD setup with thickness separation of 22 cm.

Patient is moved to cobalt with 80 cm SSD setup. What is the new field size?

### B. Oblique beam increase skin dose

$$\frac{80}{91} \cdot FZ$$

Assuming the field size at the treatment depth 11 cm is FZ, move to the patient with Co60 setup, but we need to maintain the same field size at depth, and the field size defined for Co60 is at surface for SSD setup,  $\rightarrow FZ/(80+11) \times 80 = 80/91 \times FZ$  ()

16. Given the attenuation coeff of 0.018 cm<sup>2</sup>/gm, depth of 5.5 cm with dmax of 2 cm, what is PDD at depth? TSD = 100 cm

No information given for scattering part, so ignore it for this question;

$$PDD = \exp(-0.018(5.5-2)) \times (102/105.5)^2 = 0.88$$
 ()

41. 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. Basically I think the depth was measured assuming isocenter at midline, then question was asking what is the true depth.

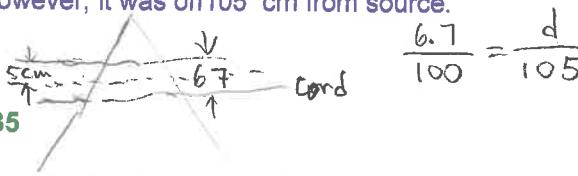
Assuming the cord depth (pt in supine, from posterior) was already taken into account the source to film depth, meaning the therapist thought the cord was at midline at isocenter. However, it was on 105 cm from source.

film cord depth fx, source to film distance SFD, so

$$fx/SFD = 6.7/100 - (1)$$

$$fx/SFD = \text{true depth}/105 - (2)$$

$$\text{Therefore, the true cord depth can be } 6.7/100 \times 105 = 7.035$$



The choice of photon beam energy in a treatment plan is governed by all of the following, except:

- A. Depth to the isocenter.
- B. Proximity of PTV to lung.
- C. Depth of PTV below the surface.
- D. Neutron leakage outside the beam.
- E. PTV dimension in the longitudinal direction.

In general, a higher beam energy will deliver a more homogeneous dose distribution, with a lower maximum dose. However, if the PTV is close to the skin or to overlying lung, a lack of buildup may underdose part of the PTV. Also, a 15 MV photon beam delivers a small neutron leakage dose to the patient outside the beam, while a 6 MV photon beam does not.

Longitudinal direction is the direction parallel to the beam!!

When the gross tumor volume is expanded to create the clinical target volume, it will typically be limited by physical boundaries such as bone, which will limit the spread of disease. However, the expansion of the CTV to create the PTV is to allow for patient movement and setup error, so this margin is not limited.

When expanding a \_\_\_\_\_ to create a \_\_\_\_\_, expansion into bone will typically be excluded.

- A. GTV, CTV

Regarding virtual simulation, all of the following are true, except:

- A. The time for simulation of the patient can be reduced.
- B. The treatment isocenter can be related to arbitrary triangulation points marked on the patient's skin and visible on the CT.
- C. 3-D visualization of the patient is used to optimize beam placement.
- D. Any beam that can be visualized in 3-D can be treated on the linac.

Beams that appear to be optimal sometimes cannot be physically set up on the linac. For example, some posterior oblique fields with a couch rotation could result in a collision between the head and the couch. Plans with this type of field must be checked on the linac before the plan is finalized.

The f-factor is all of the following except:

- A. The roentgen-to-rad conversion factor.
- B. Generally greater for high-Z materials.
- C. Generally greater for low energy.
- D. Has the value 0.876 in air for Co-60 photons.
- E. Is 1.0 for water at 1 MeV.

(E): For choice (C) for low very energy, the f factor is greater due to photoelectrical effect

(Kahn, p110)

In soft tissue, a beam of 9 MeV electrons loses most of its energy by:

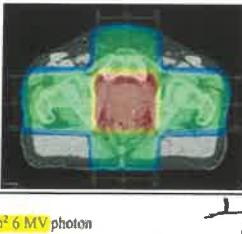
- A. Bremsstrahlung radiation.
- B. Ionization.
- C. Compton interactions.
- D. Collisions with nuclei.

Electrons lose most of their energy in soft tissue by ionization and excitation of the tissue atoms. Collisions with atomic nuclei resulting in radiative losses are also possible, but less likely in low-Z media.

That's why use 9MeV for treatment!!

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.

4 field box, the dose distributed very uniformly in the center box, Bentel (p466 Fig. 13.25) The anterior rectum wall is



$$3\% \times (1 - 15\%) \\ 3\% / \text{cm} \times 5 \\ 0.85$$

within the target, so 200 cGy is correct.

The dose under a 1.5 cm width lead block (5 HVL thickness) in a 15 x 15 cm<sup>2</sup> 6 MV photon beam at 5 cm depth due to transmission plus scatter is approximately \_\_\_\_\_ % of the dose in the open beam.

- A. 3
- B. 7
- C. 15

Should be 3% → transmission

3% + 12% scattered from tissue. Example 8 p183 in Kahn gives around 17% scatter dose under 4 x 15 block for Co60.

T33. Decreasing CT slice thickness during CT-simulation is useful in image-guided radiation therapy (IGRT) because:

- 1. Of decreased CT dose to the patient.
- 2. Less work is required for normal tissue contouring.
- 3. Inhomogeneity corrections are significantly more accurate.
- 4. Image quality of DRR improves.

T33. D

Spatial resolution in the caudal direction for CT-generated digitally reconstructed radiographs (DRRs) is compromised when scanning with large slice thicknesses. The disadvantage of using a small slice thickness is the increased size of the dataset, and hence possibly more work involved in contouring structures.

T31.

For a superficial x-ray unit, if there is no measured data, the two factors necessary to select the correct PDD table from published data are:

- A. Field size and kVp.
- B. kVp and SSD.
- C. HVL and SSD.
- D. Filtration and SSD.
- E. Filtration and field size.

T31. C

The HVL (in Al or Cu) defines the penetrability of a low-energy X-ray beam. Different combinations of kVp and filtration can produce beams with the same HVL, and hence the same depth dose characteristics. The SSD also affects the PDD and is important for superficial x-ray units that typically treat at short SSDs.

The HVL define the energy and SSD is important to determine the PDD.

T18.

In a 3-field plan to treat the rectum using open PA and wedged lateral fields, a homogeneous distribution can be obtained in the PTV with either 45° or 60° wedges. With 60° wedges, the relative dose at the isocenter for the PA field would be \_\_\_\_\_ that in the 45° wedged plan.

- A. Greater than

T18. A

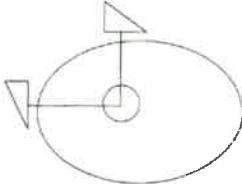
The lateral wedges compensate for the dose falloff across the volume from the open field. The greater the weight of the open field, the greater the actual difference in dose across the volume, and hence the greater the wedge angle required to compensate for this gradient. The difference between the two plans would be seen in the exit dose of the open beam, and the entrance doses of the wedged fields (i.e., femoral head vs. small bowel dose).

T15.

The wedge angle that would give the most homogeneous distribution in the "wedged pair" in the diagram below is \_\_\_\_\_ degrees. (Field axes are at 90°).

- A. 10
- B. 20
- C. 30
- D. 45
- E. 60

$$\theta = 90^\circ - \frac{\phi}{2}$$

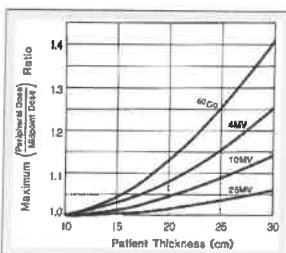
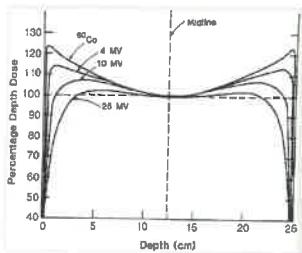


$$D: 45 = 90 - 90/2$$

T7.

A patient is planned for equally weighted, parallel-opposed 6 MV photon fields treating the mediastinum, AP thickness 22 cm. If the beam energy is changed to 18 MV photons, all of the following would decrease except:

- A. MU.
- B. Skin dose.
- C. Depth of maximum tissue dose.
- D. Percent variation in dose across the treated volume.

10 x 10, SSD 100 (Kahn)

A: The MU decrease because the PDD for 18x is higher than the 6x, so for the same dose,  $MU(18x) = D/PDD(18x)$ , larger  $< D/PDD(6x)$ , smaller  $= MU(6x)$ . C. The d<sub>max</sub> is deeper for high energy therefore the depth of d<sub>max</sub> for parallel opposite beam for 18x is larger/deeper (C is the answer)

T4.

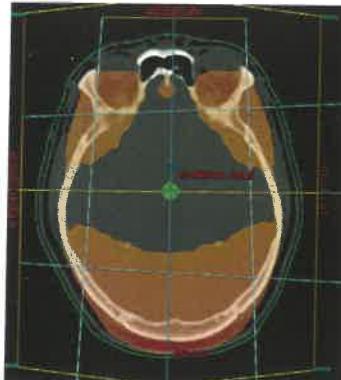
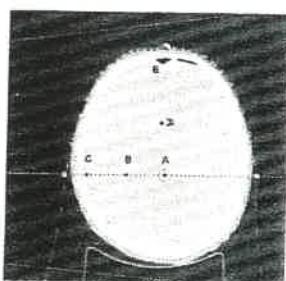
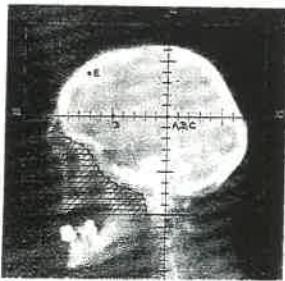
The maximum dose along the beam axes in T3 is:

- A. 250 cGy.
- B. About 20% greater than 250 cGy.
- C. About 10% greater than 250 cGy.
- D. About 2% greater than 250 cGy.

2% for 6x thickness is around 16 cm

T5. The location of the maximum dose, for treatment with 6 MV photons, is point \_\_\_\_\_ on the diagram below.

- A
- B
- C
- D
- E



E due to less thickness

A patient is treated with AP/PA isocentric fields to the mediastinum. The total midplane dose on the axis is 4500 cGy. The dose to the spinal cord will exceed 4500 cGy:

- A. If the patient is treated with 4 MV x-rays.
- B. If the cord is not a midplane structure.
- C. If the patient's AP thickness is less at the neck end of the field.
- D. All of the above.

The increase in cord dose over midplane dose on the central axis will be greatest for lower photon energy, and for the greatest difference between AP thickness at the neck and at the beam axis. Also, for AP/PA fields, the closer the point is to d<sub>max</sub>, the greater the increase over the midline dose.

D

When treating a lung volume with off-cord parallel-opposed oblique fields, 10 MV photons may be chosen by the physician over 6 MV photons because:

- A. 6 MV would give inadequate dose in the build-up region.
- B. Lung corrections are more accurate with higher energy.
- C. The total dose at d<sub>max</sub> is less with 10 MV.
- D. The cord dose is less with 10 MV.

Look at the question!, it already said "off-cord"!

A wedged tangential breast plan is calculated without heterogeneity corrections. The same plan is then calculated with heterogeneity corrections, then adjusted to optimize dose homogeneity. In general, the plan with heterogeneity:

- A. Requires a smaller wedge angle.
- B. Results in a greater maximum tissue dose.
- C. Results in a higher skin dose.

A

The increased transmission through lung at the chest wall side of the field generally requires a smaller wedge for a homogeneous distribution. The effective patient thickness will be less, resulting in a lower maximum tissue dose.

Large penetration so we need less wedge to push the dose toward deeper side.

T43. Variations in size, shape, and position of the target due to a patient's breathing and internal organ motion are accounted for in creating the \_\_\_\_\_.  
(definitions per ICRU report 62: ITV = internal target volume  
IM = internal margin  
SM = set-up margin)

- A. GTV
- B. CTV from the GTV
- C. PTV from the ITV
- D. PTV from the GTV and SM

T43. C ICRU Report 62 defines the Internal Target Volume (ITV) as the volume formed by the Clinical Target Volume (CTV) and the Internal Margin (IM). The ITV represents the volume encompassed by the CTV as it moves with breathing and internal organ motion, and is distinct from the Setup Margin (SM). Both SM and IM are used to create the Planning Target Volume (PTV) from the CTV.

T40. A pregnant woman is treated for Hodgkin's disease with AP/PA 6-MV mantle fields, to a total dose of 4000 cGy. The fetus is 15 cm from the field edge. Without supplementary shielding, the maximum dose to the fetus would be approximately \_\_\_\_\_ cGy.

- A. 300-400
- B. 100-200
- C. 20-80

T40. C

The dose to the fetus depends on its distance from the field edge, but from 10 to 20 cm the dose at 10 cm 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 Radiation Therapy Committee Task Group 36, Reprinted from *Med Phys* 22(1):63-82, 1995.) The dose is made up of patient scatter, head leakage, and radiation scattered from the collimators and blocking tray.

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

10X10 field 10 deep (TG36, data	2 cm	5 cm	10-20 cm
6x	5 - 7 %	3 %	2 - 0.6 %
15x	5 %	2 %	0.4 - 0.1 %

A patient is treated with 6 MV tangential breast fields. The dose to the patient's ovaries 20 cm inferior to the fields, is approximately \_\_\_\_\_ % of the prescribed dose.

- A. 0.005
- B. 0.05
- C. 0.5
- D. 5

It has been recommended that the dose to a pacemaker be kept below 2.0 Gy. In a lung treatment of 40 Gy with 6 MV photons, the fields should be no closer than \_\_\_\_\_ to the pacemaker.

- A. 0.5 cm
- B. 2 cm

T18. The surface dose for a  $10 \times 10 \text{ cm}^2$ , 6-MV photon field at 100 cm SSD is about:

- A. 95%-100%.
- B. 80%-95%.
- C. 15%-40%.

T18. C The surface dose is about 15% to 40%, depending on field size.

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

T93. If a 1 mm Al filter is replaced with a 2 mm Al filter on a superficial x-ray machine, the effect will be to:

- A. Harden the beam.
- B. Reduce the dose rate at  $d_{\max}$ .
- C. Increase the PDD at 1 cm depth.

A, B & C. Beam harden induces stronger penetration, higher mean energy, so the PDD increase after  $d_{\max}$ .

T138. Comparing prostate treatment using a 5-field 15 MV IMRT photon treatment plan with a proton plan using parallel-opposed lateral fields, the proton plan has:

- A. A lower integral whole-body dose.
- B. Better conformality to the PTV.
- C. Lower rectal dose.
- D. Lower bladder dose.

T138. A This is the only advantage for prostate treatment with protons.

The seminal vesicles are located \_\_\_\_\_ and \_\_\_\_\_ to the prostate superior and posterior

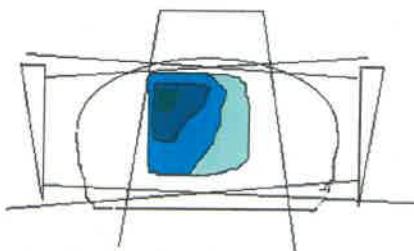
\*What is the duty cycle in respiratory gating? the beam on fraction of the whole respiratory cycle ... (perez and brady's Fig. 10.28 and p288)

Question on Gating : (perez and Brady's 284-285)

\*A 5.4cc target in SRS has a conformity index of 2.3. How much normal tissue received the prescribed dose? following ICRU62, CI = treated vol / PTV , so  $5.4 \times 2.3 - 5.4 = 7.02 \text{ cc}$  ()

\*Determine the linear attenuation coefficient for a material, where both of d and d(eff) are given, and also HVL is given.  
 $\mu = \ln 2 / HVL$

\*Shown a setup with AP, Lt Lat, and Rt Lat fields. The Rt and Lt Lateral fields were wedged. The isodose distribution looks like the picture below. Another picture with a uniform isodose distribution is shown. You must choose which field weights and wedge weights to change in order to make the picture below look like a uniform isodose distribution:



$$\textcircled{2} \quad \frac{100}{(X+12)} = \frac{25}{20}$$

$$X = 80 - 12 \\ = 68 \text{ cm}$$

Increase the wedge angle and increase the weight of LLat, lower the weight of AP as well? ...  
 i may increase the wedge and lower the weight of AP and R-Lat or just increase the weight of L-Lat()

238. A setup calls for a 25 cm field length at 100 SAD. The SSD is 88 cm. However, the field requires a wedge that has a field size limit of 20 cm at isocenter. What must the new SSD be in order to accommodate the wedge?  
 depth = 12cm;  $20/25 = \text{SPD}/100 \rightarrow \text{SPD} = 80 \rightarrow \text{SPD} = 80 - 12 = 68\text{cm}$ , SPD source to the treatment point.

\*Gap calculation: SAD 90 depth = 10, FS = 24cm , but the treatment distance is changed to 100 SAD, d=10, FS=32cm  
 $S = S_1 + S_2 = 0.5L_1x(d/\text{SSD}_1) + 0.5L_2x(d/\text{SSD}_2)$ ,  $0.5(24)x(10/90) + 0.5(32)x(10/100) = 1.33 + 1.6 = 2.93\text{cm}$  (SC)  
 The question most likely ask SSD rather than SAD for the 2<sup>nd</sup> setup

\*Standard Gap Calc between a treatment with an SSD setup and a treatment with an SAD setup. Answer was 1.95 cm gap on skin. Options included 1.9 cm and 2 cm. I chose 2.

\*What happens to surface dose and %DD by adding a physical wedge?

I vote surface dose will decrease due to beam hardening so it will be large penetration and %DD will increase (Kahn Fig. 11.6, , ) Wedge is more toward beam hardening and lesser extent by Compton scattering.

\*Film exposed for dosimetry. Given transmitted light is 200 times smaller than original, what is the dose? OD vs dose table is given.

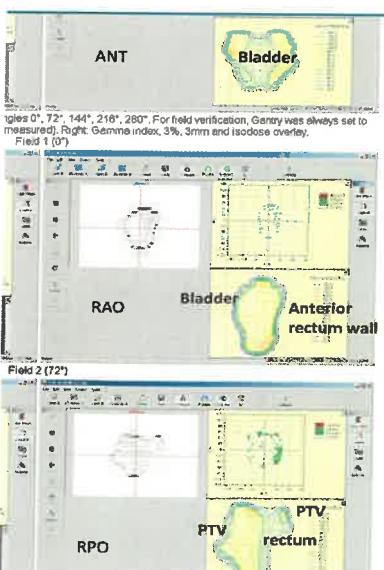
$1/200 = 10^{(-OD)} \rightarrow OD = 2.3 \rightarrow$  dose based on OD vs DOSE table.

$\log 200$

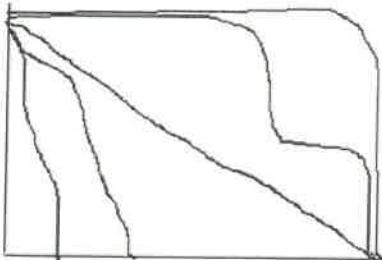
130. Which organ shows partial volume effect? Brachial Plexus, Kidney, Optic nerve, etc.  
 kidney, lung, liver, bladder, rectum, parotid, heart, esophagus.

125. Shown an IMRT fluence map for a 5 fields prostate IMRT, identify the various fields.

Find this link, it's not fluence but dose distribution. For AP field, it faces bladder, so the central dose is low. Because the dose constraint for rectum is more stringent than bladder, so we can see the RAO and RPO field show higher dose on the bladder side, same thing for LAO & LPO. ()  
[http://www.wienkav.at/kav/kfj/91033454/physik/aS500/aS500\\_imrt.htm](http://www.wienkav.at/kav/kfj/91033454/physik/aS500/aS500_imrt.htm)

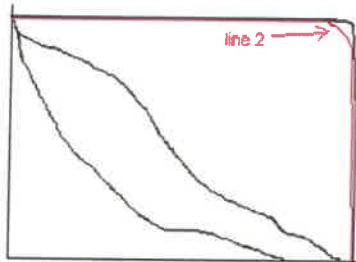


Shown DVH and must choose the DVH line representing most heterogeneous dose distribution the diagonal line



188. Given a diagram of a DVH that shows critical organs, PTV and GTV curves. Choose which curve represents the GTV

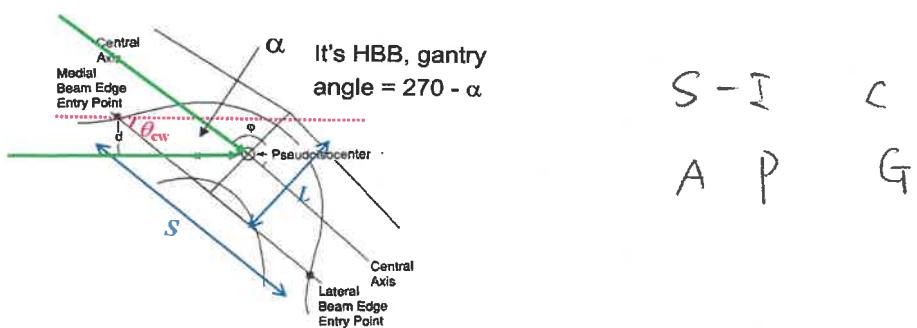
- Which structure does line 2 represent on this DVH for an IMRT plan? PTV



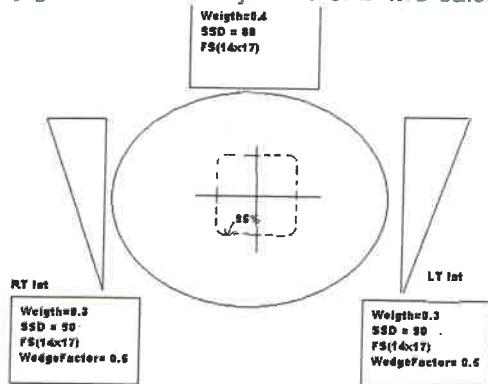
- Which of the following is used for palliative treatment of bone mets? Sr-89, I-125, P-32 (from 2002 recall)  
I think the problem could also be asking which isotope is used to treat Bone Meta. If so, my answer would be Sr-89 or P-32.()  
Sr-89 (also for eye treatment) and Sm-153 are given by Handbook of evidence-based radiation oncology 2nd p681,()

\*For a H&N case, calculate couch kick given the field sizes to match the inferior borders to an SCLAV field.  
It can be the 2 lateral field + 1 anterior SCV field treatment. (Fig. 9.15 Bentel, )  
Not sure if this expression is applicable to this problem couch =  $\text{arcTan}(L_2 * \text{SAD})$  JPS

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



My guess: this could just be SAD MU calc. ()



Yes but be careful; The SCD is given at SSD+dmax not at SAD=100cm. JPS Assuming this is isocentric 15x treatment, but the calibration was done at dmax + SSD. The output should be corrected by inverse square as  $1 \text{ cGy/MU} \times ((100+2.5)/100)^2 = 1.05 \text{ cGy/MU}$

Equivalent square field size =  $2 \times 14 \times 17 / (14+17) \sim 15$

Dose for AP at iso ( $D_{AP}$ ) =  $200 \times 0.4 / 0.95$

Dose for RT Lat at iso ( $D_{RT}$ ) =  $200 \times 0.3 / 0.95$

Dose for LT Lat at iso ( $D_{LT}$ ) =  $200 \times 0.3 / 0.95$

$$MU_{AP} = D_{AP} / (1.05 \times TMR(d=20, 15) \times Sc(15) \times Sp(15))$$

$$MU_{RT} = D_{RT} / (1.05 \times TMR(d=10, 15) \times Sc(15) \times Sp(15) \times 0.5)$$

$$MU_{LT} = D_{LT} / (1.05 \times TMR(d=10, 15) \times Sc(15) \times Sp(15) \times 0.5)$$

$$\text{The ratio of MU} = 0.4 / TMR(20, 15) : 0.6 / TMR(10, 15) : 0.6 / TMR(10, 15) ()$$

13. Calibrated in SSD100+dmax, TPS set SAD, depth 10cm, what is the dose/MU should be?

convert calibration at 100SSD Dmax: 100 SAD Dmax by inverse square law as:

$$(100+dmax)^2 / 100^2 \rightarrow \text{calc D10cm by TMR} ()$$

This question may ask calibrating machine at SSD = 100, dmax (6x 1.5 cm) with 1 cGy/MU and what's the dose/MU at SAD 100 d = 10 cm; the output will be changed from  $1 \text{ cGy/MU} \times (101.5/100)^2 = 1.03 \text{ cGy/MU}$  and then  $1.03 \text{ cGy} \times TMR(10)$  to get the Dose/MU at depth 10 cm

$$\text{SAD} = \left( \frac{101.5}{100} \right)^2 \cdot TMR$$

Find the MU's to deliver 90cGy (isocentric) with a wedge (WF=0.77) and open field size of 17x17 and blocked field of 11x11. Machine calibrated at SSD, dmax=3.3cm, 1cGy/MU. Current SSD=88cm (so treating 12 cm depth), Sc, Sp, and TMR tables given for all field sizes and all depths.

inverse square:  $1 \text{ cGy/MU} \times 1.033^2 / 1^2 \rightarrow 1.07 \text{ cGy/MU}$  for SAD setup  $\rightarrow$  SAD MU calc (please correct me if I'm wrong)

Assuming the machine was calibrated at SSD = 100, and dmax = 3.3 cm at 1cGy/MU, we will need to correct the output using the inverse square law

$$MU = 90 \text{ cGy} / (TMR(12, 11) \times Sc(17) \times Sp(11) \times 0.77 \times 1 \text{ cGy/MU} \times (103.3/100)^2) ()$$

\*A dose calc where you have SSD, Dose rate at Dmax for 100 SSD setup, and a depth of 10 (PDD given). For the given setup, they give you the MU required to give the dose. For the same dose delivered to an SAD field at a depth of 10 (They stated the TMR), how many MU's do you need?

Here is my calculation, assuming machine is calibrated 1 cGy/MU at dmax, SSD = 100 for 6x, field size S, and Sc and Sp measured at dmax;  $MU_{ssd} = D / (1 \text{ cGy/MU} \times \%DD(10) \times Scp(S))$ .  $Scp(S) = D(10) / (\%DD(10) \times MU_{ssd}) - 1$

Changing to SAD setup;  $1 \text{ cGy/MU} \times (100+1.5/100)^2 = 1.03 \text{ cGy/MU}$  at dmax with SAD setup.

$$MU_{SAD} = D / (1.03 \text{ cGy/MU} \times TMR(10) \times Scp(S)) - 2$$

We put eq. (1) into (2), we can get the  $MU_{SAD} = 0.97 \times (\%DD(10) / TMR(10)) \times MU_{ssd}$  ()

\*The Sc(S) does not change from SSD to SAD setup, and for Sp, even the field size change due to divergence at dmax from SSD to SAD setup, Sp(S) normalized to the same 10 x 10 field or  $10 \times (90+1.5)/(100+1.5)$  field, so the Sp still won't change

Another observation for this problem is that; we can get the dose from the SSD setup, and then plug into the SAD setup to calculate the MU but changing the output with inverse square law.

\*When transferring a patient to a Co-60 unit after being simulated and treated in a SAD = 100 cm calculate the changes to the setup in linac. The treatment in Co-60 had to be done with SSD setup. Thickness of patient given.

The MU will be corrected by the inverse square law, and also the change of the collimator scattering factor Sc, assuming we treat the patient at the same depth and same field size at that depth. Therefore, the phantom scatter Sp will not be changed. A good example is shown in the ESTRO booklet, [http://www.estro-education.org/publications/Documents/Booklet\\_n6PhysicsforClinRTcorected17May2011.pdf](http://www.estro-education.org/publications/Documents/Booklet_n6PhysicsforClinRTcorected17May2011.pdf) Example 6 p74-75 ()

1. Tables of 4 MV and 6 MV PDD and TMR VS field size given. Also. BSF, not Normalized Peak Scatter Factors were given. Know how to obtain MU settings for different field sizes:

-In general: most of the time the calibrations were at SSD + dmax.

-In some problems the Scp was not given.

- 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). (Kahn Ch9 sec c)

- Calculate the dose to cord at 4 cm, given everything needed for a SAD setup.

2. Be able to find cord dose given CAX dose from AP/PA treatments.

**T56.** A patient's spine is treated at 130 cm SSD, in order to obtain a longer field. Compared with the same collimator setting treated at 100 cm SSD, all of the following are true, except:

- A. The PDD at 6 cm depth will be slightly greater.
- B. The output (cGy/MU) at  $d_{max}$  will be  $[(100+d_{max})/(130+d_{max})]^2$  of that at 100 cm SSD.
- C. The exit dose will be greater.
- D. The surface dose will be slightly greater.

**T56. D** The surface dose will be slightly less at extended SSD.

4 cm

Check my personal note

**T58.** A patient's abdomen is treated with AP/PA isocentric 6 MV photons. During treatment the patient's AP separation increases from 24 to 28 cm. The dose delivered, if uncorrected, will be:

- A. 15% low.
- B. 7% low.
- C. 3% low.
- D. 7% high.
- E. 15% high.

**T58. B** Attenuation is about 3.5% per cm for a 20x20 cm 6 MV photon beam at  $d = 12$  cm. An increase of 4 cm total, or 2 cm per beam, will reduce the dose at the isocenter by about 7%.

The timer error of a orthovoltage unit is + 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.

@2cm, the dose rate is 75cGy/min  $\rightarrow 1.25cGy/sec$ ;  $1.25 \times 0.02$ (dose within this 0.02s) / 0.01(this dose only can be 1%) = 2.5cGy ( ) Basically, 0.02s needs to be with 2 s to be 1% uncertainty, so  $2.5 \text{ cGy} / 1.25 \text{ cGy/s} = 2 \text{ sec}$ , reasonable number

\*What is the definition of wedge angle?

The angle through which an isodose curve is tilted at the central ray of a beam at a specified depth, currently the depth is 10 cm. Khan sec. 11.4.a ()

\*Given mixed energy, electron and photon, dose to surface = 40 Gy and PDDs at surface for each given, and dose to  $d=5$  cm = 55 Gy, PDDs for each at  $d=5$  given, what are the relative contributions of photons and electrons at  $d_{max}$ ?  
My try:  $X*PDDe(\text{surface}) + Y*PDDx(\text{surface}) = 40$ ;  $X*PDDe(5\text{cm}) + Y*PDDx(5\text{cm}) = 55$  ()

\*Why does the equivalent square technique work?

The equivalent square gives the same PDD and output because it emulates the same scattering property of the true field (Metcalfe, p391, )

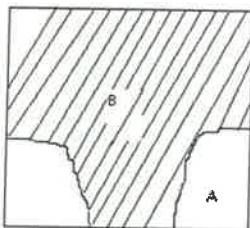
32. Mayneord's Factor is more accurate for: 6MV, 6x6, 110 SSD; 6MV, 30x30, 150 SSD; 15MV, 6x6, 110 SSD; 15MV, 6x6, 150 SSD; etc.

The Mayneord F factor is not considering scattering, so it's more accurate for the beam that has less scatter. So, smaller field size will be more accurate to use the Mayneord's factor, large SSD will have beam divergence so we will have large field size on the surface (Kahn sec. 9.3.c, ) F factor doesn't work well for 1. Low energy, 2. Large field, 3. Large SSD and 4. Deeper depth due to scatter (Kahn 3rd p163, and MetCalf p272)

\*Three isocentric beams 120 deg apart, AP and post obliques. Each goes through 15 cm depth to isocenter. 180Gy at isocenter weighted equally for three beams. Post beams transfer 9cm lung (electron density= 0.33), TMRs given at 3,6,9,12,15 cm. Calculate MU(post obliques)/MU(AP).

Here is my formula;  $MU(\text{oblique})/MU(\text{AP}) = \text{TMR}(15)/\text{TMR}(\text{radiological depth}) = \text{TMR}(15)/\text{TMR}(9/3+6) = \text{TMR}(15)/\text{TMR}(9)$ , (TG114, )

Given dose to point A 200 cGy, calculate thickness of block to achieve point B dose 90 cGy. TMR, %DD, and HVL given,



depth may be different for B.

Here is my thought, following Kahn sec 10.3 example 8: Assume depth at point A, and B =  $d_A$ , and  $d_B$ , respectively. The field size for the whole field as S, and for B block field as  $S_B$ , and A field as  $S_A$ ;

The MU can be obtained from field A;  $MU = 200/\%DD(d_A, S_A) * Sp(S_A) * Sc(S) * OAR(\text{pointA})$ , if no OAR was given in the question, we can just assume it's CAX for point A.

For point B,  $90 = MU * \%DD(d_B, S_B) * Sp(S_B) * Sc(S) * 0.5^n$ , we can solve this equation to get block thickness n. ()  
Here assuming the corner block contribution to the point B is small.

\*Sim film taken at 102cm SSD, SFD 140cm. Want to treat at 120cm SSD. What distance to film should be used when cutting blocks.  $102/140 = 120/X \rightarrow X = 164.7$

\*If the patient thickness is 22 cm, SAD=100 cm, source to film distance is 130 cm, d=11 cm if technique is changed from SAD to SSD, What is the new source to film distance.

$$100/130 = 111/X \quad X = 144.3$$

\*Field size is measured 56 cm on patient skin and collimator 40 cm with table at its lowest position 167 cm from the source. What's patient size (including setup bag etc.)?

$$40/56 = 100/X \rightarrow X = 140 \rightarrow 167 - 140 = 27\text{cm}$$

$$\frac{40}{56} = \frac{100}{X} \quad \cancel{X} \quad \frac{40}{56} \approx \frac{100}{X} \quad \frac{56}{40} = \frac{X}{100} \quad \frac{56}{40} = \frac{X}{167} \quad \frac{56}{40} = \frac{700}{X} \quad \frac{56}{40} = \frac{700}{167} \quad \frac{56}{40} = 7 \quad \frac{700}{167} = 7$$

\*Given diagram of one dimension blocked field with distance from CAX and table of SARs (0cm 6cm 9cm 10cm etc), calculate SAR.

CLARKSON's method, simple subtraction?

Agree (Kahn sec. 9.5.A)

Yes. I think Bentel has a detailed example of this calculation. JPS

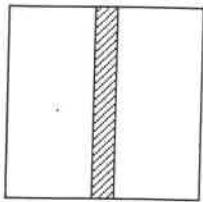
$$167 - 87.5$$

\*Given readings at 10 cm depth for 10 x 10 and 20 x 20 fields with 100 cm SAD, and two TMRs, calculate the Scp(20). It may calculate in this way; Dose1(reading1) =  $MU/(TMR(d=10, FZ = 10) * Scp(10))$ , where  $Scp(10) = 1$ , I assumed d = 10 cm is the reference depth, and Dose2(reading2) =  $MU/(TMR(d=10, FZ = 20) * Scp(20))$ , so  $Scp(20) = (D1 * TMR(10, 10)) / (D2 * TMR(10, 20))$  ()

15 x 15 field with 3 x 15 block in the center, which has 5% transmission factor. Depth at 7 cm, dose to point A given with 1.01 OCR, calculate dose to CAX under block, given table like:

FS	5, 7, 10, 15, 20
OF	
TMR(7cm)	
%dd(7cm)	

*dose  $\propto$  TMR Scp*



my try:

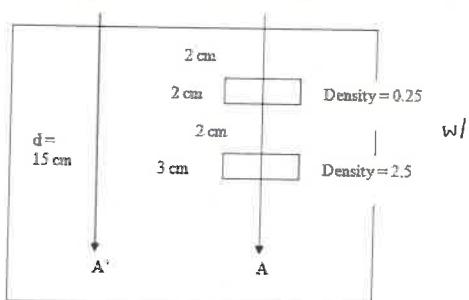
Assume point A is under one of the open portions of the field. Assuming no scatter from the other open field. for the open field, it's  $6 \times 15 \rightarrow F_{eq} = 8.57$ ; the block  $3 \times 15$ ;  $F_{eq} = 5$

Not sure if this question gives correct information, output factor is  $Sc$ , but we will need  $Sp$  as well, so

$$MU = \text{Dose at } A / (Sc(15) * Sp(8.57) * OCR * TMR(7, 8.57))$$

$$\text{Dose at CAX} = MU(Sc(15) * Sp(15) * TMR(7, 15) - Sc(15) * Sp(5) * TMR(7, 5) * 95\%) ()$$

179. From source to point A, there are: 100 cm SSD to surface, then 3 cm tissue, 2 cm inhomogeneity ( $re=0.25$ ), 3 cm tissue, another 3 cm inhomogeneity ( $re=2.5$ ), finally 4 cm tissue. So depth is 15 cm. 4MV beam delivers 200 cGy to point A with inhomogeneities. What's the dose to point A without the inhomogeneities? TMRs were given.  
 $3+2*0.25+3+3*2.5+4=18\text{cm} \rightarrow \text{use TMR}$



$$3 + 2 + 3 + 3 + 4 = 15$$

$$\text{Dose to point A' without inhomogeneity} = (200 / (\text{TMR(depth} = 18))) * \text{TMR(depth} = 15) ()$$

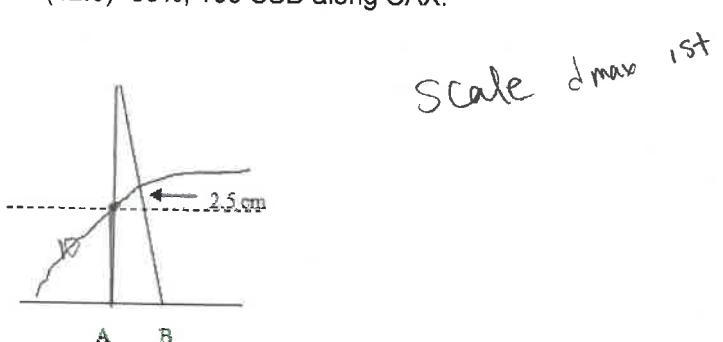
Similar question: Lung correction given dose with no correction - the corrected dose has 2 cm of lung and 4 cm of dense medium (4x tissue) - what is the dose at that second point?

Patient is treated to 10cm depth of chest wall with SAD of 100cm. There is 6cm lung within the central axis of beam. How much more dose will be delivered without heterogeneous correction? TMR for different depth are given.

$$\text{True radiological depth} = 6 \times 0.25 + (10 - 6) = 5.5 \text{ cm.}$$

$$\text{TMR}(5.5) / \text{TMR}(10)$$

\*If dose to point A (depth 10 cm) is 200 cGy, calculate dose to point B ignore beam divergence. %DD(10)=65%, %DD(12.5)=56%, 100 SSD along CAX.



Dose at  $D_{max}$  with  $SSD = 100$  is:  $200 / 0.65 = 307.7 \text{ cGy} \rightarrow D_{max}$  with  $SSD = 97.5$  is:  $307.7 * 100^2 / 97.5^2 = 323.7 \text{ cGy}$   
 Assume 6MV: %DD(12.5) with  $SSD = 97.5$  is:  $0.56 * ((97.5 + 1.6) / (100 + 1.6))^2 * ((100 + 12.5) / (97.5 + 12.5))^2 = 0.557$   
 Dose at B:  $323.7 * 0.557 = 180.3 \text{ cGy}$ .

$$\left( \frac{SSD_2 + d_{max,2}}{SSD_1 + d_{max,1}} \right)^2 \cdot \left( \frac{SSD_1 + d_0}{SSD_2 + d_0} \right)^2$$

Observe here that the PDD(12.5) does NOT change ( $0.56 \Rightarrow 0.557$ ) with the Mayneard Factor. In fact in Khan's discussion, the PDD correction factor by Mayneard Factor is not considered at all with the assumption that it does not change much. AA

Dose at Dmax with SSD = 100 is:  $200/0.65 = 307.7\text{cGy} \rightarrow$  Assuming 6x, Dmax with SSD = 97.5 is:  
 $307.7*(100+1.5)^2/(97.5+1.5)^2 = 323.4\text{cGy}$ , Dose at B:  $323.4*0.56 = 181\text{cGy}$ .  $\hookrightarrow 2.5$

\*Parallel opposed fields with equal weighting. 60 Gy in 30 fractions is prescribed to the isocenter. The fields are equally weighted. (SAD setup with iso at midsep). The patient separation is given, as well as the depth to the cord.

\*Cord sits 5cm posterior to midplane of a 24 cm thick patient treated 180cGy/day AP/PA to 12cm. How many fractions can be treated to keep the cord below the 45Gy tolerance. TMR's for d=5, d=12, and d=19 given. ---> needed to use ratio of TMR's to solve.

PA field MU =  $90/\text{TMR}(12\text{ cm})$

$$\frac{SSD}{D_{max,2}} = \frac{SSD_1 + d_0}{D_{max,1}}$$

$$\begin{aligned} PA \text{ to cord} &= MU \times \text{TMR}(5\text{cm}) \times (100/93)^2 = 90/\text{TMR}(12) \times \text{TMR}(5) \times (100/93)^2 - (1) \\ AP \text{ to cord} &= 90/\text{TMR}(12\text{cm}) \times \text{TMR}(19\text{cm}) \times (100/107)^2 - (2) \\ fx &= 4500 / (\text{eq}(1) + \text{eq}(2)) \end{aligned}$$

Shouldn't there be an inverse sq factor here too since the cord is at extended distance to the isocenter? JPS  
thank you for catching this!

If we consider more difficult version, the field size changed at the depth of cord  
FZc = field size at iso

FZ at Cord from PA (FZo1) = FZc x 93/100

PA field MU =  $90/[\text{TMR}(12\text{ cm}, FZc) \times \text{Sc}(FZc) \times \text{Sp}(FZc)] - (1)$

$$\frac{(SSD_1 + d_0)}{SSD_2 + d_0} \left( \frac{SSD_2 + d_m}{SSD_1 + d_m} \right)^2$$

$$PA \text{ to cord} = MU \times \text{TMR}(5\text{cm}, FZatCord) \times \text{Sc}(FZc) \times \text{Sp}(FZo1) \times (100/93)^2 = 90 \times [\text{TMR}(5, FZo1)/\text{TMR}(12, FZc)] \times [\text{Sp}(FZo1)/\text{Sp}(FZc)] \times (100/93)^2 - (1)$$

$$\left| \frac{160}{MU} - (160) \right| \times 10/20 + \frac{160}{WF}$$

\*Treating with parallel opposed wedge fields for 60 Gy in 30 fxs and the MU per beam in 160 MU. After 10 fxs you realize WF was not in calc. How many MUs required for remaining 20 fxs to get to 60 Gy?

Assuming the WF is given, the correct MU/field =  $160/WF$ , so  $(160/WF - 160) =$  the missing MU/field, so the MU/field from 11 to 30 fx should be  $((160/WF - 160) \times 10/20 + 160/WF)/\text{field}$  ()

\*Prescription is 200 cGy/day delivered by parallel opposed, equally weighted beams. They say they gave 147 MU per beam, but left out a wedge factor of 0.8 for the first 10 treatments. The patient is to receive 30 treatments total. What is the MU required (per beam) for the remaining 20 treatments in order to deliver the prescribed dose for the entire course of treatment?

Assume the wedge was used for both beams.  $1/0.8 = 1.25 \rightarrow 200 * 1.25 * 10 = 2500\text{cGy}$ ;  $200 * 30 - 2500 = 3500\text{cGy} \rightarrow 3500/20 = 175 \rightarrow 175/200 * 147 = 129\text{MU}$

I think the wedge was in the treatment but it wasn't taken into account in the MU calculation; so  $(147/0.8 - 147) \times 10/20 + 147/0.8 = 202\text{ MU /per field for 11 - 30 fx, ()}$

Give a tangential plan, with open and wedge combination, and wedge factor, if the MU for open was delivered to wedge, and vice versa, what is the real dose.

MU1 is open beam, and MU2 is the wedge beam

Prescribed Dose (T) = MU1 + MU2 x WF

Real Dose (R) = MU1 X WF + MU2

R =  $((MU1 \times WF + MU2) / (MU1 + MU2 \times WF)) \times T$  ()

\*Multiple beams plan: AP weighted to 100% at dmax, laterals weighted to 100% at dmax. 200 cGy delivered to 238% isodose line. What is the dose delivered by AP beam?  
 $200\text{cGy} / 238\% = 84\text{cGy}???$

This is what I got. 3 equally weighted beams giving 200cGy to the 238% isodose line will each contribute 84 cGy. JPS  
From Bentel's example,  $200/2.38 = 84\text{ cGy}$

TG51:

- T96.** Regarding the AAPM's TG51 calibration protocol, all of the following are true except:
- The ion chamber must be calibrated at an accredited lab, in water, and in a Co-60 beam.
  - Beam quality is defined by the ratio of readings at 10 and 20 cm depth in water.
  - Only Farmer-type chambers can be used.
  - TG51 protocol can be used for photons and electrons.

B and C both are not right (C we can use parallel plate chamber as well) for B (TG51 use %DD which is more consistent than TPR20 10 for wider range of x-ray (MetCalf p533)

\*Where is the effect point of measurement for a parallel plane chamber? Half way between capacitor plates, 2/3 between, 1/3 between, just inside the thin window. just inside the thin window (the center of the front face of the chamber air cavity, TG51, )

\*Cross calibrate a parallel plane chamber with a farmer. Calculate correction factor with TG-51 type data given for the farmer.

\*Question on TG-51. Determine K(Q). All other factors are given.

\*Question on TG-51. Determine Kcal. All other factors are given.

\*Question on TG-51 for photon calibration, what is the difference between 10 AND 10(X). electron contamination

\*What we do to cancel the e contamination effect at energy higher than 10 MV

1mm lead foil to be placed about 50cm from the phantom surface

7. Question about TG-51, about the right procedure to perform electron calibration. Given the following options: field 10 x 10 cm

$$\begin{aligned} R_{50} & \text{ is } 8.5 \text{ cm} \\ d(\text{ref}) & = 0.6 R_{50} - 0.1 \\ R_{50} & \end{aligned}$$

$$d_{\text{ref}} = 0.6 R_{50} - 0.1$$

\*TG-51 calc. Given raw data. Need to calculate Pion and Ppol. Need to know standard pressure in kPa. Find dose at isocenter if 100 MU were given. Also given Rcav

101.33kPa

$$R_{\text{cav}}, R_{50} = 7.5 \text{ cm}$$

2. TG51 question 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)

\*TG-51 photon calibration. Serial measurements are listed with all the P. What is the calibration factor at dmax? (A) 0.98 cGy/MU (B) 1.00 cGy/MU (C) 1.02cGy/MU (D) 1.04cGy/MU

8. Given lots of TG-51 parameters, calculate cGy/MU for electrons

\*You calibrate a machine with the outside temp and press.... But this is the inside temp and press... how far off is your output? Use TG51 eq  $P_{\text{tp}} = 273.2 + T/(273.2 + 22) \times 101.33/p$  to calculate the difference outside and inside temp and pressure ()

O \*Pick out the false statement about TG-51 given a selection (applicable to 3-50 MeV e-?, from 2002 recall)

Photon: Co60 - 50 MV

Electron 4 - 50 MeV

\*TG51: What's energy specification for electron beams?

What is the Electron beam quality is specified by?

R50 (TG51, )

photon:  $Co^{60} - 50 \text{ MV}$

Electron:  $4 - 50 \text{ MeV}$

\*TG51 calculation. You have to calculate Ppol, Pion and Ptp (in kPA). Mraw high and low given.,

$P_{\text{ion}}(V_h) = (1 - V_h/V_L)/(M_h/M_L - V_h/V_L)$  for pulse beam regular linac

$P_{\text{pol}} = |(M_+ - M_-)/2M_+|$

$P_{\text{tp}} = (273.2 + T)/(273.2 + 22) \times 101.33/p$ , ()

\*TG51: what's upper limit for Pion? 1%, 3%, 5%, 10%. 1.05 AA

\*TG51: where is cylindrical chamber's center placed for photon beam calibration?  
depth 10 cm (TG51, )

\*TG51: KQ depends on what? (choices included beam energy, ion chamber, both)

Quote TG51 p1849,  $k_Q$  is a function of beam quality Q [specified by %dd(10)<sub>x</sub> or  $R_{50}$ ] and chamber type ()

\*TG51: to cross calibrate parallel-plate chamber for electron dosimetry, what should use? High Energy Electrons AA

\*TG51: where is the effective point of measurement of parallel-plate chamber?

The center of the front (upstream) face of the chamber air cavity ()

\*Given a graph of raw (not shifted) PDD's VS depth shown. Diameter of chamber 0.6 mm. Determine the PDD(10 cm).  
Shift upstream for 0.6\*0.3mm () TG51

Q What percent higher/lower difference is expected when going from TG21 to TG51  
How much difference will the calibration be by using TG 21 and TG51 for photons? 1%  
Higher, 3% higher, same, 1% lower, 3% lower.

For photon the reading is around 0.5 - 1.5% higher for TG51,  
& for electron the reading is around 2 - 3% higher for TG51. Ref: Med. Phys. 27, p1217 (2000) & Med. Phys. 28, p46  
(2001), ()

\*The only factor less than 1 in TG-51. (Select from Ptp, Pelec, Ppol, Pgrad. from 2005 recall)

$k_Q$  for most chambers and beam Q is also less than 1! (See table-11 in TG51)! (AA)  
PgrQ TG51 () for the dref > dmax + 0.5r, ()

Photon: 0.5 - 1.5% higher @ TG-51

Electron: 2-3% higher @ TG51

$P_{gr}^Q < 1$  for dref > dmax + 0.5 r<sub>car</sub>

\*TG51: total consecutive measurements were done with 20% difference, the reason for this could be?

The reference photon dosimetry is supposed to be done with SAD setup but performed on SSD setup, or vice versa. The inverse square law shows  $(110)^2/100^2 = 1.21 \sim 20\%$  off, anyone? ()

\*TG51: How do you convert ionization curve to %dd curve?

If we use cylindrical chamber

Photon we don't need to convert when the depth is beyond

Electron: We will need to use stopping power ratio as specified in Eqs. (6) and (8) in TG70, ()

$$\%dd_w(d) = 100 \frac{M(d)}{M(I_{max})} \quad \%dd_w(d) = \%dd_w(d) \times \frac{(\bar{L}/\rho)_{air}^w(R_{50}, d) \cdot P_{fl}(E_d)}{(\bar{L}/\rho)_{air}^w(R_{50}, d_{max}) \cdot P_{fl}(E_{d_{max}})}$$

The reference depth for electron-beam dosimetry is at dref = 0.6R<sub>so</sub>-0.1cm, which is essentially the depth of maximum dose for beams =10MeV, but is deeper for higher energy beams. By going to this depth, the protocol (TG-51) makes use of stopping power ratios which account for the realistic nature of electron beams. TG-51

Basically I<sub>so</sub> is used to determine R<sub>so</sub> (the depth (cm) where the dose falls to 1/2 its maximum value) via

$$R_{so} = 1.029(I_{so}) - 0.06 \text{ (cm)} \quad (2 \leq I_{so} \leq 10 \text{ cm})$$

$$R_{so} = 1.059(I_{so}) - 0.37 \text{ (cm)} \quad (I_{so} > 10 \text{ cm})$$

JPS

T33. The AAPM recommends the use of a \_\_\_\_\_ to calibrate a 6 MeV electron beam.

- A. Thimble ionization chamber
- B. Parallel-plate ionization chamber

TG51 & 21 suggest parallel-plate chamber for electron beam. Due to the size of the cavity of many ion chamber is too large used in the low energy electron beam high gradient area. (p122, Hendee)

SRS:

T44. For stereotactic radiosurgery (SRS) performed on a Gamma Knife®, the prescription level normally chosen is \_\_\_\_\_ % of the maximum.

- A. 100
- B. 90
- C. 80
- D. 50

T45. For arc-based SRS treatment on a brain, using at least 300° of arc in total to achieve a spherical isodose volume, the size of the circular cone used corresponds to the size of the \_\_\_\_\_ % isodose cloud around the target.

- A. 95
- B. 90
- C. 80

- TIII.** For cranial stereotactic radiosurgery, accuracy and reproducibility should generally be on the order of \_\_\_\_\_ mm.  
 A. 7  
 B. 5  
 C. 2  
 D. 0.5

\*Stereotactic Question: what would be the dose to the surrounding healthy tissue to achieve a uniform dose to the target of 20 Gy.

\*AAPM Report 54 (TG-42? SRS)- What is the max size of a scanning ion chamber for SRS beams?

\*Detector resolution required for SRS field profile is (less than 1mm, 2mm, 3mm, etc)

TG42: Linac based SRS: 2 mm or less as the detector diameter for profile

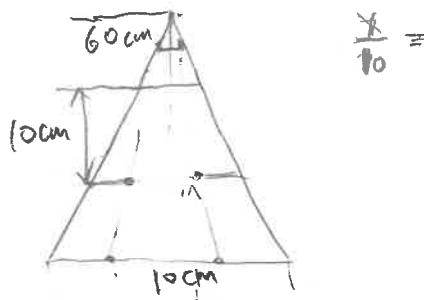
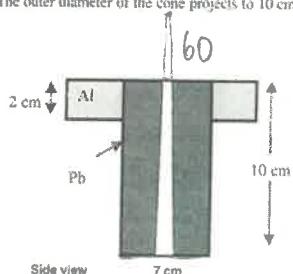
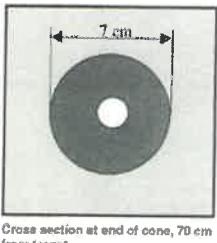
3 mm or less as the detector diameter for TMR and output factor

Gamma knife:  $1 \times 1 \times 1 \text{ mm}^3$  detector dimension ()

TG101 requires detector size < 1 mm.

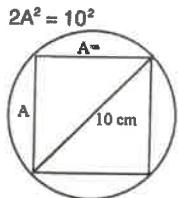
- TIII-TII13.** Use the following diagrams for the next three questions.

The lead SRS cone shown below is attached to an aluminum mounting plate. The bottom of the cone is 70 cm from the target. The outer diameter of the cone projects to 10 cm at isocenter.



- TIII.** What is the largest square jaw setting, in cm, that can be used for SRS treatment?  
 A. 10x10  
 B. 4x4  
 C. 8x8  
 D. 7x7

- TIII. D** The projection of the largest jaw size must fall completely inside the circle, or radiation will leak through the aluminum plate and irradiate the patient. Further, since the aluminum plate blocks the light field but not the radiation field, it is possible to not notice this error.



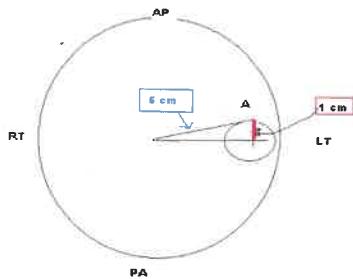
- TII13.** Once the cone system in the figure on page 21 is attached to the linac, the light field can only be observed through the cone aperture. Which of the following should be performed?  
 A. Winston-Lutz test using film large enough to detect radiation outside the area of the lead cone  
 B. Verifying the appropriate jaw size has been set  
 C. Disabling jaw motion  
 D. All of the above.

- TII13. D** About 80% of 6 MV radiation will be transmitted through 2 cm of aluminum. The Winston-Lutz test, although intended for determining target accuracy, will show areas of leakage if the jaws are set too large, provided large enough film is used. Even with the jaws set so that there is no leakage beyond the cone, output (dose/MU) will be affected if the jaws are not set to the correct size. Once set and verified, jaw motion should be disabled to prevent the therapist from inadvertently changing jaw size while using the pendant to position the patient and gantry.

About the Winston-Lutz test [http://www.wienkav.at/kav/kfj/91033454/physik/as500/as500\\_sphere.htm](http://www.wienkav.at/kav/kfj/91033454/physik/as500/as500_sphere.htm)

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

recall it) is tilted 1 degree. The isocenter was centered on the origin from where the 5 cm are measured. This is a key issue for solving the problem.



If the patient rotates 1 degree in counterclockwise ( LT to AP), and I assumed the circle is the coverage, and the cross is in the center, the distance from the iso to the center of the coverage is  $\sqrt{25 - 1} = 4.9$  cm. If the patient head tilted 1 degree counterclockwise, the coverage should move Rt-Lat ( $4.9 - 4.9 \times \cos(1)$ ) ~ 0 mm, and Anterior  $4.9 \times \sin(1)$  ~ 0.85 ~ 1 mm. ()

I got the same thing as . Anyone else?

$$\sin(\theta) = 1 \text{ cm}/5 \text{ cm} \rightarrow \theta = 11.5 \text{ deg}$$

$$\text{Tilt 1 deg} \rightarrow \theta_{\text{new}} = 12.5 \text{ deg}$$

Assume 5 cm radius remains the same.

$$\sin(12.5) = x/5 \rightarrow x = 1.1 \text{ cm post in the head - head moves, dose stationary}$$

I agree with blue solution, but i guess the coverage moves posteriorly for 1mm (1.1cm - 1cm)

I agree. JPS

My thought is that when patient head tilts, coverage should move to cover the target, such as cyber knife case. ()

What "stereotactic" means in stereotactic radiosurgery 3D AA

\*SRS treatment, 4mm cone... what is max dose?

(from yahoo group) 1; We treated a trigeminal(三叉神經) with 8000cGy to 100% line, single fraction , 5mm cone (radionics). 2; For trigeminals at our clinic we routinely prescribe 80Gy to the 90%IDL(88Gy) with a 4mm cone in 1 fraction. 3; In SRS the only site that needs 4-5mm cone alone is Trigeminal and the typical prescription is 80 Gy to Max. So max dose for 4mm cone is 80 Gy.

From Handbook of evidence-based radiation oncology 2nd, p67 "SRS is used with 80Gy at 100% IDL for Trigeminal Neuralgia(神經痛)" ()

80Gy

### Brachytherapy:

When an HDR planning system uses optimization to create a homogeneous dose along the surface of a cylindrical applicator, the dwell times will be:

- A. Higher in the center than at the ends.
- B. All approximately equal.
- C. Alternately high and low.
- D. Higher at the ends than in the center.

**Due to the inverse square law, a point near the end of the cylinder is further away from most of the sources than a point at an equal radius near the center. Thus, longer dwell times are required at the ends to compensate for this effect.**



T121. An HDR vaginal cylinder plan is optimized to deliver a uniform dose 0.5 cm beyond the cylinder surface. Which of the following is true regarding the dose distribution at different distances?

- A. At shorter distances, the ends will be hotter than the center, whereas at longer distances, the center will be hotter.

The dwell time is always higher at ends to achieve a uniform distribution at certain depth say 1cm , and when the distance is shorter than 1cm you calculate the dose at a point by looking at each dwell time of the cylinder and the ends are hotter so end high, middle low  
Therefore, it tries to achieve uniform at a certain distance (1cm for microdisease).

17. According to TG60, what is the reference point for IVBT(intravascular BT) ? (2 mm from source center, Kahn3rd p558)

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, 185 Bq Kahn 3rd p414**).

Just confirmed about 5nCi, so this is a simple algebra?

$$5\text{Ci} \times 10^{-9} \times (3.7 \times 10^{10}) \text{dps/s} \times 60 = 1.11 \times 10^4 \text{ cpm}$$

Wipe test 5 nCi 185 Bq

$$185 \times 60 = 11100 \text{ cpm}$$

Regarding ultrasound used to localize the prostate in treatment position before radiation therapy, all of the following are true, except:

- A. The patient must have a full bladder.
- B. The patient must have an empty rectum.
- C. The prostate cannot be imaged through the pelvic bone.
- D. The operator must be trained to correctly interpret the images obtained.
- E. The system must be calibrated to correctly align with the linac isocenter.

B

Although rectal (and bladder) filling may alter the position of the prostate relative to skin marks or bony landmarks, ultrasound localization customizes the daily setup to the actual prostate position on that day. A full bladder is, however, necessary to transmit the ultrasound.

T71.

Unused  $^{125}\text{I}$  seeds must be stored for a minimum of \_\_\_\_\_ before being discarded.

- A. 10 months
- B. 5 years
- C. 10 half-lives**

T71. C

After a minimum of 10 half-lives (20 months for  $^{125}\text{I}$ ) the seeds must be surveyed with an appropriate instrument to ensure that the dose rate is not above background. They can then be discarded in regular trash, provided documentation is kept.

T62.

Historically,  $^{137}\text{Cs}$  activity has been expressed in terms of mg-Ra eq. because:

- A. The activity in millicuries is difficult to determine.
- B. The gamma-ray energy is the same.
- C. Patterson-Parker tables designed for radium could be used.**
- D. Shielding requirements are the same for 1 mg radium and 1 mg-Ra eq.  $^{137}\text{Cs}$ .

T62. C

Although the gamma energies are different, the dose distributions in tissue around Ra and Cs sources are similar.

T128.

The advantage of using larger diameter ovoids in a Fletcher-Suit applicator is:

- A. They are easier to see on a localization radiograph.
- B. They result in a higher mucosal dose rate.
- C. They result in a lower mucosal dose rate and better depth dose distribution.**
- D. They result in a lower dose to the bladder and rectum.

T90.

All of the following could result in an *overdose* to tissue when treating a patient with a MammoSite® balloon, except:

- A. Fill volume is less than the minimum recommended for balloon diameter.
- B. Central catheter is displaced more than 3 mm from balloon center.
- C. Skin distance is less than the minimum recommended by manufacturer.
- D. Air pocket outside balloon is 30% of the PTV volume.**

T90. D

An air pocket pushes the volume of tissue to be treated away from the balloon, thus potentially underdosing it. The recommended maximum volume is 10% of the PTV.

T77.

After removing a temporary implant of iridium seeds from a patient, the physician should *immediately*:

- A. Call the radiation safety officer to request that a room survey be performed within 24 hours.
- B. Monitor the patient and bedding for remaining sources with a sensitive detector.
- C. Order radiographs to detect any remaining sources.
- D. Count each of the sources to verify that all sources inserted are present.

T77. B

**A sensitive detector is the fastest and most reliable way to verify that no sources have been left in the patient or dropped in the bed during removal.** This should be done as soon as the sources have been removed because of the serious consequences to the patient if sources are left in place longer than intended. The removed sources should be moved away from the patient's immediate area during the measurement. **The sources must be counted before return to the manufacturer, but this does not have to be done immediately at the patient's bedside.**

T134.

A patient is to receive  $^{131}\text{I}$  therapy. Which of the following methods can be used to calculate the effective half-life,  $T_e$ , and the biological half-life,  $T_b$ , so that the correct activity can be administered to the patient?

- A. Once treatment has begun, collect all urine for each 24-hour period. Knowing the volume and counting a urine sample will determine clearance ( $T_b$ ).
- B. Several days prior to treatment, a small tracer dose is given to the patient. A whole-body assay is performed the following day, and again a few days later.**

T134. B

Answer A might give a reasonable value, but iodine can be cleared by other routes. Also, the question asked for a calculation of  $T_b$  prior to administration.

T130.

Post prostate implant dosimetry is performed using a CT scan several weeks after the implant. All of the following are possible reasons why the dose distribution looks different from the pre-plan, except:

- A. The preplan was done with ultrasound images, and the prostate volume may appear to be different on US and CT.
- B. The implant was performed under ultrasound guidance, but the post-plan was done with CT images.
- C. The prostate swelled during the implant and shrank down again later.
- D. The source strength of the seeds decayed since the implant.

D: the source strength decay is already included in the post plan calculation.

- T131.** QA tests that should be performed before MammoSite® treatment include verification of the constancy of all of the following, except:
- The balloon dimensions.
  - The product of source activity and total dwell times.
  - The accuracy of the source position.
  - D. The minimum distance from the balloon to the skin.**
- T131. D** The minimum balloon-skin distance is determined initially, when planning the treatment. If it is too small (e.g., <7 mm), the physician may decide not to treat. Balloon dimensions can be verified to make sure that the balloon is not leaking. This can be done once per day for BID treatments.
- 
- T127.** A  $5 \times 7$  cm two-plane implant of uniform activity  $^{192}\text{I}$  seeds is proposed. To calculate the required activity to deliver 1000 cGy/day at 0.5 cm from the upper surface, which of the following calculation systems could be used?
- Paterson-Parker tables
  - Quimby tables
  - A commercial computer treatment planning system
  - All of the above
  - B & C only
- T127. E** Paterson-Parker tables cannot be used for seeds of equal activity. They were designed for Ra needles, with lower activity at the center of the plane to give a more uniform dose at the treating distance. Commercial computer treatment planning systems can calculate the 3-D dose distribution for any seed arrangement.
- Quimby sys is characterized by a uniform distribution of sources with equal linear activity, consequently this arrangement of sources results in a nonuniform dose distribution, higher in the central region of treatment. (Kahn p381)
- Paterson-Parker: Nonuniform seed activity -> uniform distribution  
 Quimby : Uniform seed activity -> non uniform dose distribution
- T126.** For the same source geometry and effective dose at point A, high dose-rate (HDR) afterloader treatment of the cervix would be expected to give increased rectal complications, compared with conventional low dose-rate (LDR) brachytherapy with  $^{137}\text{Cs}$  sources. Rectal problems are reduced in HDR treatment by:
- Reducing the dwell times in the colpostats.
  - Reducing the number of fractions for the HDR treatment.
  - Reducing the dwell times in the tandem closest to the rectum.
  - D. Using a rectal retractor and/or more packing.**
- T124.** For an "ideal" Fletcher tandem and ovoids, with the loading shown below (a total of 65 mg Ra eq), the typical dose rate at point A is \_\_\_\_\_ cGy/h.
- Tandem: 15-10-10 mg Ra eq sources  
 Ovoids: 15 mg Ra eq each
- 90
  - 75
  - C. 55**

The Manchester applicators consisted of a rubber tandem and two ellipsoid "ovoids" with diameters 2, 2.5, and 3 cm. No shielding in ovoids, so needed generous packing anteriorly and posteriorly. Used radium. Used 17.5, 20, and 22.5 mg Ra for the small, medium, and large ovoids, respectively.

Designed such that:

- Point A dose rate was approximately 55 cGy/hr for all allowed applicator loadings (wiki or AAPM review course brachytherapy planning p 39)

for Ideal Fletcher tandem and ovoids

Chapter 18 Physics and Biology of Brachytherapy 457

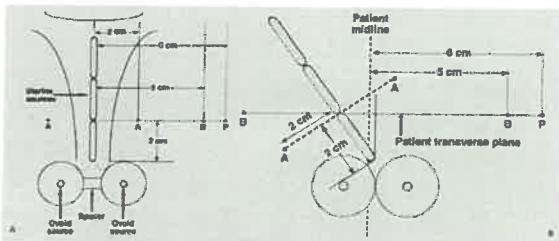


FIGURE 18.26. Relation of points A and B to an ideal applicator (A) and a distorted applicator (B), which is displaced to the left of the patient's midline, and 3 ovoids, which is tilted toward the right. Note that point A is carried with the uterus, whereas points B and P are displaced to be 1 and 5 cm, respectively, to the right and left of point midline. Point P is used by the Manchester Institute of Radiology to indicate the position of the tandem. (Reprinted with permission from Fletcher JG, eds: Textbook of Radiation Oncology, 2nd ed. Philadelphia: WB Saunders, 1987:42-50, with permission.)

remember  $8.25 \text{ Rcm}^2/\text{mg h}$  for Ra!! And inverse square law

**T114.** All of the following are good reasons for moving from low dose rate to high dose rate brachytherapy in the treatment of cervical cancer, except:

- Higher dose rate is radiobiologically advantageous.
- Geometry: The shorter irradiation time assures that packing will not move over the time of the implant.
- Shielding: Irradiation of staff members is basically nonexistent.
- Less chance of deep vein thrombosis (DVT).
- The possibility of only one OR visit.

**T114.** A. Some radiation oncologists prefer low dose rate due to the historical data on LDR treatment of cervical cancer; it is for this reason that "pulsed dose rate" systems were developed, although they have not enjoyed wide popularity in the United States, partially due to regulatory issues.

However, with LDR, there is more of a chance that packing will move during an extended irradiation time, possibly delivering higher doses than expected to the rectum and bladder. HDR suites are well-shielded and exposure is only to the patient, whereas LDR patients need monitoring over the span of several days, causing exposure to nursing and other staff. DVT is more likely when patients are confined to bed for several days. For HDR, a Schmidt sleeve can be placed following dilation of the cervix, thereby requiring only one visit to the OR.

**T116.** For a Stage IIIB cervical cancer, the appropriate brachytherapy applicator is:

- A. Henschke applicator.
- B. Fletcher/Suit tandem and colpostats.
- C. Fletcher/Suit colpostats alone.
- D. Syed/Neblett or MUPIT applicator.
- E. Vaginal Cylinder.

**T116. D** The Syed/Neblett or MUPIT applicator allows the use of interstitial needles to treat the tissues near the cervix, which are too far away from the colpostats or ring applicators to receive sufficient dose from these applicators alone.

\*Question on changing Brachytherapy sources from 192Ir to 125I (or vice versa) and calculating activity/dose rate

3. I-125 seed, Dose Rate Constant = 0.5 cGy/hr per U, Sk = 0.7 U. 87 seeds were used to cover 95% of the prostate volume to a dose of 145 Gy. If the same number of Pd-103 seeds were used to cover the same volume to 90 Gy (Pd-103 dose rate constant= 0.7 cGy/hr per U), What air kerma strength Sk should be?

$$\text{total dose ratio} = 90/145 \rightarrow 87 \cdot 0.5 \cdot 0.7 \cdot 1.44 \cdot 59.4 \cdot 24 : 87 \cdot 0.7 \cdot \text{Sk} \cdot 1.44 \cdot 17 \cdot 24 = 145:90 \rightarrow 0.5 \cdot 59.4 : 17 \cdot \text{Sk} = 145:90 \rightarrow \text{Sk} = 1.08\text{U}$$

Following the TG43 equation, at 95% line we need 145cGy,

$D'(t) = \text{Sk} \times \text{Dose rate constant} \times G \times g \times F$ , Total dose at 95% line will be

$$145 = 87 \times 0.7 \times 0.5 \times 1.44 \times 60 \times 24 \text{ GgF for I-125}$$

90 = 87 x Sk x 0.7 x 1.44 x 60 x 17 GgF for Pd-103, assuming the G, g, F factor they are the same for both elements, so Sk = 1.1 U

\*Given the formulae between dose limit for releasing patient and half life, initial activity of I-131 ask the initial activity. Need to know the half life and dose limit.

The release criteria is based on USNRC regulatory guide 8.39 ([http://www.nucmed.com/nucmed/ref/8\\_39.pdf](http://www.nucmed.com/nucmed/ref/8_39.pdf)) and its errata <http://pbadupws.nrc.gov/docs/ML0037/ML003739562.pdf>.

The release criteria can be (1). The dose at 1 m away from pt. < 5 mSv. Therefore, the initial activity needs to be less a certain value or (2). If the initial activity is > a criteria, measured dose rate needs to be less a certain value.

The total accumulated dose at a certain distance can be calculated from

$$D(t) = \frac{34.6 \Gamma Q_i T_{1/2} (1 - e^{-0.693 t / T_{1/2}})}{r^2} \quad (\text{Equation 1})$$

Where  $D(t)$  = Accumulated exposure at time  $t$  in roentgens,

34.6 = Conversion factor of 24 hrs/day times the total integration of decay (1.44),

$\Gamma$  = Specific gamma ray constant for a point source, R/mCi-hr at 1 cm,

$Q_i$  = Initial activity of the point source in millicuries, at the time of the release,

$T_{1/2}$  = Physical half-life in days,

$r$  = Distance from the point source to the point of interest in centimeters,

$t$  = Exposure time in days

For conservative choice, USNRC pick physical half life and  $1 \text{ R} = 10 \text{ mGy}$ , and take the  $(1 - \exp)$  term as 1. For the occupancy factor, it uses 0.25 for physical half life > 1 days, and 0.75 to 1 for physical half life < 1 days. Therefore,

$$\begin{aligned} &\text{I-125 , } 1 \text{ mR/hr} \\ &\text{Pd-103 , } 3 \text{ mR/hr} \\ &\textcircled{Q} \text{ I-131 , } 5 \text{ mR/hr} \end{aligned}$$

For radionuclides with a physical half-life greater than 1 day:

$$D(\infty) = \frac{34.6 \Gamma Q_0 T_p (0.25)}{(100 \text{ cm})^2} \quad (\text{Equation 2})$$

For radionuclides with a physical half-life less than or equal to 1 day and if an occupancy factor of 1.0 is used:

$$D(\infty) = \frac{34.6 \Gamma Q_0 T_p (1)}{(100 \text{ cm})^2} \quad (\text{Equation 3})$$

For I-131, the physical half life is 8 days, effective half life is 4 days.

According to the release criteria 1, (5 mSv at 1 m away) using Eq. 2

Initial Activity (A)  $\times 24 \text{ h} \times 8 \text{ days} \times 1.44 \times 2.2 (\text{R cm}^2/\text{mCi h}) \times 10 \text{ mSv/R} \times 0.25 / 10000 = 5 \text{ mSv}$

A = 33 mCi (consistent with the Table 1 first criteria, in USNRC regulatory guide 8.39)

According to the release criteria 2

If we have activity 33 mCi of I131,

The dose rate at 1 m away is

$33 \times 2.2 \text{ R cm}^2/(\text{mCi h}) \times 10 \text{ mSv/R} \times 1/10000 = 0.07 \text{ (mSv/h)}$  (consistent with the Table 1 2<sup>nd</sup> criteria, in USNRC regulatory guide 8.39)

\*Due to XXXXX, who should show up during a HDR procedure? (A) Certified physicist, user or console operator (B) Certified physicist, user (C) User and console user (D) Certified physicist, console user

TG59, p392: "USNRC requires that both an authorized user ~a radiation oncologist authorized to prescribe brachytherapy! and medical physicist ~or radiation safety officer! be physically present at all HDR treatments"

I would go with (B), Certified physicist, user. (AA)

\*if you order seeds for an I-125 prostate seed implant, according to AAPM recommendations, what percentage off can your in-house measured activity be from the manufacturer's activity?

5% for individual seed, 3% for the mean batch of the seed (TG40 P600 Table1x)

49. What percent of a batch of seeds has to be checked in a prostate seed implant procedure.

10% or 10 seeds per batch, ex: 120 seeds we check 12 seeds ()

For a large number of seeds in ribbons, a minimum of 10% or 2 ribbons (whichever is larger) should be calibrated.  
Agree. TG 46 p12 KMW

Source QA tests and their frequency and tolerances are presented in Table IX. It should be noted that the recommended 3% tolerance between manufacturer and institution calibrations discussed above applies to the mean of a batch of sources. Since individual sources may differ from the mean by a greater amount, we recommend a deviation from the mean of 5% for individual sources.

43. Best survey meter for lost I-125 seed? Cutie pie, GM tube, Thin window GM tube, Scintillation detector.  
From TG64, it suggested GM counter and scintillation detector

TG56 (page2061), it specifically mentioned scintillation detector

2 websites say GM counter won't be able to detect I125 < 0.05 uCi

[http://web.princeton.edu/sites/ehs/radmanual/radman\\_app\\_b.htm#i125](http://web.princeton.edu/sites/ehs/radmanual/radman_app_b.htm#i125) ()

<http://researchcompliance.uc.edu/radsafety/isotope/isds-i125.html>

\*Which of the following element has equal effect from both Compton & Photoelectric effect: I, Ir, Co, Cs.  
Ir and Au (Khan P329) I think it is iodine at 25 kev

For which isotope do Monte Carlo calculations account that photoelectric interaction and Compton scatter cancel out so that only primaries are considered?

I agree with Ir and Au (principles and practice of radonc p 425 – 427)

Ir and Au only show inverse square law dependence extended to large distance (Kahn p374).

For the PE effect, the photon is absorbed and electron deposited the dose locally. For the Compton effect, there is still scattered photon which can travel further and induce the dose deposition in the large distance. I consider it is scattered effect. Therefore, the radionuclide show no inverse square law are the one with no photon attenuation and scattered cancel out.

I think here are the scenario depending how the question askes

1. if the questions asking equal probability as PE (50%) and Compton scattering (50%), it should be I-125 or Pd-103
2. if the questions asking the photon attenuation and scattering compensate each other, therefore only geometry (inverse square law) concern affects the dose fall off, it will be Ir or Au which strictly following the inverse square law.

\*Using HDR Brachtherapy, Which is better to employ Ultrasound or CT scans or both of them. Both, just like LDR procedure (Kahn 3<sup>rd</sup> p547)

Ir-192 & Au-198      Au-198 (0.412 MeV)  
Ir-192 (0.38 MeV)

\*Giving a dose rate constant of I125 (Ir192?) measured experimental 0.7, two numbers calculated by Monte Carlo method (0.64, 0.67), something like that, ask according to TG-43, which one to use in planning system, 0.64, 0.67, 0.7, 0.65 (the experiment one, one of the Monte Carlo one, or the average of the two Monte Carlo)

According to TG43U1 p640, the dose rate constant is calculated as the (average measured value + average MC value)/2. Therefore, the dose rate constant = ((0.64 + 0.67)/2 + 0.7)/2 = (0.655 + 0.7)/2 = 0.6775 ()

\*You measure a brachy source and get a measurement in air at 1 meter of (given)R/S. The chamber volume is given, the chamber calibration factor is given (in cGy/C?). You are given the density of air in kg/m<sup>3</sup>. The stated activity from the manufacturer is given. Given 0.876cGy/R, given 33.95 J/C, NOT given 2.58E-4 C/Kg = 1R. What is the relationship between your measured dose rate and the dose rate stated by the manufacturer?

\*Why would a doctor use Pd103 instead of I125 for prostate implant?

dose would be delivered in a shorter time. (the major difference between Pd103 and I125 is the half life, 17 and 60 days, Hendee p288)

\*Dose rate at 30 days from a 0.46mCi Pd source (given t 1/2 = 17days) if the total dose delivered is 120Gy?

$$D_0 = 4.9 \text{ Gy/day} \quad D_t = 1.44 \text{ Gy/day}$$

I didn't ignore the exp term so  $120 = D_0 \times 1.44 \times 17 (1 - \exp(-\ln 2/17 \times 30)) \Rightarrow D_0 = 6.9 \text{ Gy/day}$ , and  $6.9 \text{ Gy} \times 0.5^{(30/17)} = 2 \text{ Gy/day at 30 days. ()}$

$$D = D_0 \cdot 1.44 T_{1/2} \times (1 - e^{-\frac{D_0}{T_{1/2}} \cdot t})$$

\*What detector is best for calibrating an Ir-192 IVRT source? Re-entrant well chamber () (Kahn Ch22.4.)

\*An I-125 implant gives 95% of the total dose in \_\_\_\_ days?

$$0.95 = (1 - \exp(-0.693/59.6 \times n)) \Rightarrow n = 259 \text{ days ()}$$

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

Sr-90 beta average energy is 2.28 MeV (Hendee Table 12-1), Range of Beta particle is more accurate calculated by using 1 MeV traveling 4 m in air, so  $2.28 \text{ MeV} \times 4 = 9 \text{ meter ()}$

Please see this link <http://www.alpharubicon.com/basicnbc/article16radiological71.htm>

\*What is the range of a Y 80 beta 2.2Mev in air? 9meter

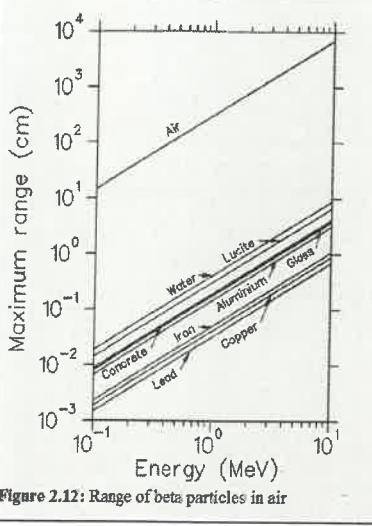
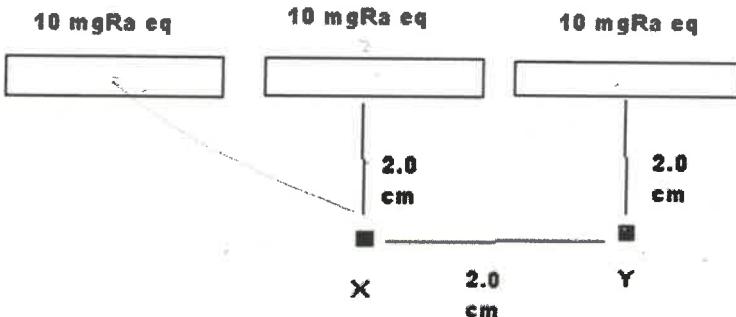


Figure 2.12: Range of beta particles in air

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



The dose are calculated at the points X and Y which is  $\Rightarrow$  2 cm away from the sources with active length less than < 2 cm. According to Kahn Fig. 15.11, the dose fall off from a linear source at the distance  $>$  1 cm, we can approximate it as a point source following inverse square law. The dose ratio of  $Y/X = (1+1/2+1/5)/(1+2*1/2) = 17/20 ()$

\*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. What is the ratio of dwell times 1 to 2 to make dose A equal dose B? inverse square law

I calculate as 20:17 () Point A dose =  $1 + \frac{1}{2} + \frac{1}{5}$ , and Point B dose =  $1 + \frac{1}{2} \times 2 = 2$  so the time is 20:17 between point A and B.



In the treatment of metastatic thyroid cancer, some institutions attempt to administer the maximum tolerated activity of  $^{131}\text{I}$  consistent with dose limiting toxicity. What is the usual dose-limiting organ when treating thyroid cancer with orally administered radioiodine?

- A. Salivary gland
- B. G.I. tract
- C. Lung
- D. Retina
- E. Bone marrow

**TI29. E**

Ingested radioiodine rapidly crosses the stomach wall, where it enters the blood stream. Because the half-life of  $^{131}\text{I}$  in the blood is several hours, the whole marrow space is continuously irradiated. Dose-limiting toxicity for whole marrow begins at doses in excess of 2 Gy. Some patients can experience salivary gland complications, but these are usually reversible and not life threatening.

**TI22.** The energy of the most prevalent gamma ray emitted by  $^{131}\text{I}$  is \_\_\_\_\_ keV.

- A. 21
- B. 28
- C. 110
- D. 364

**TI22. D** The  $^{131}\text{I}$  gamma rays have a range of energies. The most prevalent (82%) is 364 keV.

$$\begin{aligned}
 & \text{Handwritten notes: } \sqrt{20}, \frac{1}{4 \times 4 + 4} = \frac{1}{20}, \\
 & 16+4, 2\sqrt{2}, \\
 & \frac{1}{8} + \frac{1}{4} + \frac{1}{8}, \\
 & \frac{1}{4} + \frac{1}{8} + \frac{1}{16}, \\
 & \frac{1}{4} + \frac{1}{8} + \frac{1}{16} = \frac{17}{40}, \\
 & \frac{10+5+2}{40} = \frac{17}{40}, \\
 & \frac{1}{2} + \frac{1}{2} = 1, \\
 & \frac{6+3+2}{24} = \frac{11}{24}, \\
 & \frac{1}{2} + \frac{1}{2} = 1, \\
 & \frac{11}{24} + \frac{1}{2} = \frac{17}{24}, \\
 & \frac{17}{24} : \frac{1}{2} = \frac{17}{12} = \frac{17}{20}.
 \end{aligned}$$

$$T_{1/2} = 8 \text{ days}$$

for  $^{131}\text{I}$

$$\begin{aligned}
 & E = 0.364 \text{ MeV} \text{ (}\gamma\text{-ray)} \\
 & E = 0.606 \text{ MeV} \text{ for } \beta\text{-decay}
 \end{aligned}$$

(Hendee, p288) The gamma ray energy range for  $^{131}\text{I}$  is from 8 – 640 keV.

T123. All of the following are *true* of  $^{125}\text{I}$ , except:

- A. Strands of seeds can be used for permanent implants.
- B. It is commonly used for prostate implants.
- C. It can be created by neutron activation.
- D. Mean energy is about 350 keV.
- E. The useful radiation is mostly characteristic x-rays, not gamma rays.

D. Hendee p 288, & Kahn 3<sup>rd</sup> p362

T124. A permanent  $^{125}\text{I}$  seed implant has an initial dose rate of 0.1 Gy/h. The total dose delivered by this implant is \_\_\_\_\_ Gy.  
A. 207

$$0.1 \text{ Gy/h} \times 24 \times 1.44 \times 59.4 = 207$$

\*Permanent implant of Pd-103. Activity was given. Calculate total dose delivered.

total dose = dose rate\*(1.44T<sub>1/2</sub>) = Activity x exposure rate constant (1.48 R cm<sup>2</sup>/(mCi)h)x1.44x17x24

T119. For HDR treatment using a titanium tandem and ovoid applicator, it is suggested that planning be done using MR scans to better delineate the tumor. Which of the following is correct?

- A. The plan can be done from an MRI scan, using the same applicator.
- B. The plan can be done from an MRI scan, but a non-metallic applicator must be used.
- C. The same applicator can be used, but an additional CT scan should be acquired to calculate inhomogeneity corrections.
- D. A non-metallic applicator must be used, and in addition to the MRI, a CT scan should also be acquired to calculate the inhomogeneity corrections.

T119. A Titanium applicators are CT/MRI compatible and are available from several brachytherapy equipment providers and, as such, allow both modalities of scans. Inhomogeneity corrections are not usually done for T&O planning.

T118. A MammoSite HDR treatment, with a single dwell position at the center of the spherical balloon, is planned from orthogonal x-rays. By mistake, a magnification factor of 1.4 is used instead of the correct value (1.29). The delivered dose will then be:

- A. 9% too high.
- B. 8% too low.
- C. 15% too low.

T118. C Because the wrong magnification is used, the balloon radius will be assumed to be too small and lower dwell time will be prescribed, resulting in an underdose equal to  $(1.29/1.4)^2$ .

The dose is lower according to inverse square law  $(1.29/1.4)^2$

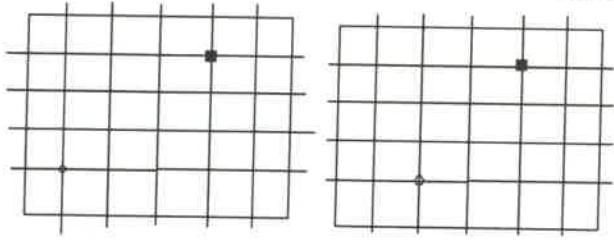
\*HDR scenario: Given activity of Ir-192 source 10 Ci, the exposure rate constant of Ir-192 was not given here, I used 4.6 R-cm<sup>2</sup>/(mCi – hr), then you had to know the f factor also for Ir-192. Balloon with 4 cm diameter. Calculate the approx. time to deliver 340 cGy's at 1 cm from the surface of balloon.

For Ir-192: 4.69 R-cm<sup>2</sup>/mCi-h: f factor is 0.971cGy/R in water for energy 380 keV(Kahn, Table 8.1 & 15.1); 340 / (4.69 x 10<sup>4</sup> mCi/3<sup>2</sup> x 0.971 /60) = 4 mins (,

31. A question involving 10mg Ra – simple application of  $\Gamma x A/d^2$  – but needed to know (ie not given) exposure rate const. = 8.25 Rcm<sup>2</sup>/mg.hr

\*Have a 1 cm grid superimposed on a AP and Lateral Fletcher applicator. 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-cm<sup>2</sup>/(mCi – hr) one had to know, I think f factor also was not given (source was Cs-137).

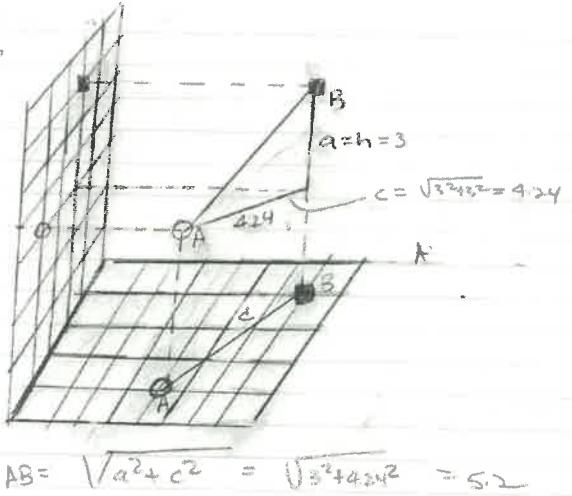
\*Given the grid in which every line intersection is at 1 cm. Determine the distance between the source (black dot) and the



point of interest (white dot).

2005 Part 2 TX

1. continuous



$$\sqrt{3^2 + 3^2 + 3^2} = 5.2 \text{ cm}$$

I think these 2 are from the same question set. If so, the distance = 5.2 cm, and I assumed the given mg-Ra-eq is S, and f factor for Cs-137, 662 keV = 0.971 cGy/R (Kahn table 8.1), the dose rate at point of interest =  $S(\text{mg-Ra-eq}) \times 8.25 \text{ R cm}^2/(\text{mg hr}) \times (1/5.2^2) \times (1/60) \times 0.971 \text{ cGy/R} = 5 \times 10^{-3} \text{ S (cGy/min)}$

\*Total dose at 2 cm from one seed of Pd-103 given its dose rate constant (0.868 cGy/hr) should be 0.686 cGy/(h U), g(2cm) was given, Sk for the source was given= 2.5 U. Phi (anisotropy) = 0.939.

$$D_0 = 2.5 \times 0.868 \times g \times 0.939 / 4; \text{ total dose} = 1.44 \times 17 \times D_0; \text{ ()}$$

The Dose rate can be calculated by  $D_0(r) = AS_k g(r)/r^2 \phi$ , for Pd-103, g(2cm) = 0.576 (Kahn table 15.7), Half-life = 17 days, so  $D_0(r) = 0.686 \text{ cGy/(h U)} \times 2.5 \text{ U} \times 0.576 / 4 \times 0.939 = 0.23 \text{ cGy/h}$ , total dose =  $0.23 \text{ cGy/h} \times 1.44 \times 17 \text{ (days)} \times 24 \text{ h} = 135 \text{ cGy}$ , ()

*Sr-90 0.546 MeV β decay*

\*Radionuclide and energy emission from Sr-90 eye applicator.

90Sr undergoes β- decay with decay energy of 0.546 MeV distributed to an electron, an anti-neutrino, and the yttrium isotope 90Y, which in turn undergoes β- decay with half-life of 64 hours and decay energy 2.24 MeV distributed to an electron, an anti-neutrino, and 90Zr (zirconium), which is stable. Note that 90Sr/Y is almost a perfectly pure beta source; the gamma photon emission from the decay of 90Y is so weak that it can normally be ignored. -- wikipedia ()

The half life of Sr-90 is 28.9 year and the product Y-90 is the main component to treat disease and Sr-90 which is usually in plaque form to treat superficial ocular lesions. ( principle and practice of radiation oncology Table 19.1),

Here is the more complete question; How would you calibrate Sr-90 applicator in the clinic if you do not have the calibration certificate and also why is Sr-90 used for an eye applicator?

To calibrate the Sr-90/Y-90 ophthalmic applicator, it can calibrated using re-entrant chamber, and it can be positioned at the top of the well when the central tube assembly is removed. (Kahn 22.4.A, ). I think the reason to choose Sr-90 for eye treatment, because it's B emitter and the energy is 2.28 MeV so the  $R_{90} = 2.28/3.2$  is only 0.7 cm which is suitable for eye treatment. Anyone? () From Hendee p316, the dose rate from the beta applicator decreases to ~5% at the depth of 4 mm, the depth of the lens below the cornea.

**T124.** Which of the isotopes below is used for temporary implants of the eye?

- A.  $^{137}\text{Cs}$   
B.  $^{125}\text{I}$

$^{125}\text{I}$  also used for eye treatment (Raphe 2010)

\*For what isotope is the ratio of dose at  $d=5\text{ cm}$  to the dose at  $d=1\text{ cm}$  the lowest (from 2006 recall, ? Co, Cs, I, Pd)?

Which isotope decays fastest along the radial direction. Pd-103 is the fastest Fig. 2 in TG43. ()

18. g(r) for  $^{125}\text{I}$  vs  $^{103}\text{Pd}$ . 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.

Also Pd exceeds I below 1cm

$$28 \quad | \quad z_1$$

$$\left(\frac{x+1}{x}\right)^r = 1.5$$

96. Which has a larger value for the radial function beyond 1cm  $^{125}\text{I}$  or  $^{103}\text{Pd}$ ?  $^{125}\text{I}$  (TG43 Fig.2)

\*MammoSite balloon w/ diameter = 4 cm and Rx point at 1 cm from surface of balloon. What is the minimum balloon to skin distance to minimize the hot spot to 150%?

$100\% * 3^2 = 150\% * X^2 \rightarrow 0.449\text{cm away at least. (Agree, ) Mammosite reference (Handbook of treatment planning in radiation oncology p78 + Haibo's case conference)}$

$$q = 1.5 \times x^2$$

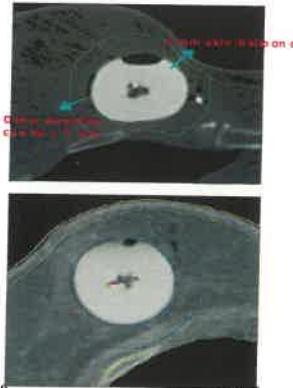
## Planning - structures

- Chest Wall
- Eval: (PTV minus balloon). Chestwall and volume outside the body are to be excluded from the PTV. Remove the PTV that is within **5mm** of the skin and chestwall.

- Skin Distance

3-10-2011

MammoSite ML Case Conference



$$\left(\frac{3}{2}\right)^r \quad \frac{9}{4} = 2.25$$

$$\left(\frac{x+3}{x+2}\right)^r = 1.5$$

$$4.69 \quad \text{Ir} \quad 82$$

$$8.25 \quad \text{Ra} \quad 226$$

$$1.225 = \frac{x+3}{x+2}$$

$$0.225x = 3^{-2.45}$$

$$x =$$

We need at least 5 mm from balloon to skin, but in the other direction can be more than 5 mm

\*How many seconds to deliver a mammosite plan?

MammoSite treatment is usually prescribed 340cGy, 10fx (340 ? AA) cGy at 1 cm from the balloon surface, and the source is Ir-192 with 10 Ci initial activity. We know the exposure rate for Ir-192 is  $4.6 \text{ R cm}^2/\text{mCi h}$

Therefore, the time can be calculated as  $10 \text{ Ci} \times 4.6 \text{ R cm}^2/\text{mCi h} \times 0.97 \text{ cGy/R} \times \text{Time} \times 1/9 = 340 \text{ cGy}$

Time = 0.06 h = 4.08 mins (The typical mammosite treatment is around 5 - 8 mins depending on the activity) ()

\*TG43: what is  $\Lambda$ ? Dose Rate Constant AA

\*If you were going to use a thimble chamber to calibrate an Ir192 source what type of beam would need to be used in determining the calibration factor?

interpolation of the calibrations of Cs-137 662 keV gamma ray and 250KeV x-ray, Ir192: 380 keV (Kahn, sec.22.4)

\*What is the decay rate of 192Ir per day. ~1% AA

$\exp(-0.693/74 \times 1 \text{ day}) \sim 0.99$

What is the dose rate constant for a 2mCi Ir-192 source?  
 $4.7 \text{ R}^{\star} \text{cm}^2/\text{mCi-hr} \rightarrow 4.7 \times 0.876 = 4.12 \text{ cGy}^{\star} \text{cm}^2/\text{mCi-hr}$

Exposure rate constant for Ir-192 =  $4.7 (\text{R cm}^2)/(\text{mCi} \times \text{h}) = 4.7 \times 0.876 (\text{cGy cm}^2)/(\text{mCi h}) = 4.12 (\text{cGy cm}^2)/(\text{mCi h})$

\*HDR 192Ir. Patient treated with time 420sec with Activity 3.75Ci on Aug 1st. Source got replaced with activity 9.43Ci on Aug 16th. Calculate treatment time on Aug 21st. No 192Ir half life given.

With Taylor expansion, for simplicity:  $3.75 \times 420 = 9.43 \times T_2 \rightarrow T_2 = 167\text{s}$ .

I calculate as  $3.75 \times 420 = 9.43 \times 0.5^{(5/74)} \times T_2$ ,  $T_2 = 175\text{s}$  ()

$$D_t T_{AV} (1 - e^{-T/T_{AV}})$$

$$\frac{17 \times 1.44 \times (1 - e^{-120/175})}{60 \times 1.44 \times (1 - e^{-120/60 \times 1.44})} = 0.38$$

\*Two isotopes Pd and I-125 half life is 17 days for Pd and 60 days for I125. After 120 days what is the ratio of doses?  
 $17 \times (1 - \exp(-0.693/17 \times 120)) / 60 \times (1 - \exp(-0.693/60 \times 120)) = 0.38$

\*HDR Cylinder with 5 sources 1 cm apart. Point A is midline, 4 cm from sources and receives 200 cGy. Point B is 2 cm lateral to Point A. What is Point B dose?

Say dose from each source at 1cm is X:

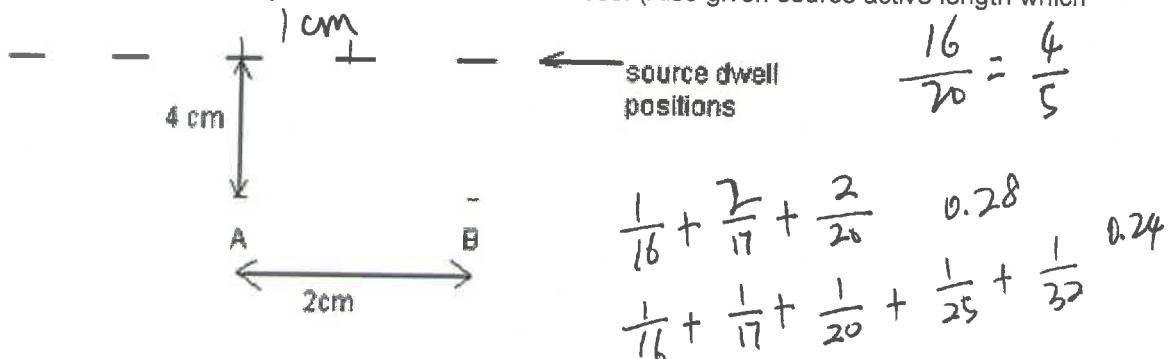
$200 = X(1/16 + 2/17 + 2/20) \rightarrow X = 714$ ; Dose at B =  $X(1/16 + 1/17 + 1/20 + 1/25 + 1/32) = 173.18\text{cGy}$

I take point B is 2 cm away from point A so it's 6 cm from midline source.

$200 = X(1/16 + 2/17 + 2/20) \rightarrow X = 714$ ; Dose at B =  $X(1/36 + 2/37 + 2/40) = 94.25\text{ cGy}$  ()

$$\frac{1}{16} + \frac{1}{17} + \frac{1}{20} + \frac{1}{25} + \frac{1}{32}$$

\*Given 5 HDR sources. 1 cm between each source dwell position. 4 cm between middle source and point A. The dose at point A is given. What is the dose at point B. Equal dwell times for all sources. (Also given source active length which is less than 2\*distance)



Checked with a brachy guru at our center, it should be: source active length which is less than 0.5\*distance. Then we can assume point source and simply use inverse square.

Given 125I half life of 59.4 days, given exposure rate constant in cGy/hr/U or cGy/U/hr. After 30 days what is the dose rate to the tumor in mSv/hr?  $D_t = D_o \times \exp(-0.693/59.4 \times 30)$  or dose rate = initial dose rate  $\times 0.5^{(30/59.4)}$

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.

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

Question not clear

The App activity (mCi) = exposure rate at 1 m / exposure rate constant of the unfiltered source at 1 m

### LINAC/Machine

All of the following are advantages of a dynamic wedge (created with a moving jaw) over a conventional physical wedge, except:

- A. Same depth dose as the open beam.
- B. Field is not limited in the non-wedge direction.
- C. Therapists do not have to lift a heavy wedge.
- D. Less dose outside the field (e.g., to contralateral breast).
- E. Wedge transmission factor is independent of field width.

E

With a dynamic wedge the wedge factor (measured on the beam axis) is a function of both the starting and ending moving jaw position, i.e., both field width and offset.

From TG114, WF is function of field size, and Varian EDW is function of fixed jaw position. From Green p87, the wedge effect of EDW is not produced by differential attenuation through a filter the beam is not subject to changes in energy as is the case for physical edge, so the depth dose will not be changed.

With regard to the production of electron beams by linear accelerators, which of the following is true?

- A. The beam current is much higher in the "electron mode" than in the "photon mode."
- B. Electron beam flatness depends on the design of the cone or applicator.
- C. The bending magnet is rotated out of the beam when "electrons" are selected.
- D. Thick scattering foils can be used to reduce bremsstrahlung.

T12. B

The beam current is higher in the photon mode. The bending magnet is fixed in position and is required to point the electrons toward the isocenter. The thicker the scattering foil, the greater the number of interactions and the higher the percentage of bremsstrahlung. Cone design and collimator settings are both important for electron beam flatness.

Following Green p89 -90, the electron beam is scattered by "thin" foil (copper). Ideally, there would be wide-angle scattering and no energy loss or bremstralung production. The cone/applicator (low z material Al, high z would generate unwanted x-ray) should be placed as close as patient surface so that limit the electron scattering.

43. Beam steering vs gantry angle in a linac. Signals to steer originate from ..... ion chamber .... various other options. Using Varian machine as an example, steering magnetic coils are placed at the gun end, and at the end of the waveguide, used to correct the geometric misalignments in the e gun, and guide the beam accurately onto the x-ray target (or electron window). The beam incident position and angle uncertainty onto the ion chamber are monitored by the 2 ion chambers placed after the target. The 2 ion chambers send the signal back to the coils to adjust the beam alignment (or steering the beam) ()

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.

This recall can be wrong, because both answers are correct. When changing from photon to electron mode, the gun current can change from 600 mA for 6x to 150 mA for 18 MeV due to large electron current required to generate Bremsstrahlung photon. The double scattering foil are mounted together, so they are in the place when changing photon to electron mode. (MetCalf p22, 26 p31, )

\*To increase the energy in the accelerator, what you do? Increase the current in the magnetron, or Increase the voltage in the magnetron, Increase the current in the Thyratron, or, increase the current to the Gun  
(Green:Linear accelerator for radiation therapy:p32, increase the voltage )

In magnetron, the magnetic field strength and anode-cathode voltage are chosen, so increase voltage makes more sense than increase current. (p30)

More detail: (p32-p33) High power level of the magnetron can be achieved by increasing the anode and cathode structure and supplying the magnetic field by the use of a coaxial coil. This sys allows the possibility of changing the magnetic field strength and consequently changing the voltage at which conduction is established, which in turn allow the microwave power output to be varied. This allows the magnetron operating between 2 to 5 MW, and allows the sys to accelerate the electron beam current in the accelerating waveguide to different energies.

The better answer may be changing the length of the structure as well as the magnetic field and voltage.

20. There is a 1 mm crack on the linac vault and you a large ion chamber to measure the exposure rate of 1 mR/hr. You move the chamber away from the crack behind the "good" wall and the exposure rate is 0.5 mR/hr. Is your exposure rate at the crack smaller or larger than 1 mR/hr?

Since it's a small crack, and we have large volume chamber, I assume the chamber effective measured area larger than the 1 mm crack. Therefore, chamber can measure the exposure from crack and also from the "good" wall. The actual exposure rate at the crack should be > 1 mR/h

\*Which part of linac is not water cooled?

Water cooling for linac is either to maintain the frequency or remove excessive heat. It may be easier to list the component needing the water cooling rather than not water cooled; the components need water cooled are 1. Microwave valve, 2. Accelerating waveguide, 3. Resonant cavities, 4. Target 5. Focusing and steering coils 6. RF isolator, 7. Transformers (Green p53, )

What is the purpose of the bending magnet and where is it located? Options included: to accommodate a horizontal waveguide, and to focus the electron beam on the target.

Used to bending electron path so that for high energy linac, it won't have unacceptable high isocenter (D. Greene, linear accelerators for radiation therapy, ) After waveguide and upstream relative to the target

\*Suppose we have a malfunction in the bending beam magnet system, What would you expect to realize a change in: flatness and output will be off ... (the profile (symmetry) will be off which is more obvious than flatness and output, needs to adjust the steering coil, )

\*Where are the electrons generated in a linac? gun/cathode AA

\*Electrons are produced in a linac by (thermionic emission from anode, thyratron anode, heating a filament, etc)

\*Which components of a LINAC are pulsed after Thyratron is fired?

electron gun and magnetron/klystron (D. Greene, linear accelerators for radiation therapy, )

\*What is the Klystron's function. RF power amplifier AA

\*Select proper order of parts in a LINAC.

Electron: electron, collimator 1, scattering foil, MU chamber, collimator 2

photon: electron, target, primary collimator 1, flattening filter, MU chamber, collimator 2 (SC)

Remember the scattering foil is at the same level as the flattening filter.

(Electron beam can be produced by single or double scattering foil (green Fig. 6.12 & 6.13), ()

\*What is the main difference between Magnetron and Klystron. (from 2005 recall Hint: Klystron is not a microwave generator.)

Klystron is essentially an amplifier with a low-power microwave input, while the magnetron is a self-oscillator, producing the microwave in response to a DC input.

Klystrons are usually used to power high-energy linacs; magnetrons are used for lower energy linacs.

Klystron and magnetron and output is usually 5 and 2 MV peak power, respectively, for medical linac.

The operation life is 10,000, 2000 hour for klystron and magnetron, respectively.

The operation of magnetron is temperature dependent, but klystron is not.

Klystrons are large, which can not be mounted on the gantry, and magnetrons are mounted on the gantry.

Compared to a magnetron, the klystron is more stable, expensive, and complicated. ()

**T38.** For a superficial x-ray unit, if there is no measured data, the two factors necessary to select the correct PDD table from published data are:

- A. Filtration and kVp.
- B. kVp and SSD.
- C. HVL and SSD.
- D. Filtration and SSD.

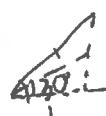
**T38. C** The HVL (expressed as mm of Al or Cu) defines the penetrability of a low-energy x-ray beam. Different combinations of kVp and filtration can produce beams with the same HVL, and hence the same depth dose characteristics. The SSD also affects the PDD and is important for superficial x-ray units that typically treat at short SSD.

\*Superficial therapy 50 – 150 KV (1 – 8 mm HVL Al). Varying thickness of filtration (usually 1- 6 mm Al) are added to harden the beam quality (Kahn 3<sup>rd</sup> ch4.1.c). The SSD for superficial therapy is 15 – 20 cm. The effective treatment depth for superficial dose range is 5 mm 90% dose line.

**T65.** Electrons appear to emanate from a virtual source. The virtual source, relative to the photon source, is:

- A. Closer to the patient.
- B. Further from the patient.
- C. In the same place.
- D. Both A and B can be true depending on the electron energy.

**T65. A** A pencil electron beam, after passing through scattering foils, is spread into a broad beam that appears to diverge from a point that is closer to the patient than the photon beam source.



\*Given a universal wedge with Wedge Factor = 0.5. Calculate the ratio of wedged / open field to make the wedge a 30 degree wedge.

Universal wedge is 60 degree. ()

The fraction of wedge field for the universal wedge,  $w_2/(w_1+w_2) = \tan(30)/\tan(60)$ , where  $w_2$  and  $w_1$  is the weight of wedge and open field, so the ratio of the  $w_2/w_1 \rightarrow w_2/w_1 / (w_2/w_1 + 1) = \tan(30)/\tan(60)$ , where  $w_2/w_1 = \frac{1}{2}$  (Green, linear accelerator for radiation therapy, p85 )

$$\frac{w_2}{w_1+w_2} = \frac{\tan 30}{\tan 60}$$

$$x \neq 1$$

$$\frac{0.5x}{0.5x+1-x} = \frac{1}{3}$$

\*A universal wedge has a 0.65 wedge factor. A 60 degree wedge is needed. 100 MU are given for open and 200 MU given for the wedge field. What is the average WF?

This question asks average WF than the effective wedge angle; my approach is (chamber reading of wedged field/chamber reading of open field) =  $(100 + 200 \times 0.65) / 300 = 0.77$  ()

\*Universal Wedge, WF = 0.2, what % MU needed for 30 degree effective wedge

$$0.2^*X / (0.2^*X + Y) = \frac{1}{3} \rightarrow X:Y = 5:2$$

$\tan(30)/\tan(60) = p \times 0.2 / (p \times 0.2 + (1 - p))$ , where p is the %MU for wedge field, so p = 71% of MU delivered for wedge field ()

$$\frac{0.2X}{0.2X+Y} = \frac{\tan 30}{\tan 60} = \frac{1}{\sqrt{3}} \rightarrow 0.6X = 0.2X+Y \rightarrow 0.4X = Y$$

\*A universal wedge with a wedge factor of 0.25 is used to deliver a beam with an effective wedge factor of 30 degrees. What is the fraction of MU's delivered by the wedged portion of the field.

$\tan(30)/\tan(60) = p \times 0.25 / (p \times 0.25 + (1 - p))$ , where p is the %MU for wedge field, so p = 67% of MU delivered for wedge field. For universal wedge, the equation is  $\tan(\theta')/\tan(\theta) = W_2/(W_2+W_1)$  theta' is the effective wedge angle, and W2 and W1 are the beam weight related to "the dose portion" of the field for wedged and open field (linear accelerator for radiation therapy, Green, p 85-86)()

\*If a patient is prescribed 200 cGy a fraction with 30% open and 20% wedged for each field, what dose does the patient receive if the wedge is put in the wrong field? WTF=0.25

If we assume the open and wedge field are 60 and 40% of the dose,

the dose for open is  $200 \times 0.6 = 120$  cGy, and for wedge is  $80$  cGy

$$80/0.25 + 120 \times 0.25 = 320 + 30 = 350$$
 cGy

$$\frac{120}{20} \times 0.25 + \frac{80}{0.25}$$

Or we can look in this way

$$MU_1 \text{ for open} = 120 \text{ cGy}$$

$$MU_2 \text{ for wedge} \times 0.25 = 80 \text{ cGy, and delivered dose} = MU_2 + MU_1 \times 0.25 = 80/0.25 + 120 \times 0.25 = 350 \text{ cGy}$$

\*Penumbra calculation from LINAC given target surface distance (SSD = 100cm), target block distance (d1=30cm), depth in patient (d=10cm) and target dimensions 3 mm S.

The penumbra is calculated on the depth, which can be calculated as Penumbra =  $S(SSD + d - d_1)/(d_1)$ , here I assumed r is the target radius, (Kahn 3rd, sec 4.7.A.3, )

$$\text{Penumbra} = 3/30 \times (100+10 - 30) = 8 \text{ mm} ()$$

\*An error of 2 mm in MLC opening causes an error of xx % in 2cm radiation field

Not sure what % error means here. For Varian machine, the MLC is 53.5 cm relative to the target, and for Elekta and Siemens, the distance is around 37 & 38 cm. If 2 mm off in MLC positioning, for Varian, it will be around 4 mm in field size, which is 20% of the 2 cm field size. However, if for the DMLC field, using 1 cm slit with 1 mm position off for MLC for 10 cm field size, the dosimetry error is 10%. (Phys. Med. Biol. 47 N159, 2002),

The question most likely asked the 2 mm gap error how much it will translate the dose error to a 2 cm nominal leaf gap instead of radiation field. The answer is as simple as  $2 \text{ mm}/20 \text{ mm} = 10\%$  reference (Med. Phys. 25, 1919 (1998) Fig. 8 ()

\*Which part of the linac will give rise to a low gas pressure fault? , Waveguide, Magnetron, Accelerating tube, etc.

The more detail answer is the transition section between the magnetron\klystron and the transmission waveguide. (p52, Green, linear accelerator for radiation therapy, )

\*If a Linac's outputs are off the same way for all the beams, what could be the problem?

Ion chamber (leakage from ion chamber)

\*Difference between physical wedge and dynamic wedge is?

Dynamic wedge has less beam hardening and less scatter...

\*When the current in the magnetron increases what is the resulting change:

The magnetron provides high power microwave to waveguide, if changing the current in the magnetron, the output power of the magnetron will be increased, and the energy of the electron traveling in the waveguide will be increased as well. Any other opinion? (Green, p32, )

\*If the high voltage power source is pushing too much, what is the most likely observed result on the accelerator.

From AAPM review course 2011, it mentioned that if we increase magnetic field too much for magnetron, it will leads sudden drop of electron current in the magnetron. Therefore, it will be no output. Any better answer?()

This is sort of a vague question. If the high voltage power source is powering the direct current perpendicular magnetic field then I agree with the previous statement. A higher magnetic field will cause the trajectories of electrons to bend more and they will therefore pass further away from the cavities decreasing the overall microwave power. However, if the high voltage power source is powering the electric field between the anode and cathode, that will increase the overall kinetic energy of the electrons therefore increasing the overall microwave power induced in the cavities.

More generally (for machines with a klystron) an instability in the high voltage power supply will lead to energy instabilities as well as output instabilities because it will affect the gun filament as well. JPS

### **IMRT(intensity modulated):**

An MLC is used for static field shaping. Compared to standard (5 HVL) blocks, the primary beam transmission through the MLC is \_\_\_\_\_ when averaged over the blocked area:

- A. Larger
- B. Smaller

PCAM block and MLC transmission are 5 and 2%, respectively.

For patient-specific IMRT QA, measured dose distributions obtained with film or detector arrays can be compared with calculated dose distributions in terms of % dose difference and distance-to-agreement (DTA). Which of the following statements is *false*?

- A. The dose difference tolerance is typically 3%.
- B. The distance to agreement tolerance is typically 3 mm.
- C. The score of the percentage of points that are within tolerance is typically 95%.
- D. Complex intensity patterns with large dose gradients generally have lower scores.
- E. The distance to agreement criteria compensates for dose differences in low-gradient regions.

Leaf positioning accuracy is critical for IMRT because:

- A. Round leaf edges found on many MLC increase leaf transmission at field edges.
- B. MU are greater for IMRT fields.
- C. IMRT apertures are irregular in shape.
- D. Dose reproducibility is more important for IMRT.
- E. Gaps between leaves determine the dose delivered.

T51. E

Dose differences within 3% are hard to achieve in *high*-gradient regions due to spatial uncertainties in dose calculation and measurement. The DTA criteria is designed to compensate for small spatial errors in high-gradient regions.

The accuracy of leaf positioning affects the width of the gaps in an IMRT field. The dose delivered is sensitive to small variations in gap width. Therefore, the dose is sensitive to errors in leaf position. This is true for step-and-shoot IMRT as well as for sliding-window IMRT.

\*Question on the effect of IMRT on a treatment planning: low gradient & low dose, low gradient& high dose, high gradient & low dose, high gradient & high dose. high gradient & high dose (High dose is due to high gradient that we can deliver high dose to PTV but low dose to the OAR)

\*In IMRT the physicist does not define: A. Beam Weights B. Field Sizes C. Gantry Angles

\*The definition of Sliding window in IMRT means \_\_\_\_\_  
dynamic MLC, dose delivery while MLC moving simultaneously, MLC speed is also changing while MLC moving ()

\*What method cannot be used to verify an IMRT plan Film, point hand calc and single ion chamber?

\*IMRT dose verification using small volume chamber (0.1cc). What should its resolution (or measured error) be in order to be able to use for dose verification (**ans: 0.1%, 0.5%, 1%, 3%, 10%**)

IMRT QA usually employs 3% 3 mm criteria. The measured error should be less than 3 %. Anyone ? ()

In our clinic, we allow 1% measurement error on CAX diode ()

The ionchamber and electrometer uncertainty is only 0.1%.

### **Beam Data/Measurements:**

3. According to TG-59, an ionization chamber reading is corrected to compensate for the temperature and pressure dependence of the \_\_\_\_\_.

1. air volume in the ionization chamber
2. **mass of air in the ionization chamber**
3. mass stopping power ratio for electrons in the ionization chamber
4. mass stopping power ratio for electrons of the phantom material
5. density of air in the monitor chamber **Dose is defined as J/kg(mass)**

Match the quantity measured by the dosimeter with the type of dosimeter::

- A. Charge collected
- B. Optical density
- C. Light emitted on heating
- D. Temperature change**
- E. Change in viscosity

T98. Calorimeter

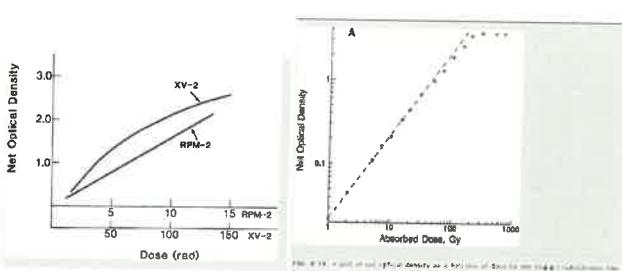
It is based on the principle that the energy absorbed in a medium from

radiation appears ultimately as heat energy while a small amount may appear in the form of a chemical change. This results in a small increase in temperature of the absorbing medium which, if measured accurately, can be related to absorbed dose. (Kahn 3<sup>rd</sup>, p142)

- 6) Spatial resolution of MOSFET detectors, possible answers were in units of **micrometer**  
 The MOSFET effective measurement size can be as small as 10 um (MetCalf p171, )

The advantages of radiochromic film, as compared to radiographic film, for purposes of x-ray and electron dosimetry include all of the following, except:

- A. It is nearly tissue equivalent.
- B. It does not require post irradiation processing.
- C. It is relatively insensitive to visible light.
- D. Its response (optical density vs. absorbed dose) is more linear.
- E. It requires a lower dose.



Radiochromic film (frequently used in brachy) also has high special resolution, large dynamic range ( $10^{-2} - 10^6$  Gy), relatively **low energy dependence**. (Kahn 3<sup>rd</sup>, p153). The disadvantages are (1)higher dose required, (2) more expensive (3) slightly higher noisier image than regular film.(Raphex 2009 T41)

Radiochromic film offers the following advantages as a dosimeter, except:

- A. High resolution.
- B. No chemicals or darkroom needed for development.
- C. Tissue equivalence.
- D. Small dependence on photon energy.
- E. Very high sensitivity.

(E) The disadvantage of Radiochromic film is that it requires several Gy

or more for accurate dosimetry.

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.

\*What is the Stem Effect for cylindrical chamber from? (A) Leakage from chamber ionization (B) Air outside the chamber stem. **stem effect is caused by measure of ionization in the body of stem and ionization of air between end of chamber and metal cap Kahn p86**

*Stem effect } Interactions of radiation with air near the chamber end or*

Question on stem effect (Kahn p86 – 87)

99. Manufacturer calibration for a source is given as  $6.3 \times 10^5$  Gy/hr. Two weeks later a reading of 71 nA is given, the calibration factor for chamber is X (Gy/C). How far off is the source from the manufacturer's stated calibration?

$$I(A) = Q(C)/Time(s)$$

$$71 \times 10^{-9} \text{ C/s} \times X \times 3600 = 2.6 \times 10^{-4} X \text{ Gy/hr};$$

\*For IMRT plan verification, which of the following has the best spatial resolution (A) Diode array (B) Laser (C) Film

Given a picture of non-wedged profile scans obtained using a scanning water tank, questioned asked what was wrong with the superficial-most profile (which appeared somewhat wavy in comparison to the others).

\* One beam profile diagram was provided with profile line variation at the surface. The reason for that....Ans was---Water fluctuation.

\*Purpose of the guard ring in a plane parallel chamber is to? A. Define the collection volume" (Sue) <http://www.hps.org/publicinformation/ate/q8149.html> The guard rings play a major role in reducing the leakage of extraneous charge to the collecting electrode.

() Additional info from Frank Attix (Intro. to radiological phys....) p312. The guard electrode is primarily to provide a uniform electric field, thus allowing the radius of the collecting vol to be well defined. In some parallel plate chamber, the guard rings also stops the leakage current from HV electrode.

\*Given the density of air 0.001293 g/cc, chamber with 0.19 cc, given  $1 R = 2.58 \times 10^{-4}$  C/kg. Calculate the approximate exposure calibration factor of the chamber in R/C.

$$1R = 2.58 \times 10^{-4} \text{ C/kg} \times 1.293 \times 10^{-6} \text{ kg/cc} \times 0.19 \text{ cc} = 0.634 \text{ nC} ()$$

$$1R = 1.293 \text{ kg/cc} \times 10^{-6} \times 1.9 \text{ cc} \times 10^{-1} \times (2.58 \times 10^{-4}) \text{ C/kg} = 0.63 \text{ nC} () \Rightarrow 1.58 \times 10^9 \text{ R/C}$$

\*1 R delivered, 3x10-10 C measured, what's the size of the chamber?

$$1R = 2.58 \times 10^{-4} \text{ C/kg} \rightarrow 1.16 \times 10^{-6} \text{ kg} \rightarrow \text{get volume with air density}$$

$$IR = 2.58 \times 10^{-4} \frac{\text{C}}{\text{kg}} \cdot x = 3 \times 10^{-10} R = 2.58 \times 10^{-4} \frac{\text{C}}{\text{kg}}$$

$$\underline{2.58 \times 10^{-4}}$$

$$\frac{R}{\underline{2.58 \times 10^{-4}}} = \frac{3 \times 10^{-10}}{\underline{2.58 \times 10^{-4}}} M = 0.001293 \times 0.19^{46} = 0.00024567 \text{ g}$$

The air density is about 1/1000 of tissue so chamber size is around  $1.16 \text{ cm}^3$  ()  
 Air density is  $1.2 \text{ kg/m}^3$  at 20 degree, so  $0.97 \text{ cm}^3$

Air density  $1.2 \text{ kg/m}^3$   
 @  $20^\circ\text{C}$

18. Give you dose and charge, ask you to calculate the chamber volume

dose ( $\text{J/kg}$ ) → by devide 0.0876 Gy/R to get exposure  $R_1$ ;  $R = 2.58 \times 10^{-4} \text{ C/kg}$ ; also need calibration factor  
 $\rightarrow (\text{charge} / R_1) / 1.29 \text{ kg/m}^3 \rightarrow \text{volume}$

f factor for air is 0.876 cGy/R, and air density at 20 degree is  $1.2 \text{ kg/m}^3$  at 0 degree is  $1.29 \text{ kg/m}^3$  ()  
 $X(\text{cGy}) / 0.876 (\text{cGy/R}) = R_1$ ,  $R_1 \times 2.58 \times 10^{-4} \times \text{Air density} (1.2 \text{ kg/m}^3) \times \text{Vol} = \text{measured charge, } C_1$   
 $\text{Vol} = C_1 / (R_1 \times 2.58 \times 10^{-4} \times 1.2)$  in  $\text{m}^3$

\*13.05 nC exposure,  $W/e = 33.3 \text{ J/c}$ ,  $2.58 \times 10^{-4} \text{ C/kg}$ . What is the volume of gas in the chamber?

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

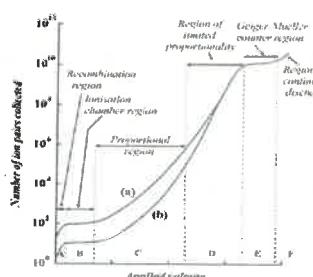


FIG. 4.1. Various regions of operation of gas-filled detector; region A represents the recombination region; region B the ionization region; region C the proportionality region; region D the region of limited proportionality; and region E the Geiger-Muller region. Curve (a) is for 1 MeV beta particles; curve (b) for 100 keV beta particles.

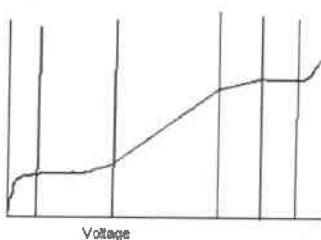
Podgorsak, Review of radiation oncology physics: a handbook for teachers

and students,

\*What are the properties of a GM counter.

GM is much more sensitive than ion chamber, which can detect individual photon. However, this detector is not a dose-measuring device but rather than a preliminary surveys to detect the presence of radiation. It can significantly underestimate dose. The voltage applied to GM is much higher than the ion chamber. (Kahn sec.16.8.A.2), any other comment? ()

\*In which region would a cylindrical ion chamber be operated on a voltage versus ion pairs collected graph? the second section from left



\*Question on the disadvantages of Diodes.

Over response to soft photon especially for deeper depth and large field size (TG106 Fig 1.c, )

Dependence on temperature, angle, dose rate and energy, radiation damage (Kahn 3rd p150) need electric connection (AAPM summer school 2011)

\*What does Gamma measure?

Both dose difference and distance to agreement.

distance axes. The  $\gamma$  quantity, calculated independently for each reference point, is the minimum distance in the renormalized multidimensional space between the evaluated distribution and the reference point. The  $\gamma$  quantity degenerates to the dose-difference and distance-to-agreement tests in shallow and very steep dose gradient regions, respectively. Since being introduced, the  $\gamma$  quantity

shallow means low gradient region.

2455 Med. Phys. 30 (9), September 2003

$$\Gamma(\vec{r}_e, \vec{r}_r) = \sqrt{\frac{r^2(\vec{r}_e, \vec{r}_r)}{\Delta d^2} + \frac{\delta^2(\vec{r}_e, \vec{r}_r)}{\Delta D^2}}$$

Generalized  $\Gamma$  function, computed for all evaluated positions  $\vec{r}_e$  and reference positions  $\vec{r}_r$

\*In a PTV point of IMRT plan the prescription dose is 240cGy, the most nearby point of closest dose is 232cGy in 2.3mm away, for a 3% dose limit, what is the Gamma factor? (A) 0.92 (B) 0.98 (C) 1.12 (D) 1.15  
Assume 3%, 3mm,  $(240-232)/240=3.33\%$ ,  $\text{gamma}=\text{sqrt}( (3.33\% / 3\%)^2+(2.3/3)^2)=1.35$

\*The PDD for wedge increases over open field due to what property of the wedge Beam hardening AA

\*What condition is not required for collimator output factor Sc. (Answer: phantom measurements from 2005 recall, )

\*According to Bragg-gray cavity theory, the diameter of the air cavity should be what?

The cavity is sufficiently small so that its introduction into the medium does not alter the number or distribution of the electrons that would exist in the medium without the cavity. Khan 3<sup>rd</sup> P113 or we can restate the detector size is much smaller than the mean electron (not photon) range (AAPM2011 review course, measurement of radiation)

\*What is the difference between Acceptance Testing and Commissioning of Linac.

Acceptance test: Verification process of the machine based on manufacturer's guidelines for a small subset of beam data.

Commissioning: A process where a full set of data is acquired that will be used for patient treatment. (TG106, )

\*What is the effect on point outside treatment field when using dynamic wedge versus hard wedge. Less scatter

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

### Atom and radioactive decay:

T1. Beta-plus decay has a \_\_\_\_\_ energy distribution because the energy is shared between the \_\_\_\_\_.

- A. Discrete beta-plus particle and the recoil nucleus.
- B. Continuous beta-plus particle, antineutrino, and recoil nucleus.
- C. Continuous beta-plus particle, neutrino, and recoil nucleus.
- D. Discrete beta-plus particle, anti-neutrino, and recoil nucleus.

T2. Listed below are some elements and their atomic numbers ( $Z$ ).  $^{60}\text{Co}$  decays via beta-minus decay to which of the following isotopes?

Element	Z
Fe	26
Co	27
Ni	28
Cu	29

- A.  $^{59}\text{Fe}$
- B.  $^{59}\text{Co}$
- C.  $^{60}\text{Ni}$
- D.  $^{60}\text{Cu}$



T1. C

T2. C.  $^{60}\text{Co} \rightarrow ^{60}\text{Ni} + ^0\text{B}$  , Kahn(3<sup>rd</sup>, p20)

- T4.** A novel isotope with a half-life of 15 days was used for a permanent seed implant. Total dose will be 100 Gy. When the patient returns for further evaluation 30 days post-implant, what dose has he already received?

- A. 75 Gy
- B. 78 Gy
- C. 83 Gy
- D. 90 Gy

Using the average life  $T_a = T_{1/2}/\ln 2$

$$100 \propto \text{initial } A \times T_a$$

$$25 \propto \text{initial } A (1/4) \times T_a$$

So 75 Gy is already delivered

- T21.** Concerning pair production, which of the following is *true*?
- A. The threshold energy for pair production is 0.51 MeV.
  - B. An electron and a positron are produced.
  - C. The energy of the incident photon is equal to the sum of the kinetic energies of the pair of particles.
  - D. Annihilation produces 1.02 MeV photons.
  - E. A pair of electrons is produced.

B (Raphex 2011) Kahn sec 5.9

- T22.** Which of the following statements regarding photoelectric interactions is *false*?
- A. They are mainly responsible for differential attenuation in diagnostic radiographs.
  - B. The incident photon is absorbed.
  - C. The probability increases rapidly with increasing energy.
  - D. Bound electrons are involved.

C (Raphex 2011) Kahn sec 5.7,  $\mu/p \propto z^3/E^3$

- T29.** Neutrons have a higher Quality Factor than electrons because:
- A. They transfer energy to protons, which have a high LET.
  - B. They slow down in tissue, and deposit most of their energy at the end of their track.
  - C. They have a large mass and charge.
  - D. They are directly ionizing.

- T29. A** Neutrons are indirectly ionizing. They transfer energy to protons, which have a large mass, and are densely ionizing, especially at the ends of their tracks (the "Bragg peak" for protons).

Neutrons interact basically by 2 processes (1). Recoiling protons from H and recoiling heavy nuclei from other elements & (2) nuclear disintegrations. For the 1<sup>st</sup> process, the energy transfer is very efficient if the colliding particles have the same mass, ex: H nucleus, so the paraffin wax or polyethylene are good material for shielding neutron. Lead is transparent to neutron (Kahn 3<sup>rd</sup> p75)

### Imaging:

Ultrasound can be used to help to localize all of the following *except*:

- A. The site of surgical resection of a brain lesion.
- B. The prostate, during radioactive seed implantation.
- C. The prostate, prior to external beam radiation therapy.
- D. A breast lumpectomy site to help to localize an electron breast boost. **A**

**Ultrasound does not penetrate dense bone.**

In diagnostic x-ray systems, filters are used to "harden" the beam. This process is mainly due to:

- A. Coherent scattering.
- B. Photoelectric effect.
- C. Compton effect.

**B** With the exception of the K edges, photoelectric interactions are more likely at low energy than at high energy. After passing through a filter, the total beam intensity is reduced, but the beam contains a relatively greater number of high-energy photons than before filtration.

The idea of this one is using high-z material so that the low energy photon will have large probability to have PE and then attenuated within the filter.

Which of the following is true, regarding patients scanned on a PET-CT unit?

- A. Patients should remain in a shielded room after the scan for the rest of the day, and are then released with specific radiation precautions.
- B. When the dose rate at 1 meter is less than 5 mR/hr, patients can be released with no radiation precautions.

This dose rate is generally achieved by the time the scan is completed. The half-life of FDG is 110 minutes.

0.05 mSv/R

Question on 3 D cone beam artifact. What is reason of the noise? someone provided this answer: combination of beam hardening effect and x-ray scatter causing increase of CT# reducing contrast well, the noise is same as for CT. So, although the answer they provided you is correct by itself, it is the reason for contrast degradation as well as uniformity and etc.

It can also beam the high-z material or the intrafractional movement (MetCalf p742)

258. On fluoro images in the simulator, wires used toward the outer edges of the field of view can appear to be (farther apart?) than they actually are. This is due to: image intensifier, automatic brightness control, scatter grid, another choice I don't remember...

### pincushion distortion

Compared to a conventional spiral CT, a linac-based cone beam CT has all of the following, except:

- A. Poorer soft-tissue contrast because of increased scatter dose.
  - B. Shorter image acquisition time.
  - C. Better spatial resolution in the craniocaudal direction.
  - D. Comparable patient dose.
- B      Spiral CT slice thickness is rarely less than 1.0 or 1.5 mm, but CBCT can have submillimeter slice thickness. CBCT has a larger beam area than spiral CT (fan beam), and therefore more scatter to degrade image quality.

### CBCT and CT has similar acquisition time.

Why CBCT has better spatial resolution in the craniocaudal direction: Ricardo: One answer can be because CBCT uses a Flat Panel Detector which has similar spatial resolution in the axial and craniocaudal direction. Whereas CT only uses a "line" detector so its resolution depends on the pitch. Briefly, The "line" detector has a spatial resolution that is transmitted to the axial plan. But you go around in a helical movement, so you combine information in the z-direction to create a slice thickness (slice thickness is equal to your resolution in z-direction).

In CBCT, it is only a circular scan. So, the resolution in the z-direction is the same as the resolution in the axial direction. To put it in another way, a Flat panel detector is like a combination of a line detector in both directions. Of course, now the line detector is getting thicker (many lines detector put together). So, its z-spatial resolution will increase as well.

The main advantage of modern linac-based EPIDs, compared to conventional portal images taken with radiographic film, is:

- A. Greater spatial resolution.
  - B. Improved signal-to-noise ratio.
  - C. Significantly less dose required to achieve good images.
  - D. Images can be digitally enhanced.
  - E. All of the above.
- D      The main advantages of EPIDs are that the images are in digital format and thus instantly viewable, can be digitally enhanced, are easily archived to a PACS, require no film processing, and do not require the radiation therapist to enter the treatment room.

### No difference between the portal film and EPID in terms of dose and image quality.

A 100-slice CT simulation for radiation therapy treatment planning requires approximately \_\_\_\_\_ of computer (or disk) memory:

- A. 100 kilobytes
  - B. 5 megabytes
  - C. 50 megabytes
- C      Each slice contains approximately  $512 \times 512$  pixels, and each pixel is 1 to 2 bytes. Therefore the total is  $100 \times 512 \times 512 \times 2$  bytes = 52.4 MB.

Hounsfield numbers in a CT image are linearly related to the:

- A. Mass attenuation coefficient.
  - B. Linear attenuation coefficient.
  - C. Electron density of the patient.
  - D. Number of photoelectric interactions per centimeter.
- CT number =  $1000 \times [(\mu_{\text{material}} - \mu_{\text{water}}) / \mu_{\text{water}}]$ , where  $\mu$  is the linear attenuation coefficient.

The correct ordering of imaging modalities from poorest to best resolution is:

- A. PET, CT, film.

CT and MRI resolution depend on field of view (FOV), but are usually 1 mm or less. PET scan resolution is limited to a few millimeters, mainly because of the finite range of the positrons, and also because the 511 keV annihilation gammas are not exactly antiparallel.

### Film has the best resolution!!

PET images have a spatial resolution of approximately \_\_\_\_\_ mm in the axial plane:

- A. 0.5–1.0
- B. 1–2
- C. 3–4
- D. 5–6

4–5 mm

Unlike CT and MRI, which have pixel sizes less than 1 mm, PET scan resolution is limited to a few millimeters, mainly because of the finite range of the positrons, and also because the 511 keV annihilation gammas are not exactly antiparallel.

T54. In a head & neck MRI, when gadolinium is used as a contrast medium for a T1 acquisition, A which of the following is true?

- A. Nasal mucosa will appear bright.

Gadolinium is a ferromagnetic agent that is useful in the imaging of a variety of lesions. It is always important to verify that adequate gadolinium was delivered, and looking at the intensity of uptake (i.e., brightness) of the nasal mucosa can help confirm this.

### Gadolinium (Gd)

T50. Spatial resolution in a PET scan is dependent on all of the following except:

- A. Decay energy of isotope.
- B. Tissue density inhomogeneities.
- C. Amount (mCi) of isotope injected.
- D. Physical size of detector crystals.
- E. Scanning 2-D or 3-D acquisition mode.

C

T49. What type of MRI study best helps differentiate CSF from surrounding edema?

- A. T1 with gadolinium.
- B. T2.
- C. Fluid attenuated inversion recovery (FLAIR).

T49. C	Cerebrospinal fluid (CSF) appears dark on a T1 image, and bright on a T2 image. Findings of interest such as transepndymal edema or intraventricular tumor can be obscured by the brightness of the CSF on a T2 image. FLAIR allows the CSF to appear dark, and thus make T2 changes more conspicuous.
T48. C	Orthogonal films of a gynecological applicator are required for dosimetry planning. AP and lateral films are taken, but the lateral film has very poor contrast. All of the following solutions may provide films with acceptable contrast <i>except</i> :
	A. Retake lateral, and reduce collimator setting to the minimum area possible. B. Retake lateral using a higher ratio grid. C. Retake lateral with increased mAs. D. Take orthogonals at 45° and 315° instead of 0° and 90°.
T48. C	Increasing mAs will make the film darker, but have no effect on contrast. Contrast is improved by reducing scatter. Reducing the collimator setting to the minimum necessary field of view usually has the greatest effect. If different grids are available, the one with the greatest grid ratio will "clean up" the most scatter. If these two techniques still do not work, for patients with very large lateral separations one solution is to take orthogonal R and L anterior obliques, making use of the somewhat reduced separation.
T74. C	When reconstructing the 3-D positions of a tandem and ovoid applicator from orthogonal films, it can be difficult to distinguish the R and L ovoids on the lateral film. All of the following can be helpful, <i>except</i> :
	A. Using different dummy seed markers in each ovoid. B. Rotating the orthogonal films a few degrees (e.g., gantry angles of 10° and 100° until the ovoids are separated on the lateral view). C. Taking films at gantry angles of 45° and 315°. D. The ovoid with the larger diameter is the one closest to the film cassette.
T74. D	The ovoid closest to the cassette will appear smaller. However, this is a small difference and may not be helpful in distinguishing the ovoids.
T89.	Computed tomography images are typically acquired with a 120-to-140 kV peak x-ray beam. Which best describes the interactions of the incident x-rays in a patient's body?
	A. Mostly photoelectric absorption with some Compton scattering B. Mostly Compton scattering with some photoelectric absorption C. Mostly Compton scattering with some pair production D. Mostly pair production with some Compton scattering
T89. B	In a 120-to-140 kVp x-ray beam the photons mostly undergo Compton scattering. However, there are a sufficient number of photoelectric interactions to achieve differential attenuation in bone.
	C. The average x-ray energy is 2 MeV and maximum energy is 6 MeV. The dominant type of interaction is Compton scattering with very small amounts (few percent) of pair production.

After 50 kVp, Compton becomes important, Kahn p74 Table 5.2

In 4 D CT Helical, what is the pitch?

pitch is the ratio of table increment over slice thickness. For multi-detector row CT, pitch is generally defined as the table travel per rotation divided by the collimation of the x-ray beam.

\*For a 4 slice CT scanner with a slice thickness of 1mm a pitch 1.5 and a gantry rotation of 0.5 sec, how long will it take to scan 100mm?

$$(100 / 1.5 * 4) * 0.5 = 8.3 \text{ s}$$

Pitch is defined as table travel per rotation divided by the collimation of x-ray beam. However, more intuitive way to define pitch is table travel per rotation divided by the effective detector raw thickness. (Radiology, 233, 323-327 (2004))

$$\begin{aligned} \text{Table speed} &= \text{beam collimation (effective detector raw thickness)} \times \text{pitch} \times \text{gantry rotation per sec} \\ &= 4 \times 1 \text{ mm} \times 1.5 \times (1/0.5) = 12 \\ 100/12 &= 8.3 \text{ s} \end{aligned}$$

\*Pitch = 0.5. For 10 gantry rotation the slice of 5mm, what distance does collimator move? (A) 2.5cm (B) 5cm (C) 10cm (D) 20cm

I would assume it's asking couch move. It will be  $10 * 0.5(\text{cm}) * 0.5 = 2.5\text{cm}$  ()

\*A question about scout images and DRs.

DR is a map of average attenuation coefficients computed along each of large number of rays drawn from the source of radiation to the location of virtual film. The result is an image comparable to a simulator film. (Hendee p253, )

Scout image: A scout view is a preliminary image obtained prior to performing the major portion of a particular study. There may be one or more reasons to get a scout view: to make sure the region of interest is included in the field of view, to check the exposure technique, or as a baseline prior to administration of contrast material.

\*What does a fMRI measure

the most popular fMRI sequence is Blood oxygen level dependent (BOLD) MRI, so my guess would be blood oxygen level. <http://en.wikipedia.org/wiki/FMRI>

3. Parts definitely not included in EPID – options were ion chamber, CCD camera, mirror, silicon screen, some other dose detection device. (Is that correct?)

For Varian, an array of image detector is based on a-Si, and within this units a scintillator converts the radiation beam into visible photons. The light is detected by the photodiode array implanted on the a-Si panel. (Kahn, sec. 12.3.B.) Do I miss other important part?

T5.

A diagnostic x-ray tube is running at 80 kVp and 10 mAs. The settings are changed to 120 kVp and 5 mAs. What is the approximate change in tube output?

- A. Does not change
- B. Decreases by 50%
- C. Increases by 10%
- D. Decreases by 10%
- E. Increases by 50%

X-ray output (quantity)  $\propto Z_{\text{target}} \times (kVp)^2 \times mAs$ , (Bushberg sec 5.7 very good!)

$$\text{So } 120^2 \times 5 / 80^2 \times 10 = 1.125$$

T5.(C)

T6. In the last question, what happens to the image contrast?

- A. Contrast does not change.
- B. Contrast increases.
- C. Contrast decreases.
- D. Cannot be determined.

→ Noise →

Tube output  $\propto Z_{\text{target}} \cdot kVp \cdot mAs$   
Image quality 15% rule

15% increase in

$kVp = \text{doubling}$   
 $mAs$

T6. X-ray energy increase contrast decrease, subject contrast  $C_s = 1 - e^{-\mu z}$  which is also the reason that mammography uses lower 20 keV (compared to the conventional radiologic energies 35 – 70 keV) Bushberg Ch10.1 has a great section about contrast

T83. In lung patient simulation, a slow CT scan is sometimes performed when 4DCT is not available. Which of the following is not true regarding slow CT scanning?

- A. The scan needs to cover multiple respiration phases.
- B. The image resolution will be better.
- C. The purpose is to capture extent of tumor motion.
- D. Patient dose will be more than for a normal CT scan.
- E. The CT can be used for target delineation.

B. The image resolution will degrade because of the blurring caused by lung motion.

T87. In amorphous silicon electronic portal imaging devices (EPIDs), the main purpose of the combination metal plate/phosphor screen is to:

- A. Convert incident x-rays into visible light.

PMB 2002, 47 R31-R65

As illustrated in figure 4, the approach involves the use of an x-ray converter that is optically coupled to a camera by means of a mirror and a lens. The converter consists of a flat metal plate (typically an ~1 to 1.5 mm copper, steel or brass plate) and a gadolinium oxysulfide ( $Gd_2O_2S:Tb$ ) phosphor screen. The metal plate serves to convert incident primary x-rays into high energy electrons, some of which escape the plate into the phosphor, as well as to block low-energy, scattered radiation which would otherwise reduce the contrast of the imaging system. The phosphor serves to convert primary x-rays into high-energy electrons and transforms a fraction of the energy of the high-energy electrons passing through it into light. Some of the light diffuses through the screen, exiting on the mirror side. The camera and lens serve to capture a fraction of this emerging light and transform it into a video signal that is then sent to other hardware for digitization, processing, display and archiving. It is estimated that, depending on the thickness of the phosphor and the energy of the radiotherapy beam, on the order of only ~2–4% of the incident x-rays interact and generate measurable signal in such systems.

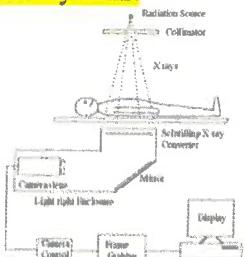


Figure 4. Schematic diagram of a scatter-based EPID with the x-ray detector in phosphor directly coupled to the sensor using a mirror and lens.

- T90.** Which of the following is *true*? A cone beam CT:
- Is generally acquired in a single rotation of the x-ray tube.
  - Has worse resolution than regular diagnostic multiple-slice CT in the cephalocaudad direction.
  - Requires roughly three times as much dose as regular diagnostic multislice CT.
  - Is ideal for scanning long treatment volumes.
- T90. A** Generally, CBCT is acquired in one single full or partial rotation of the kV tube. Because it is a cone-beam acquisition, resolution in the cephalocaudad direction is superior or similar to a regular multislice scanner, as is dose. On a linear accelerator, the length of the scan volume is limited by the size of the kV detector and the single rotation acquisition. Generally, CBCT over lengths greater than approximately 15 cm is not currently possible.

(Metcalf, p749 table 12.2)

- T91.** Regarding 2D kV planar imaging and 3D kV CBCT used for IGRT, which of the following is *true*? Both 2D and 3D kV:
- Require higher resolution image detector plates than MV imaging.
  - Are excellent for determining rotational setup errors.
  - Are valuable when used for patients with small implanted metallic fiducials.
  - Allow visualization of soft-tissue anatomy.

The current detector plates for MV and KV are aSi plates which is most commonly available.  
C. kV is good to visualize the metal marker.

- T92.** A half-fan CBCT (i.e., imager is shifted laterally) is taken instead of a full-fan CBCT in order to?
- Avoid collision.
  - Increase the reconstruction volume in the axial plane.
  - Increase the reconstruction volume in the sup-inf direction.
  - Increase image quality, keeping the reconstruction volume the same.

B. The axial plan means the transverse plan in the Eclipse treatment sys.

$$160 \times 0.8 = 128$$

- T100.** Two orthogonal MV localization images (one AP plus one LAT) are taken daily for 40 fractions, to image fiducials in a patient's prostate. The approximate additional dose to the isocenter from these images over the course of treatment is \_\_\_\_\_ cGy.
- Negligible
  - 10
  - 75
  - 130
  - 500
- 2.6 - 4 cGy*

$$0.78 \times 2 \times 40 \times 2 =$$

The MU for MV is around 2 – 3 MU, and the energy is 6x. The depth dose at iso is around 65%, so  $2 \times (2 - 3) \times 0.65 \times 40 = 104 - 156$  cGy (D)

- T101.** As compared to radiographs taken on a conventional simulator, digitally reconstructed radiographs (DRRs) from a CT simulation typically have which of the following?
- Comparable spatial resolution in all directions
  - Better resolution in all directions
  - Better resolution only in the cranial-caudal direction
  - None of the above.

- T101. D** DRRs typically have poorer resolution in all directions than do conventional simulation films, especially in the cranialcaudal direction because of CT slice thickness.

Because DRR is reconstructed from CT image and the resolution is limited by slice thickness. The conventional simulator shoots the regular kv image so there is no slice thickness limit.(Ref Kahn p469)

- T131.** What is the approximate whole body radiation dose to a patient who undergoes a PET scan using 10 mCi FDG?
- 0.02 cGy
  - 0.2 cGy
  - 2 cGy

- T131. C** The average radiation dose from 37 mBq (10 mCi) administration of FDG in organs ranges from approximately 1–4 cGy, the highest dose being received by the bladder wall, a consequence of the fast excretion of FDG from the body.

\*What info PET can't deliver about the tumor (metabolism, metastasis, pathology, TX follow up, tumor)

If the biologically active molecule chosen for PET is FDG, an analogue of glucose, the concentrations of tracer imaged then give tissue metabolic activity, in terms of regional glucose uptake. Although use of this tracer results in the most

common type of PET scan, other tracer molecules are used in PET to image the tissue concentration of many other types of molecules of interest. ()

Why can't MRI be used for hetero corrections?  
One of possible answers electron density compared to CT ()

\*Question about the best radioactive material used in PET to help in radiation oncology treatment planning.  
Agent used in PET? F18/FDG AA

41. Multi detector CT, when cone beam increases size, what's true: Collimator decreases, scatter photon increases, etc. (not quite sure about the answers)

$$3 + 0.8 + 1.8 =$$

### Tissue inhomogeneities:

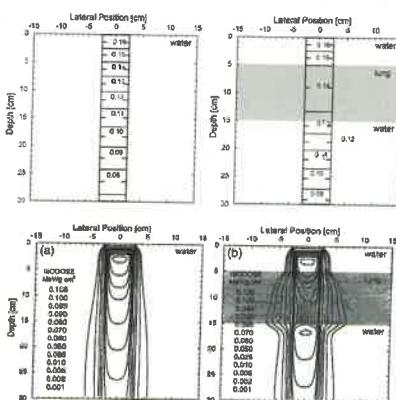
\*Three layer material. First layer is 3 cm thick, HU = 0. Second layer is 4 cm thick, HU = -800. Third layer is 2 cm thick, HU = -100. What is effective depth?

(from Yahoo group) Assume a linear relationship between electron density and HU, HU=0 is water with density =1; HU=-1000 is air with density close to 0 → HU = -800 with a density = 0.2; HU = -100 with a density = 0.9 →  $3+4*0.2+2*0.9 = 5.6\text{cm}$

**T41.** Regarding tissue inhomogeneities, changes in secondary electron fluence strongly affect the dose:

- A. Up to a few centimeters downstream of the inhomogeneity.
- B. Upstream of the inhomogeneity.
- C. Within the inhomogeneity.
- D. Near the boundaries of the inhomogeneity.
- E. C and D above.

**T41. E** For points that lie beyond the inhomogeneity, the predominant effect is the attenuation of the primary beam. The changes in the secondary electron fluence affect the tissues within the inhomogeneity and at the boundaries.



TG65 Figure 4.

**T74.** Accelerators are calibrated as dose to water or muscle. A clinic uses calibration to water but participates in a multi-institutional protocol specifying dose to muscle. A plan is done on a participating patient, and one of the beams is calculated as 100 MU, still assuming dose to water. To comply with the protocol, the beam-on-time needs to be changed to \_\_\_\_\_ MU.

- A. 98
- B. 99
- C. 101

**T74. C** The amount of radiation that delivers 1 Gy to water will only deliver 0.99 Gy to muscle.  
Therefore the beam-on-time needs to be increased by 1%.

TG21, for photon beam,  $D_{\text{muscle}} = D_{\text{water}} \left( \frac{\mu_{en}}{\rho} \right)_{\text{water}}^{\text{muscle}}$  the Stopping power and collision attenuation coefficient is about 0.99

For electron beam,  $D_{\text{muscle}} = D_{\text{water}} \left( \frac{S}{\rho} \right)_{\text{water}}^{\text{muscle}}$

\*With 6 MV incident on x1 mm tissue then x2 mm bone then x3 mm lung, what is the dose to the proximal (or distal) part of the lung?

**Based on my memory, please correct me if i'm wrong.** Lung has a density that's about  $\frac{1}{3}$  of soft tissue, bone is about 1.65 times the density of tissue. So  $1+2*1.65+3/3 = 5.3\text{mm}$ .  $6\text{mm}-5.3\text{mm} = 0.7\text{mm}$ ; 6MV attenuates about 3.5% per cm  $\rightarrow 3.5\% * 0.07 = 0.25\%$

TG65 Table 8, 6MV traveling in lung is about 3%/cm dose increase after lung, and for bone it is about decrease (-) 2%/cm, so  $-2/10 \times 2\% + 3/10 \times 3\% = 5\%/10 = 0.5\%$  (0.5% dose increase compared to homogeneity 6 mm tissue thickness),

**Table 8.** Simple correction (percent per cm) of the dose according to photon energy and tissue density.

Energy	%/cm Correction	
	Lung	Bone
Cobalt-60	+4.0%	-2.5%
4-6 MV	+3.0%	-2.0%
10 MV	+2.5%	-1.5%
18-25 MV	+1.5%	-1.0%

$$14\text{cm} \quad 2 + \frac{11}{3} + 1 = \frac{20}{3} \\ = 6.7\text{cm}$$

Given a drawing of an axial cut of the chest with lung in the field. CAX of beam goes through chest wall (2cm)-->lung(11cm)-->cord(1cm) to give 200 cGy to pt A. If the TPS did not do heterogeneity corrections to calculate MU, what would be the actual dose delivered to Pt A.

$3\% \times 11 = 33\% \text{ overdose}, 200 \times 1.33 = 266 \text{ cGy}$  (TG65 table 8)

$$73\text{cm} \times 3\%/\text{cm} = 21.9\%$$

Another method :  $(11-11 \times 0.25) \times 3.5\% = 29\%$

\*if a photon beam penetrating 3 cm of healthy tissue then 9 cm in the lung then 1 cm of healthy tissue to reach the point x, where the prescribed dose at x is 250 cGy, what is the dose at x because of the lung?

According to TG65 table 8, for 4-6MV, the dose will increase 3%/cm lung, so  $250 \times 0.27 = 67.5 \text{ overdose}$  ()

Another method:  $(9 - 9/3) \times 3.5 = 21.5\% \text{ overdose}$

\*Similar to last question, what the MU would be because of the lung/ 27% lower () or 21.5% overdose

5. An isocentric 10-MV oblique photon beam has depth of 12 cm, of which 6 cm is muscle tissue and 6 cm is lung. Without lung correction, the actual delivered dose at the isocenter compared to the calculated dose at the same point would be

1. 20% higher
2. 10% higher

$(6-6/3) \times 2.5\%/\text{cm} = 10\% \text{ higher}$  corresponding to ABR answer

\*For a 10MV plan, what the actual dose would be if the plan did not apply heterogeneity correction?

%2.5 increase for lung, %1.5 decrease for bone

\*Shown CT with depths of tissue and lung, single direct field, and attenuation coefficients, what is the dose w/ and without heterogeneity corrections?

If the question provides attenuation coefficient for water (`mu_water`) and physical depth in the tissue and lung (`d_tissue`, and `d_lung`), the ratio of the dose with and without corrections may be calculated as  $\exp(-\mu_{\text{water}} \times \text{depth}_{\text{tissue}} + \mu_{\text{water}} \times \text{depth}_{\text{lung}}/3)/\exp(-\mu_{\text{water}} \times (\text{depth}_{\text{tissue}} + \text{depth}_{\text{lung}})) = \exp(\mu_{\text{water}} \times (2/3)\text{depth}_{\text{lung}})$ , ()

Basically it's TAR method  $\text{TAR}(d,0) = \exp(-\mu(d - d_{\max}))$ , and  $\exp(-\mu d_{\max})$  term can be eliminated for this calculation.

AAPM's Report No. 85 "Tissue Inhomogeneity Corrections For Megavoltage Photon Beams" (2004) draws some general conclusions. Which of the following statements is false?

- A. The widespread availability of CT and 3-D planning systems makes inhomogeneity corrections more accurate than was previously possible.
- B. Inhomogeneity corrections should account for changes in the electron densities of tissues traversed.
- C. Because different treatment planning systems use different inhomogeneity algorithms, making such corrections will introduce even larger errors in dose reporting than were previously made without them.
- D. Monte Carlo dose calculations can calculate the effects of inhomogeneities on scatter radiation, whereas analytical dose calculations only correct for changes in effective depth.
- E. Since most prescriptions and toxicity estimates are based on historical data calculated without inhomogeneity corrections, use of these historical doses introduces considerable uncertainty to dose-response data.

Historical data reported in the literature without inhomogeneity corrections actually used a variety of beam energies and path lengths through inhomogeneities. The doses reported therefore included these uncertainties. Although different planning systems use different algorithms, the use of corrections is expected to reduce the uncertainty in dose reporting.

### Electron dosimetry:

A shaped 9 MeV electron beam with an output factor of 0.91 cGy/MU measured at  $d_{max}$  delivers a dose of 200 cGy to the 95% isodose curve. The maximum tissue dose is \_\_\_\_\_ cGy.

- A. 231
- B. 220
- C. 211

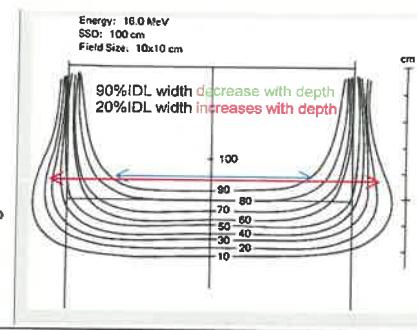
$$200/0.95 = 211 \text{ don't need to divide 0.91! idiot!}$$

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  $d_{max}$  (increase/decrease). Only one option had no change in surface dose (%DD)

The energy is most likely  $15 \times 2 = 30$  MeV already, so %DD won't change anymore.

To ensure adequate coverage of the treatment volume with an electron beam, it is important to remember that:

- A. All isodose curves decrease in width with depth.
- B. All isodose curves increase in width with depth.
- C. The 90% isodose increases and the 20% isodose decreases in width with depth.
- D. The 90% isodose decreases and the 20% isodose increases in width with depth.



Q: The electron field size required to treat a volume with a 5 cm width at the treatment depth \_\_\_\_\_ cm.

- A. 5
- B. 6
- C. 7

C

As a rule for electron treatments, 1.0 cm margin is added to each side of the volume to be treated. This is because of the penumbra width, and because the 90% isodose "curves in" with depth.

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

$$R50 = 1.029 \times 5.1 - 0.06 = 5.19; \text{ ave}(E0) = 2.33 \times R50 = 12 \text{ MeV.}$$

Question: when we are talking about 12MeV, we are referring to average E0, or (Ep).

Observation: R50 is not that much different than I50, I will just use  $I50 \times 2.3 = 11.7 \sim 12$  MeV which is E0 ()

\*On TSEI, to increase 5% homogeneity which is better to extend the distance or to reduce the energy used or what other method? (From Kahn sec 14.8 B.1, low energy electron scattered more while passing through air, combination of multiple low energy field can give adequate uniformity over pt's width. Therefore, I will choose extend distance, decrease energy, multiple fields, scattering plate placed in front of pt., multiple arc, ) Agree with , we use 9MeV here, and after the spoiler, about 6MeV reach patient.

T113. In total skin electron beam therapy (TSET), using multiple treatment beams achieves all of the following, except:

- A. Improves the uniformity of the skin dose.
- B. Decreases the effective depth of  $d_{max}$ .
- C. Increases dose uniformity in the target volume.
- D. Eliminates overdosing fingers and toes.

T113. D Using multiple fields tends to increase skin dose and decrease depth dose. In general, the more oblique fields used, the higher the x-ray dose to the patient's whole body but the greater the dose uniformity, except to thin body parts such as fingers and toes.

\*Which scenario would you most likely talk to the Dr.?

A. if he had a small cut-out to place on the skin and he ordered 12 Mev electrons? (This scenario seems OK not necessary to talk to the physician, anyone?)

\*Which curve represents 18 MeV, 6x6 FS,

Equivalent radius for 18 MeV =  $R_{eq} = 0.88 \times \sqrt{18} = 3.7$  cm which is equal to  $6.5 \times 6.5$  cm FS. After  $6 \times 6$  cm, we should see %DD not change much along with the increase of field size (Kahn 3rd p314-315 )

Or we can use  $18/2 = 9$  cm

From TG25 Fig. 14, for 15MeV, the 6x6 cm is very close to 8x8(15/2) to 25x25.

T66

A superficial tumor is to be treated to a depth of 1 cm while sparing a critical structure at a depth of 2 cm, using electrons with a 9-cm circular field. The most suitable technique would be:

- A. 6 MeV electrons without bolus.
- B. 6 MeV electrons with 0.5 cm bolus.
- C. 6 MeV electrons with 1.0 cm bolus.

C: 90% iso dose line is the most important treatment line,  $R_{90} = E_e(\text{average energy})/3.2$ ,  $R_{80} = E_e/2.8$ ,  $R_{50} = E_e/2.3$ ,  $R_p = E_p(\text{most portable energy})/2$ ,  $E_z(\text{energy at depth } z) = E_e(1 - z/R_p)$

\*Given a 45Gy photon treatment to neck. Choose electron energy for boost to treat nodes at 3cm depth and spare cord at 5cm depth.

I agree with 9MeV, or 12 MeV with 1cm bolus?

My opinion: The most useful treatment depth (Kahn, sec 14.4.A) is  $R_{90}$  which is 2.8 cm for 9MeV, and 9MeV will have better skin-sparing compared to 12 MeV, since we only want to treat the node at 3 cm depth ()

$3 \times 3.3 = 9.9$ , and  $5 \times 2 = 10$ , 10 MeV is actually better choice

\*When an electron beam has an oblique incidence on the surface, what happens?

1. increase side scatter @  $d_{\max}$
2. shift  $d_{\max}$  toward surface
3. decrease the depth penetration (as measured by the depth of the 80% dose) Kahn 3<sup>rd</sup> (p319)

T67. For a  $10 \times 10$  cm electron cone, using an energy of 12 MeV, the electron field size can be blocked down to \_\_\_\_\_ without significantly affecting the central axis depth dose.

- A. 9x9 cm
- B. 8x8 cm
- C. 6x6 cm
- D. 3x3 cm

$R_{eq} = 0.88\sqrt{E_p}$ ,  $R_{eq}$  is the equivalent radius for the field size with the lateral electron equilibrium, and  $E_p$  is the most portable electron energy. The square field size can be obtained by  $R_{eq}^2 \pi = s^2$ ,  $s = 5$  cm, closest answer

Using E/2 is faster! (c)

$$\frac{I_{d_{\max}}}{I_{Air}} = \frac{SSD}{R_{eq}}$$

\*Determine the Effective SSD for 6 MeV electrons. end of applicator at 100cm  $I_0 = 100$ , at 20 cm gap reading was 44, and at 40 cm gap reading was 25.  $d_{\max}$  for 6 MeV electrons not given.

Solve effective SSD, using  $I_{d_{\max}}/I_{airgap} = [(SSD + d_{\max} + airgap)/(SSD + d_{\max})]^2$  ()

I assumed the reading obtained from  $d_{\max}$  1.5 cm for 6 MeV, so  $\sqrt{44/25} = (SSD + 40 + 1.5)/(SSD + 20 + 1.5)$ ,  $SSD = 39.1$  cm. ()

\*Superficial X-ray, 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?

$$150/f^2 = 52.3/(f+10)^2 \rightarrow f = 14.39\text{cm}$$

$$6-12\text{MeV} \sim 0.5-1\%$$

36. Amount of X-ray contamination of 18 MeV electron beam? 1%, 4%, 10%, etc

Typical x-ray contamination dose to a patient ranges from approximately (0.5 to 1%, 6 – 12 MeV) (1 to 2 %, 12 – 15 MeV) and (2 to 5%, 15 – 20 MeV). Khan Sec. 14.4, F p318. I would approximate 4 % for the 18 MV ()

What doesn't change by reducing field size in electron beam. (Answer:  $R_p$  from 2005 recall)

Once the field size large enough for the lateral electron equilibrium, the % depth dose does not depend on the change of field size (Kahn Sec. 14.4.D, ) rule of thumb minimum field diameter for later scatter equilibrium  $E/2.5$  in cm (Kahn Sec. 14.6.C)

I think the answer should be: Practical range ,  $R_p$ , does not change. See figure 8.4 in ([http://www-naweb.iaea.org/nahu/dmrp/pdf\\_files/Chapter8.pdf](http://www-naweb.iaea.org/nahu/dmrp/pdf_files/Chapter8.pdf))

Agree, if  $R_p$  is one of the choices, it's a better answer.

\*You use a 3x3 electron cutout... what doesn't happen?  $d_{\max}$  decreases, output decreases, flatness decreases, range decreases

All of the following change when an electron beam is made significantly smaller by adding a cutout EXCEPT: Rp, dmax dose, etc.

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

For this problem, I have some uncertainty, for higher electron energy, C will change as well. So I'm thinking about A, but A will change with collimator setting as well...

It depends on the energy, TG70 Fig. 15 shows the Depth of 80% changing for high energy. Fig. 14 shows the bremsstrahlung is relative stable for 15 MeV, I would choose A ()

\*Necessary thickness of lead for 6MeV electron cut-out

4mm(rule  $\frac{1}{2}$  of energy + 1mm) for 5 % transmission. The required thickness of Cerrobend is approximately 20% greater than that of pure lead (Kahn Sec 14.6.B) ()

\*What is the energy of 12 MeV electron beam at depth of 0.5 cm of a thick lead slab?

2 MeV/mm, so  $5 \text{ mm} \times 2 \text{ MeV} = 10 \text{ MeV}$ ,  $12 - 10 \text{ MeV} = 2 \text{ MeV}$ , ()

Q Treat 4.3 cm depth with 12 MeV electron, and Rx dose is 200 cGy, what is the dose at dmax? (A) 225cGy (B) 250cGy (C) 275cGy (D) 300cGy

$$12/4.3 = 2.8 \quad \text{Rx to 80\%}$$

$$200/0.8 = 250 \text{ cGy AA}$$

\*9MeV electron beam. At 4-cm depth, how much lead should be used to shield deeper structure? No other information.

$$9\text{MeV} - 4\text{cm} \times 2\text{MeV/cm} = 1\text{MeV}$$

$$1\text{MeV} / 2\text{MeV/mm} (\text{for Pb}) = 0.5 \text{ mm AA}$$

This would be my answer as well, just wondering do we need to add the extra 1mm here?

0.5 mm + 1 mm as the safe margin (Kahn sec 14.6.B.)

\* $E_p = E_0 (1-d/R_p)$  given that at depth  $d_1$ , the energy is  $E_1$  and at depth  $d_2$  the energy is  $E_2$ , at depth  $d_3$  what is the energy

two equations, two unknown

Electron  $E_0 = 7.1 \text{ Mev}$ , mean  $E$  at 2 cm = 4 Mev. what is range?

$$E_z = E_0(1-z/R_p) \rightarrow R_p = 4.58 \text{ cm}$$

\*Beam abutment question. Patient treated with 10MV photons and 16MeV electrons. Field size given. At 5cm depth what would be the case with the dose distribution. (from 2006 recall, photon side hot spot:electron side cold spot, photon side cold spot:electron side hot spot, both sides hot spots, both sides cold spots or no hot spots)

Hot spot on the photon side. Agree. KMW

Kahn 3rd p329 provides an example for 9MeV + 6MV photon we can see the hot spot is close to the surface around 2 cm, but for 16 MeV  $R_{80} = 5 \text{ cm}$ , and 10 MV  $d_{max} = 2 \text{ cm}$ , we may see the hot spot more below surface compared to 9MeV + 6 MV but may not approach to 5 cm. However, we will still see higher dose on the photon side than electron side. () If it's abutment problem, then hotspot on photon side, coldspot on electron side; If it's calculation problem, I will use: at 5cm, it's about 80% dose for 16MeV; about 2.5%/cm dose attenuation for 10MV

You have a half beam 6 MV photon beam and a parallel 9 Mev electron that match on skin surface... where is hot spot? on the photon beam side because of electron scatter

Q Question on backscattering using block for electron beams. How does it change with energy E and Z.

my try: low energy, high Z → more scatter...

Yes Kahn (Fig. 14.37 &14.38, )

S/rho and rho given for lead. Calc thickness of lead used to shield 20MeV beam.

$S/\rho \times \rho \rightarrow X \text{ Mev/mm} \rightarrow 20/X \rightarrow \text{thickness}$

S is the stopping power, so  $s/\rho \times \rho = dE/dt$ , we can calculate how much lead we need to shield the 20 MeV electron

9. 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 ...  
Extended SSD changes output significantly following effective SSD or virtual source method, and penumbra increase due to larger electron scattering in air (TG25,p98-99,& Fig 25 )

output decrease, penumbra widening, dose uniformity degradation within the field (TG70, IIF, or TG25 Fig 25 )

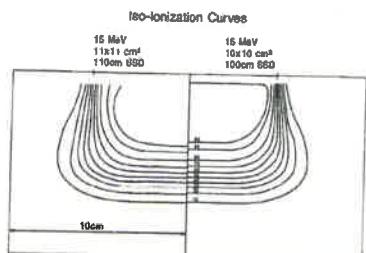


Fig. 25. Comparison of iso-ionization curves measured for nominal SSD as opposed to extended SSD conditions. [From Hogstrom et al. (1984).]

\*What would cause the biggest change of the depth of the 80% IDL for a 9 MeV electron? (choices included: add 1 cm bolus, change to 18 MeV, increase FS)  
change to 18MeV, because the R80 = E/2.8 at 18MeV is twice large than the R80 at 9 MeV, ()

\*Why should you convince the doctor to not use a 25 cm x 3 cm electron cutout?

The reason can be it's elongated cutout; because it's abnormal cutout, the field size equivalence can be difficult to be established. Therefore, it will be hard to characterize the output, PDD..etc (Kahn 3rd sec. 14.4.E, )

Sounds good and the shorter dim might not exceed the LSE point  $E_0/2.5$ : 2.4cm for 6 Mev and 3.6cm for 9 MeV JPS

32. An electron plan with the pdd, ask the depth of lung for a given dose

Khan P323,  $d_{eff} = d - z(1-CET)$ , for lung CET is about 0.2-0.25, for bone, it's about 1.65.

$$d - z(1-CET)$$

### Dose calculation:

14. Question on the definition of KERMA. ( there were: four almost very similar definitions, and I barley was able to get the right one) **KERMA**: kinetic energy released per unit mass: is the sum of the initial kinetic energies of all the charged ionizing particles(electrons and positrons)liberated by uncharged particle (photons) in a medium (Metcalf p80 – 81)

Question on kernel and heterogeneity. Question on convolution to correct the heterogeneity, what kind of Algorithm is used. 94. How are inhomogeneity corrections handled in the superposition convolution algorithm?

1. Kahn p477-479 3rd edition

$D(\vec{r}) = \int T(\vec{r}', \rho') \cdot K(\vec{r} \cdot \rho, \vec{r}', \rho') d^3\vec{r}'$  - kernel part, describes the distribution of the scatter from a primary interaction; in essence, the kernel dictates how the TERMA is going to be distributed in the medium. The heterogeneity is corrected by taking the radiological depth into account in terma and kernel. (Kahn p477 and my TG65 talk) In Kahn, they called the radiological depth correction algorithm as the convolution-superposition equation.

\*What is the meaning of a phase-space file in Monte Carlo calculations?

According to Chris A, A phase-space file would contain the initial positions and momenta (magnitude and direction) of all the particles to be transported.

Description of Phase Space Files

A phase space file contains data relating to particle position, direction, charge, etc. for every particle crossing a scoring plane. Phase space files can be output for each scoring plane in an accelerator.

In mathematics and physics, a phase space, introduced by Willard Gibbs in 1901,<sup>[1]</sup> is a space in which all possible states of a system are represented, with each possible state of the system corresponding to one unique point in the phase space.

\*Monte Carlo calculations require a random number generator and ...A. probability

distributions, B,C,D,E other options that didn't look right.

\*In Monte Carlo Treatment Planning Algorithms, what is the cutoff energy under which the path a particle will no longer be mapped discretely, and instead it will be lumped in with a general energy distribution function.

10 kev, 100 kev, 200 kev, 500 kev, 1 Mev

(from yahoo group) 10 kev is the cut-off energy for neglecting the contribution of these low energy particles to dose while 200 KeV is a cutoff energy when we do not trace particles as discrete entities but bundles all of them into one continuous distribution in the dose calculation, ie these low energy particles are still having contribution to the dose. cut-off energy for Monte Carlo calculations is usually a user defined variable. It could be 100, 300, 500 KeV, for instance. Ref: Int. J. Radiation Oncology Biol. Phys., Vol. 72, No. 1, pp. 220-227, 2008

Q IMRT: Difference between simulated annealing and gradient reduction in IMRT?

22. IMRT: Difference between simulated annealing and gradient reduction in IMRT? Faster, more accurate in dose calculation in build up, better with step-and-shoot than with sliding window, achieve global minimum instead of local, etc.

Gradient method works to decrease the cost function in the direction of the steepest descending gradient in the cost function space; the cost fun may be trapped in the local minimum

Simulated annealing use stochastic strategy (randomly varying current solution) to find optimal solution which is better finding the global minimum and avoiding solutions trapped in local minimum (2011 AAPM review course, )

#### Radiobiology:

\*What is definition of EUD?

Equivalent uniform dose (EUD) – defined as the dose that, delivered uniformly to the entire risk organ, produces the same complication as the true inhomogeneous dose distribution. (AAPM summer school book p5, 2011, )

(Yahoo group) EUD: (equivalent uniform dose), a dose when distributed uniformly across the target volume, causes the survival of same number of clonogens as the true dose distribution. It can be calculated from DVH and radiobiological parameters. min tu dose < EUD < mean dose. from Ref. (IMRT summer school 2003) by Ellen Yorke

223. What is definition of integral effective dose?

Integral dose (body dose) is defined as the total energy imparted to the body outside the target volume (Hendee, p180). In SI units, its unit is in J. So, I think integral effective dose is the similar stuff but just add the organ weighting factor for each organ, anyone?

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

The local tumor control is achieved when all clonogenic tumor cells are inactivated (Basic clinical radiobiology, p97, ) Pls let me know if there is any better answer.

(mitotic death and apoptosis are the two mechanism that cell dies, Radiobiology for the radiologist p 304 – 305)

BED if physician normally prescribes 1.8Gy/day in 30 fx, but wants to reduce the fx # to 20 fx, what's the new daily dose when according to the linear quadratic model alpha/beta = 10?

$$d_1 = 180 \text{ cGy}; 5400 * (1 + 180/10) = 20 * d_2 * (1 + d_2/10) \quad d_2 = 2.54 \text{ Gy}$$

Eric hall, p391 Calculating the BED;  $E/\alpha = \text{total dose} \times (1 + \text{single fx dose}/(\alpha/\beta))$ ,  $d_2 = 2.54 \text{ Gy}$ , using  $-b \pm \sqrt{b^2 + 4ac} / 2a$

#### Others:

What is the difference in a barometer reading if the readings are taken at a height of X and X+50 m.

\*What is the change expected in mmHg when reading at 50 meters of altitude from the airport level.

[http://www.engineeringtoolbox.com/air-altitude-pressure-d\\_462.html](http://www.engineeringtoolbox.com/air-altitude-pressure-d_462.html)

From this table looks like from -1800 to 1500 m, the pressure is change 0.09 mm Hg along with 1 meter. ()

$$50 \times 0.09 = 4.5 \text{ mmHg} \text{ (decrease) if altitude increases 50 m}$$

$$0.09 \text{ mmHg/m}$$

2. Highest neutron flux in a therapy treatment room is produced by \_\_\_\_\_.

1. a Cobalt-60 source
2. a 10-MeV electron beam
3. a 10-MV photon beam
- 4. a 20-MV photon beam**
5. a 20-MeV electron beam

5. In IMRT treatment planning, critical organs are \_\_\_\_\_.

1. shielded with superlab
2. delivered the same dose as GTV
3. prescribed 0.5 % of PTV
- 4. delivered organ tolerance dose**
5. delivered skin tolerance dose

 top

## PART 2: Therapeutic Medical Physics

### COMPLEX QUESTIONS

1. A 4-MV linac beam, 10 cm x 10 cm with a 45° wedge, is used to deliver 200 cGy to a tumor located at the isocenter (100 cm SAD) at 10-cm depth. Given the following:

1. output at 100 cm SSD at d max 1.2 cm is 1.04 cGy/MU
2. wedge factor 0.70
3. back-scatter-factor 1.03
4. percent depth dose 60%
- 5. tissue-air-ratio 0.75**

What is the number of monitor units (MU) required for this treatment?

1. 206
2. 258
3. 296
- 4. 366**
5. 468

2. A single field 6-MV beam is used to deliver 200 cGy at the isocenter (100 cm SAD), which is at a depth of 10 cm. The patient thickness is 20 cm. Using the factors given below, calculate the dose at 5-cm depth.

1. 245 cGy
2. 255 cGy
3. 261 cGy
4. 268 cGy
- 5. 281 cGy**

%DD for 100 cm SSD, 5-cm depth	87%
%DD for 100 cm SSD, 10-cm depth	68%
TMR 5-cm depth	0.93
TMR 10-cm depth	0.79
TMR 15-cm depth	0.65
TMR 20-cm depth	0.53

3. A lesion extending to 1-cm depth in tissue is to be treated with a 6-MeV electron beam with bolus. A dose of 1.5 Gy to 80% is prescribed. If the output is 1cGy/MU, the SSD is 104 cm and the cone factor is 0.97, what should the thickness of the bolus be, and how many MU should be delivered?

1. 0 cm, 153 MU
2. 0 cm, 170 MU
- 3. 1 cm, 209 MU**
4. 1 cm, 270 MU
5. 2 cm, 302 MU

4. In tissue from a 0.46-mCi permanent implant I-125 seed, what is the total dose to 1 cm distance?

1. 55 Gy
2. 10.5 Gy
- 3. 13.2 Gy**
4. 30.5 Gy
5. 50.0 Gy

### Answers for this section:

1. D
2. C

3. C
4. C
5. B

-----Other recall-----

2. What is the activity needed of  $^{198}\text{Au}$  (mCi) for a patient to receive a single plane implant with gold seeds using the Paterson-Parker technique. The area of implant is  $10 \text{ cm}^2$  and a total dose of 5000 cGy is to be delivered. Use the Paterson-Parker tables, treatment depth is 0.5cm.

(Khan A-22) based on the table, for  $10\text{cm}^2$ , 0.5cm depth → we get  $235\text{mg-h}/900\text{cGy}$ , so we need radium as  $235*5000/900 = 1305.56\text{mg-hr}$

Radium exposure rate is  $8.25 \text{ R cm}^2/(\text{mg-h})$ , and the exposure rate for Au is  $2.35 \text{ Rcm}^2/\text{mCi-h}$

$$1306 \text{ mg-h} \times 8.25 \text{ R cm}^2/(\text{mg-h}) / 2.35 \text{ R cm}^2 / \text{mCi-h} = 4526 \text{ mCi-h for Au}$$

The half life for Au is 2.7 days

The initial activity we need  $2.7 \times 1.44 \times 24 \times A = 4526 \text{ mCi-h}$ , and  $A = 48.5 \text{ mCi}$

Au is usually applied for permanent implant.

4. An SRS case use 5mm cone, prescribed dose is 90 Gy. Plan using twelve equally weighed 120 degree arcs. Each arc can deliver up to 999 MU max. Max MU per degree is 19.99 (at the iso, TPR = 0.75). How many passes each arc should go in the treatment delivery? (the output factor for 5mm cone is 0.82)

If give each of the 12 arcs 999MU →  $999/120 = 8.325 < 19.9$  within per degree constrain, but:

$$12*999*0.75*0.82 = 73.72\text{Gy} < 90\text{Gy} \rightarrow \text{each arc needs to pass 2 times during the Tx.}$$

If we assume the prescription dose is to 80% line,  $9000\text{cGy}/(0.8 \times 0.75 \times 0.82) = 18300$

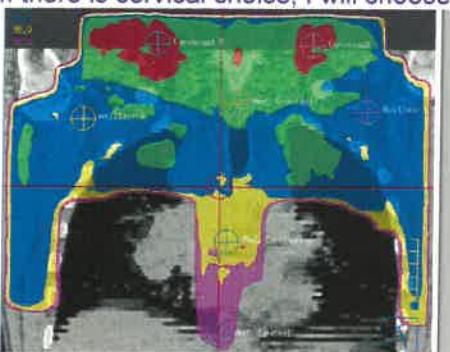
MU for each arc =  $18300/12 = 1525$ ,  $(1525 - 999)/19.99 = 26.3$  degree → For each Arc, we need 1 pass for the full arc + 26.3 degree more ()

7. what will cause a significant change in dose rate of a linac?

This question may be related to the Therac 25 event. If we are in the photon mode, but the target is not in the place, we will have significant high electron current passing through which will induce the significant change of dose rate.

9. In a mantle field, what would receive the highest dose. (celiac , axilla etc...)

If there is cervical choice, I will choose cervical. Otherwise I will choose axilla



10. Ratio of photon to electron current on linac. i only know that for electron, the current will be lower, but by how much? about 4 times?

The 4 times was compared between 6MV to 18MeV electron. However, if we compare 6MV(highest electron current required) with 6MeV electron. It can be order of hundred fold even up to 1000 fold difference (Green, linear accelerator for radiation therapy p23 or Therac 25 event, )

11) Given MHz, calculate the size of each microwave cavity

This question is asking the cavity separation in the waveguide. The microwave frequency is 3000MHz used in the waveguide. According to Hendee Radiation Therapy Physics p60, Cavity separation = electron velocity /  $2 \times$  frequency

Electron reaches light velocity after a few cavity, so

$$\text{Cavity separation} = 3 \times 10^8 / (2 \times 3 \times 10^9) = 5 \text{ cm.}$$

One may ask wavelength span 4 cavities, why shouldn't be 2.5 cm. Hendee's eq came from waveguide theory Pardogask's book "radiation physics for medical physicist" has explanation. ()

13. When should HDR room shielding be reconsidered, recalculated?

1. Thickness of Aluminum needed for 12 Mev electron. Only information given.

(Green, linear accelerator for radiation therapy p89) Empirically, Al thickness is about 1/3 of the electron range, so  $R_p = 12/2 = 6$  cm, and Al thickness =  $6 / 3 = 2$  cm ()

I will do this in a different way: lead density=11.34; Al = 2.7, for lead, we need  $12/2=6\text{mm}$   
 $6 * 11.34 / 2.7 = 2.52\text{cm}$

2. What organ can receive 40 Gy? [kidney, liver, heart, lens, lung]

From the list here, heart is the only organ with TD 5/5 3/3 with 40 Gy. Emami constraint ()

3. Problem about point that measures 187.2 cGy versus 180 cGy Rx for IMRT qa. Closest location of 180 cGy is 2.5 mm away. What is the value of gamma if using a tolerance of 5% and 3mm?

(Answers: 0.65, 0.8, 1.0, 1.155)

$\sqrt{((187.2 - 180) / 180)^2 + (2.5/3)^2} = 1.155$  ()

4. When does anisotropy function value decrease (options: when angle from perpendicular increases, when encapsulation decreases, when distance increases, one other one)

The anisotropy function  $F(r, \theta)$  describes the dose variation around the polar angle, therefore, the anisotropy function will decrease

when

1. Encapsulation thickness increase (differential radiation path-length through capsule)

2. Photon energy decrease (less photon penetration).

3. Distance decrease (less scattered photon contribution to the point)

4. Angle decrease (differential radiation path-length through capsule)

TG43 update p639 and AAPM summer school 2003 Ch13 p410 ()

6. What is the tolerance for HDR source positioning? 0.5 mm, 1 mm, 2 mm, etc.

From TG56 Table VI, for single stepping source, the accuracy is 0.5 mm, and for multiple source machine, the positioning accuracy is 1 mm. I guess most of us use multiple source machine, right? ()  
1 mm from Table XIII TG40

6. can't see the colpostat, retake the film and do what? Increase mA's, increase distance, increase/decrease kVp, etc.

My vote is decrease kVp so increasing the contrast ()

7. What is the volume in a chamber, exposed to 6MV photons. Dose to air volume = ? Gy. Density of air =  $1.29 \text{ kg/m}^3$  and density of s/p graphite = ?. Chamber wall is in air with graphite wall.

## 2003 recall---

21. Patient treated with 3 fields, equally weighted, 180cGy. Two posterior fields go through 9 cm of lung and SSD is 82 cm. If you don't correct for lung inhomogeneity, what is the percent error at isocenter?

Assuming 6x, error from 2 fields  $180 \times 2/3 \times 9 \times 3\% = 32.4 \text{ cGy}$  or 18%

If we use Raphex method,  $(9 - 9 \text{ cm}/3) \times 3.5 = 21\%$

Here you can use the expression  $P = (\text{RHO}_{\text{air}}) * (g) * (h)$  where  $\text{RHO}_{\text{air}}$  is the density of air,  $g$  is the gravitational constant and  $h$  is the height in meters. So  $\Delta P = (\text{RHO}_{\text{air}}) * (g) * (\Delta h) = (1.293 \text{ KG/m}^3) * (9.81 \text{ m/s}^2) * (50 \text{ meters}) = 634 \text{ N/m}^2 = 0.634 \text{ KPa} = 6.34 \text{ Torr JPS}$

One question related to a skyshine shielding calculation where person only needed to recall the formula for computing steradians given a diameter subtended and distance from source.

\*Calculate the steradian of a 50cm diameter area on a standard linear accelerator.

Omega =  $2\pi(1-\cos(\theta))$  → theta = arc(sin(0.5/2)) → Omega = 0.19 ... is this right? I used theta = arc(tan(0.25/1)), and get omega = 0.187 () In shielding calculation, the solid angle is simply calculated as theta = tan(SAD/half field size), McGinley book "shielding techniques" Ch7. P104 example

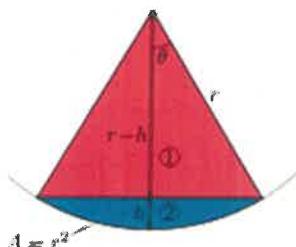
\*30 cm<sup>2</sup> field directed at roof, what is solid angle subtended at a point on the ground?

Omega =  $2\pi(1-\cos(\theta))$  → theta = arc(sin(sqrt(15)/100) = 2.22 degree → Omega =  $4.7 \times 10^{-3}$

It maybe a skyshine problem (NCRP151); theta = arc(tan(0.15/1)) = 8.53 degree, solid angle =  $2\pi(1-\cos(8.53)) = 0.07$

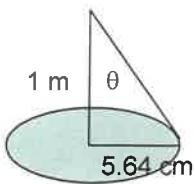
1 A number of detector area / distance from source / geometric efficiency problems like others in previous years. Some requiring steradian calculation.

Solid angle (steradian) =  $2\pi(1-\cos(\theta))$  will be an easy way to do this kind of problem. Be careful, the theta is the angle from 0 – 180 within spherical coordinate. Therefore, we only need to calculate half of the cone angle to get the full solid angle of the cone. Ex: in this figure, the theta represent the whole solid angle we will calculate in the equation. In shielding calculation, the solid angle is simply calculated as theta = tan(SAD/half field size), McGinley book "shielding techniques" Ch7. P104 example



18.2 6. The solid angle subtended by a 100 cm<sup>2</sup> circular detector at a distance of 1 m is \_\_\_\_\_ steradians.

- A. 0.01
- B. 0.03
- C. 0.12
- D. 2.0
- E. 6.5



$\theta$  is 3.22 degree and (steradian) =  $2\pi(1-\cos(\theta)) = 0.01$

\*Why do the doctors leave a strip around each side of the treated area on a sarcoma? To avoid Lymphedema

\*when treating an extremity, why do we block out a sliver of skin? (spare lymphatic system, aid in skin healing after radiation, other choices) (Arthur's material, )

76. Pacemaker dose limit. 200cGy or 2 Gy (TG34)

ABR sample:

## PART 2: Therapeutic Medical Physics

### SIMPLE QUESTIONS

1. High energy photon beams from an accelerator require flattening filters in order to \_\_\_\_\_.
  1. increase low-energy photons
  2. correct for the pulsing of radiation
  3. increase fluence along the central axis of the beam
  4. increase depth dose
  5. make the beam flat across the full field

$$\frac{500 \text{ mR}}{0.5 \text{ mSv}} = \alpha \cdot 60 \times 24 \times 1.44$$

31. You want to limit a total dose at 1 meter from a patient that has brachytherapy implants to 500 mRem, what is the maximum initial dose rate? I think the isotope was Iodine 125.

Following USNRC suggestion, I125 half life is 60 days > 1 day, the occupancy factor is 0.25 and 500 mRem = 5 mSv, so  $A \times 60(\text{days}) \times 1.44 \times 24(\text{hr}) \times 1.45 \text{ R cm}^2 / (\text{mCi hr}) \times 0.25 / (10000 \text{ cm}^2) = 5 \text{ mSv}$

→  $A = 6.5 \text{ mCi}$

32. How often do you have to calibrate the barometer according to TG 40?

Every 3 month tolerance is with 1 mm/Hg (TG40 Table IV)

TG-51: for photon calibration, above how many MV do you have to use how thick a layer of lead at how many cm from the source?

Larger than 10 MV, 1 mm thick and 50 or 30 cm from the phantom surface

For a x ray tube with 100 mA and 100 kVp, the HU has a sigma of 1.5, if the current is raised to 400 mA, what is the new sigma of HU?

Sigma by definition, there are 2,  $\sigma_1 = \sqrt{N}$  or  $\sigma_2 = \sqrt{N}/N$ . The first one characterizes the absolute broadness of the normal or passion distribution, and the 2<sup>nd</sup> one means "percentage" variation among the whole population

For HU, the sigma is normally calculated as the absolute value

$\sigma = \sqrt{N}$ , N is number of counts. The measured photon is proportional to the mA. Therefore,  $N = 100C$ , C is a constant.  $1.5^2 = 100C$ , so  $\sigma_{400\text{mA}} = \sqrt{1.5^2/100 \times 400} = 1.5 \times 2 = 3$ , which means when we have more photon, we have broader distribution (making sense).

If we look at the 2<sup>nd</sup> definition, with 100 mA, we have the % sigma =  $\sqrt{100C}/100C = 0.1/\sqrt{C}$ , with 400 mA, we have the % sigma =  $\sqrt{400C}/400C = 0.05/\sqrt{C}$ .

When we have more photon, the percentage variation is smaller (making sense)

-2000 recall---

6. Spatial resolution of MOSFET detectors, possible answers were in units of micrometer  
The MOSFET effective measurement size can be as small as 10 um (MetCalf p171, )

10  
um

One question about reasons for using a parallel-plate chamber for measuring output of a 4 MV photon beam.

The pp chamber is specially designed for low energy photon and electron because it features the steep depth dose gradients along the CAX of the beam (MetCalf p151)

- What is the NRC-required frequency of sealed source inventory?

6 months.

10CFR 35.67: (g) A licensee in possession of sealed sources or brachytherapy sources, except for gamma stereotactic radiosurgery sources, shall conduct a semi-annual physical inventory of all such sources in its possession. The licensee shall retain each inventory record in accordance with § 35.2067(b).

Q How much does a linac's workload increase for a TBI given the treatment distance, rep rate at isocenter, and dose to be delivered to the patient per week. The workload is defined as the dose delivered to iso (1m from target). According to NCRP151 p56, TBI workload increases than the conventional workload due to the extended treatment distance, so total work load can be  
 $W_c(\text{conventional treatment}) \times U(=0.25) + W_T(\text{TBI}) = 0.25W_c + \text{prescribed TBI dose} \times \text{total TBI pt/wk} \times \text{treatment distance}^2$

Most probable use for a 9" "rem counter" (as described by Kahn on page 495 of 1994 ed of *The Physics of Radiation Therapy*). Question was about what this instrument was used to detect. Possible answers included photons, thermal neutrons, fast neutrons, combinations of neutrons and photons, etc.

Kahn Ch16, 3rd p416, this one has BF3 proportional counter used to detect neutron.

One question about what is not modeled for a beam for a 3-D treatment planning computer. Possible answers included upper collimator jaws, lower collimator jaws, target, monitor chambers, or the mirror. (Answer: mirror since the beam doses not pass through the mirror, and it does not act as a beam modifier.)

One question about the uses and limitations of LiF TLD detectors for use in a radiation therapy department. Specifically, their accuracy, linearity, etc.

Q TLD is great use for in vivo dosimetry; accuracy is about 3% not as good as ion chamber, the response is linear up to 1000 Gy. (Kahn 3rd p 147)

Which of the following can occur that does not require a full re-calibration of all beams and beam scanning for a linac? (possible answers: changing klystron, bending magnet replacement, MU chamber replacement, target replacement, or waveguide replacement)

Q Chang klystron, which only provide microwave to the waveguide, we will need to check output calibration and energy consistency but it is not necessary to check profile and %DD.

### What to check after changing a .....

*For in vivo and field-to-field  
Accuracy and potential*

Machine	Component	NAP	% DD	Profiles	Dose calibration
In-line	magnetron	X		X	X
	Ion chamber			X	X
	Tg/gun/guide	X	X	X	X
With magnet	Klystron/magnetron	X			X
	Gun	X			X
	Ion chamber			X	X
	Foil/flat. Filter		X	X	X
	Guide	X	X	X	X
	Bending magnet	X	X	X	X

### One question on use of bubble-type neutron detectors.

Bubble detector, a miniature bubble chamber suitable for neutron detection, is a portable, self-reading, reusable dosimeter that is simple and relatively inexpensive. The background in the detector is remarkably as low as 1  $\mu\text{Sv}$ . Unlike voluminous neutron survey meter like rem counter, the miniaturized size of the bubble dosimeter allows measurement of the neutron dose rates in poorly accessible areas of nuclear reactors, accelerators (Medical linacs and INDUS-1) and pulsed neutron sources. Since the bubble detector is insensitive to gamma, it is ideally suited for neutron measurements in the intense gamma field



One TG-56 question about coefficient of variation of measured seed strength before you should notify the company of any discrepancies.

TG56: We recommend that if the institution's verification of source strength disagrees with the manufacturer's data by more than 3%, the source of the disagreement should be investigated.

We further recommend that an unresolved disparity exceeding 5% should be reported to the manufacturer.

One question dealt with a treatment room for a patient being treated with about 150 mCi of Cs-137. Assuming 50% attenuation by the patient and the nearest wall was 2.5 meters away, how many extra HVLs were needed to reduce the exposure level to meet NRC regulations for the occupied adjacent room? The exposure rate constant was provided, but its units were incorrect. The exam gave 3.26 R cm<sup>2</sup>/Ci hr instead of 3.26 R cm<sup>2</sup>/mCi hr. All answers were ≥ 1 HVL.

$$150 \text{ mCi} \times 3.26 \text{ R cm}^2/(\text{mCi h}) \times 0.5 \times B \times 10 \text{ mGy/R}/(250)^2 = 0.02 \text{ mSv/hr}$$

B = 0.51, so we need 1 HVL

One dealt with a maze-less high-energy linac room, and wanted to know what material would be used to patch a small opening near the door. Possible solutions included lead, steel, aluminum, borated polyethylene, etc.

According to NCRP151 p50, the lead is placed in the linac room side for photon and the BPE is outside for neutron.

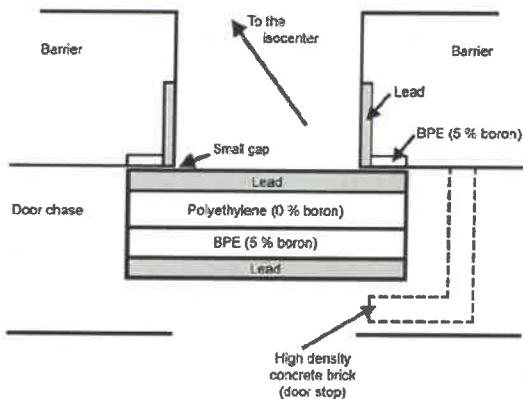


Fig. 2.11. Alternative to large overlap at door.

To study:

\*Procedures for commissioning 3 D treatment planning.

\*Ratio of Maximum Dose between 25MV and 4MV for same dose to midline using POP setup with SSD =100cm. PDD's given.

~10 - 12% (Kahn 3<sup>rd</sup> p211)

\*Single field 125 cm SSD, 4x17. 300cGy was prescribed to 5cm deep. Given PDD table and TMR table, calculate MU. No Output factor vs. field size or calibration condition provided.

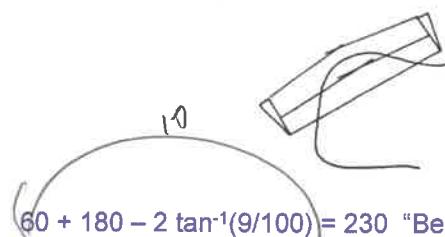
$$\frac{8 \times 17}{21} = 6.5 \text{ cm}$$

T62.

The tangential fields in the diagram are angled so that their posterior borders are aligned. LAO gantry angle =  $60^\circ$ . Field width = 18 cm (symmetrical) at 100 cm SAD. (Gantry angles are defined as:  $0^\circ$  = anterior;  $90^\circ$  = patient left.) RPO Gantry angle = \_\_\_\_\_.

- A.  $240^\circ + 5^\circ$
- B.  $240^\circ + 10^\circ$
- C.  $240^\circ + 15^\circ$
- D.  $240^\circ - 5^\circ$
- E.  $240^\circ - 10^\circ$

Angle $\theta$	0	5	10	15	20
$\tan^{-1}$	0	0.09	0.18	0.27	0.36



A → P

G

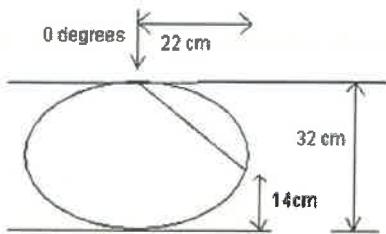


18

## Raphex 2011 Therapy

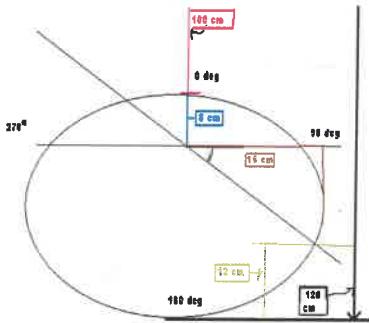
$$60 + 180 - 2 \tan^{-1}(9/100) = 230 \text{ "Be Careful that GA counterclockwise is DECREASING!"}$$

\*Find the RPO angle given the following (diagram). The line represents the central ray of the beam through the patient.



with CAX turn. Assume they are using half field block, angle for RPO =  $90 + \arctan(18/22) = 129.29$

35. Determine the angle, following the IEC convention of angles, of the medial field, given the dimensions in the figure shown below.



This diagram is not clear and out of scale but it should be  $120 - 100 - 12 - 6 = 2\text{cm}$ ,  $\arctan 2/15 = 7.56$ ,  $270 + 7.56 = 277.6$  or 278 (SC) Agree with SC if it's HBB.

\* 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?

$$\theta = \tan^{-1}(5.25/100) = 3^\circ \text{ deg.}$$

$$\text{RPO} = 180 + 45 - 2 \cdot 3 = 219 \text{ deg.}$$

S I C

\*What is the meaning of D<sub>90</sub> = 110 Gy?

90 % of the volume get 110 cGy (should be cGy) ()

\*A plot for DVH is given, what the dose is given to 90% of the organ.

\*A DVH graph was given with a point on the DVH curve was marked. Select proper meaning of this point.

\*Shown GTV, CTV and PTV asked to identify the PTV

PTV outside CTV ()

\*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. Constraint: 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)

Not sure if this recall is correct. This can be a mantle case. Even with cord block, the maximum cord dose still can go up to 70- 80 % of the prescribed dose (please see mantle case in UPenn). The question may mean 82% of the maximum cord dose without block. Considering total dose delivered to cord does not make sense. If it is the case, 25 fx is the maximum. Any comment? ()

My guess: this could be an easy type of question. I think the total fraction number was missing. Assume it's 30x200cGy, then:  $X+Y = 30; 212*X+212*0.18*Y=4500 \rightarrow Y$  is at least 11 fractions ()

\*AP/PA doses given from each field to cord for 200 cGy to tumor (62cGy AP, 150cGy PA 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?

My try: Assume total fraction number is 30;  $X+Y=30; 62*30+1.5X+1.5*0.18*Y=4000 \rightarrow Y=19.18$ , so need at least 20 fractions with cord block.

Q calculate the thickness of a compensator. What thickness of Al to compensate for 5 cm of missing tissue? Density of compensator material and electronic densities of water and compensator material. (A) 1.85cm (B) 2.15cm (C) 2.55cm (D) 3.25cm)

(Khan P232 Kahn sec 12.6 A)  $T_c = TD \times (\tau / \rho_c)$ , here  $\tau = 0.7$ ; my understanding for  $\rho_c$  is the density (instead of electronic density)

$$t_c = TD \left( \frac{\tau}{\rho_c} \right)$$

Here is my thought;  $\tau$  is a density ratio or thickness ratio which is dimensionless. The question should be 5 g/cm^2 of missing tissue instead of 5 cm. In this case, the units are consistent so  $T_c = 5 \text{ (g/cm}^2\text{)} \times (0.7 / (2.7 \text{ g/cm}^3)) = 1.29 \text{ cm}$  (Kahn 3rd sec.12.6.A and his original paper Radiology, 96, 187 (1970))

T43. Regarding dose-volume histograms, which of the following is true?

- A. The  $D_{95}$  (dose received by 95% of the PTV) is an indicator of the hot spot within the structure.
- B. The  $D_{95}$  for the PTV should ideally be as low as possible.
- C.  $D_{95}$  for the PTV should ideally be as high as possible.
- D.  $D_{95}$  and  $D_{99}$  in the PTV should be as close as possible.
- E. For an organ at risk the  $D_{95}$  should be as high as possible.

T43. D  $D_{95}$  is typically used to evaluate target coverage, not hot spots which are often evaluated using the  $D_{99}$ .  $D_{95}$  should therefore be high for targets and low for normal tissues.  $D_{95}$  should ideally be no more than 110% of the  $D_{99}$ , which means that there is good dose homogeneity within the PTV. All doses in OARs should be as low as possible.

T110. A definition for the conformity index (CI) is (volume covered by prescription isodose line)/(volume of the target). A CI = 1 implies that:

- A. The target will be perfectly covered by the prescribed dose (no over- or under-irradiation).
- B. Part of the target will receive less than the prescribed dose.
- C. Some of the normal tissue will also receive the prescribed dose.
- D. The target may be completely missed by the prescribed dose.
- E. Any of the above.

T110. E This definition of CI only takes the respective volumes into account, not the amount of overlap between them.

Which of the following lists tissues in order of increasing Hounsfield (CT) number?

- A. Bone, muscle, fat, lung.
- B. Lung, fat, muscle, bone.

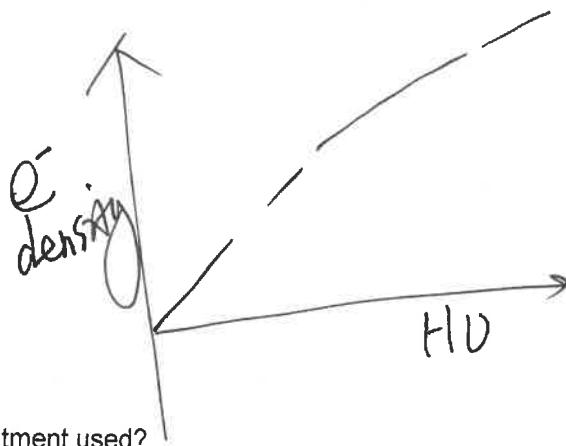
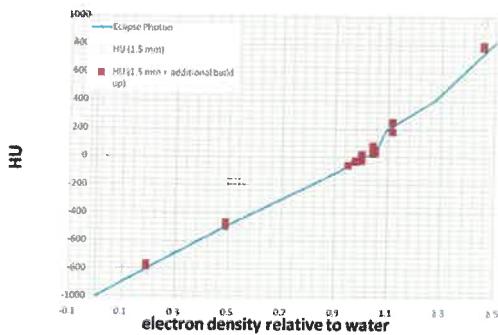
\*Given a set of CT numbers, Select proper order of tissues that correspond with the order of these CT numbers.

Typical CT numbers: Metal > 2000 HU, Hard bone → 1000; Femoral Head → 400; Breast prosthesis → 70; Mediastinum → 50; Water → 0; Fat(adipose) → -100; Lung → -800; Air → -1000

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: Air, -100: adipose=fat(lung), 0:Water, 100:Soft tissue, 1000:Bone ()

23. Choose the right graph from 4 options that shows the relation between the e density and the CT number.

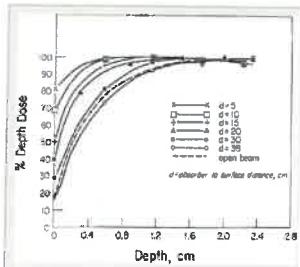
Sensation Open CT scanners (CTSim2, July 2011)



\*For what purpose is a beam spoiler for 10MV breast treatment used?

I think the spoiler will decrease skin sparing compared to no spoiler but will increase skin sparing compared to using bolus. KMW

Agree, for breast treatment, skin sparing is not desirable. Beam spoiler will increase the dose to the superficial area and also move dmax toward surface therefore decrease skin sparing compared to without spoiler (Kahn sec 13.3 D )



If the tray-surface distance is large enough, the beam spoiler will reduce the skin sparing due to absorbing the collimator 2<sup>nd</sup> electron emission, and the electron contamination from the spoiler itself is largely scattered because of the large tray-surface distance. However, if the distance is small, the skin spoiler will actually decrease skin sparing. (Kahn 3<sup>rd</sup> p281)

\*What is the tolerance dose for 1/3 of the kidney?

1/3 vol of kidney < 20 Gy (handbook of evidence-based radiation oncology 2nd, p369, )

\*What is the dose for irreparable damage to the kidney?

Emami dose tolerance: TD5/5 for whole kidney is 2300cGy

Here is the recall from 2008: What is the dose for irreparable damage to the kidney?

1000cGy, 2000cGy, 3000cGy, 4000cGy

2000 cGy ()

A P G  
S I C

\*Calculate collimator angle for opposite lateral brain fields to match the divergence from a spine field. Field size 27cm, Spine inferior 20cm and spine superior 17cm. Theta(coll)= tan<sup>-1</sup>(1/2\*17\*1/ssd) the ssd value is missing.

Assume the spine superior length is 17 cm long. Theta<sub>coll</sub> = tan<sup>-1</sup>(1/2 x 17 x SSD), field size 27 cm seems do nothing for this question. (Kahn, sec 3<sup>rd</sup> p 293 )

\*PA Spine field L=35 abuts a cranial field Ant/Post length = 24, sup/inf length = 18. What is the couch rotation needed to match the divergence? Needed to use the rotation = arc tan(1/2 \* Length/SSD)

Sup/Inf is the cranial field size used for matching the spinal field, tan<sup>-1</sup>(1/2x18/100) = 5.14 (Kahn, sec 3<sup>rd</sup> p 293 )

\*Question on definition of ITV. It is: ITV= CTV + IM (ICRU 62)

\*IMRT Head and Neck treatment. What are the dose constraints for critical organs.

Cord<45Gy, mean parotid<26Gy and 50% vol <, 20Gy, mandible<66 - 70Gy, pituitary(腦下垂體) and hypothalamus(下丘腦)<40Gy (SC)

Brainstem < 54 Gy, mean Larynx < 35 – 45 Gy, 2/3 vol < 50Gy, mean(max) cochlea < 37(45)Gy, optic chiasm and nerves < 54Gy, Lens<10Gy, Retina<45Gy. (Handbook of evidence...) ()

\*For regular fractionated IMRT, what is the TD5/5 for the parotid gland? 25Gy, 32Gy, 50Gy, 60Gy?

Emami Table 2

TD<sub>5/5</sub> the probability of a 5% complication rate Gy  
Within 5 yrs' treatment.

for more than 2/3 of parotid TD<sub>5/5</sub> = 46

- Q: What is the TD5/5 for Optical Chiasm? (A) 4000 (B) 4500 (C) 5000 (D) 5500  
 TD5/5 3/3 : 5000 cGy by Emami Inr J. Radiation Oncology Biol. Phys. Vol. 21, pp. 109-122

### Tolerant Doses of Radiation

TD 5/5- The minimum tolerance dose

TD 50/5- The maximum tolerance dose

They refer to severe complication rate of 5 & 50% within 5 years of radiotherapy completion.

The values below are approximate & for learning purposes only!

Breast: TD50/5 3/3 , Rectum: TD50/5 3/3 8000 , Liver: TD50/5 3/3 4000 , Testicles: TD50/5 3/3 2000 , Colon: TD50/5 3/3 5500  
 Kidney: TD50/5 3/3 2800 , Bladder: TD50/5 3/3 8000 , Brain: TD50/5 3/3 6000 , Lung: TD50/5 3/3 2450

\*When treating a lung tumor, what is the dose associated with radiation pneumonitis (V20=30%, V50=10% etc)?

I guess we will answer this with emami dose tolerance as i think different center use different constrains...  
 for pneumonitis, is it TD5/5 for  $\frac{1}{3}$  of the volume?

FYI, Penn use mean lung  $< 20$  Gy, V20< 35%, and sometimes, we will look at V5<60% ()

### TBI:

Basic dosimetry measurements to be done prior to implementing total body irradiation (TBI) include:

- A. Central axis dose calibration made under conditions representative of the actual treatment geometry.
- B. Central axis data such as percent depth dose or tissue maximum ratios measured with treatment geometry.
- C. Test of inverse square law over the range of treatment distances.
- D. Dose profiles of the flatness and symmetry of the beam (OCRs) at the treatment distance.
- E. All of the above.

TBI treatment, SAD = 478.5cm, the patient thickness is 39cm, the dose rate at 10cm is 0.0385cGy/MU, to avoid the dose rate at midline exceed 10cGy/min, what is the delivery rate of linear accelerator should be chosen? (Nothing else is given). (A) 200MU/min (B) 300MU/min (C) 400MU/min (D) 600MU/min

10 cm depth is 0.0385cGy/MU -> using ISL(large distance), in the midline, dose rate=0.0385 cGy/MU\*[(478.5-9.5)/478.5]^2 = 0.03698 cGy/MU, where 9.5=478.5-39/2+10; if dose rate is x mu/min, then 0.03695 cGy/MU\* x MU/min<10cGy/min => x<270 MU/min, I would pick up A, which we used in our clinic.

Actually, for large SSD, and a small change of distance of depth, inverse square law will not change things much.  $10/0.0385 = 260$  cGy/MU, and we need dose rate  $< 10$  cGy/MU. 200 MU/min is the only choice. ()

\*TBI – what is not true – A. Dose Uniformity < 15%, B. Tissue Equivalent

Compensators are used, C. High SSD, D. AP preferred over lateral, E. Lower dose conformity with increased energy.

Higher energy gives better dose uniformity (rather than conformity), TG17(Fig. 9 and 10).

APPA treatment can give 10% uniformity, but bilateral needs compensator to achieve 10% otherwise, it will be 15% (Kahn 3rd p457)

\*Question on dose homogeneity using TBI. compensators required to achieve homogeneity of +/-10% Kahn p412

\*TBI, diode reading 450cGy on surface, prescribed midline 600cGy POP laterals, 30cm separation. TMRs were given with 350cmSSD for depth 5, 10, 15, 20cm. What is error in midline dose? (A) Lower than 2.6% (B) higher than 2.6% (C) lower than 3.5% (D) higher than 3.5%

For 6x, the diode measurement in our department is placed with 1.5 cm bolus build-up on the top of it for surface measurement; which assumes the measurement is at the dmax.

The midline dose can be calculated by using TMR(15) and corrected by inverse square law;

$$D_{\text{midline}} = 450 \text{ cGy} \times \text{TMR}(15) \times (350 + 1.5)^2 / (350 + 15)^2 = 417 \text{ TMR}(15)$$

The uncertainty will be  $417\text{TMR}(15)/300$  ()

It can be more clear if we write the equation in this way

$$\text{TMR}(15) = \frac{D(d=15, \text{SAD})}{D(d \text{ max}, \text{SAD})} = \frac{D(d=15, 365) \left(\frac{365}{100}\right)^2}{D(d \text{ max}, 351.5) \left(\frac{351.5}{100}\right)^2} = \frac{D(d=15, 365) \left(\frac{365}{351.5}\right)^2}{450}$$

QA:

On linacs, therapists perform daily pre-treatment QA. Regarding the items tested daily, all of the following are true, *except*:

- A. They include devices vital for accurate patient alignment.
- B. They include devices that can drift, or have been observed to do so.
- C. They are relatively quick and simple to test.
- D. They include items that are subject to catastrophic failure, which would prevent further treatment.
- E. They include safety interlocks.

D

There is generally no way to prevent catastrophic failure. Daily QA aims to verify the accuracy of items used for patient alignment, such as lasers and ODI. Output can drift, and should be verified daily. Commercial devices such as diode or chamber arrays are designed to measure several parameters in one exposure (e.g., output, depth dose, symmetry, and flatness constancy). The door interlock and the operation of audiovisual devices are safety-related checks.

## TG40:

- T84. According to AAPM's TG-40 report on Quality Assurance, daily linac checks should include all of the following *except*:
- A. Output for each photon energy.
  - B. Patient viewing system.
  - C. Accuracy of laser alignment.
  - D. Accuracy of distance indicator.
  - E. Symmetry of each photon energy.

Symmetry is only for monthly (TG40 Table II)

Q \*What is the accepted leakage in amps for a chamber/electrometer setup?

0.1% (Table IV, TG40)

29. To compare light field vs. radiation field, film is used. Ask distances for SSD and film SAD. SSD=100, SAD=100; SSD=100-dmax, SAD=100; etc. The light field and radiation film should be at the same plane

\*definition of QA All those planned or systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality (TG40 appendix B, )

\*If the daily output is greater than what % is patient treatment suspended immediately according to TG-40?  
3 – 5% treatment continuously but notify radiation oncologist, 5% treatment stop (TG40 p592 )

\*Overall uncertainty according to TG40? 6%, 5%, 4%, 3% ()

\*What is the overall uncertainty in dose delivered to a point in a patient with all uncertainties taken into consideration?  
5% (TG40, )

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

Q \*Flatness and symmetry tolerance figure according to TG-40

X-ray flatness 2 % constancy

Electron flatness 3 % constancy

x-ray and electron symmetry 3% (TG40 table 2, )

\*How often are electron energies checked according to TG-40?

If it is output, it's daily. If it's energy verification, it's monthly (TG40, table 2, )

Q If the collimator rotation is off 1.2mm, the couch rotation is off 1.4mm and the gantry rotation is off 1.5mm, according to AAPM what is the overall uncertainty?

$$\sqrt{1.2^2 + 1.4^2 + 1.5^2} = 2.37 \text{ mm, } ()$$

\*Daily output tolerance for X-ray and electrons (3%:5%, 3%:3%, 2%:3%, 5%:5% etc) TG40 Table 2 ()

\*When to check the wedge interlock

Monthly (TG40, Table 2)

\*Describe the Morning (daily) QA for a HDR brachytherapy treatment source per TG-40

source position check with the ruler, door, light and alarm interlock, emergency stops, visual(cameras) and audio functions, compare activity printout with calculated/treatment planning.

source position check with film, dwell time check with timer. the ruler has a gaf film insert.

Check portable survey meter

TABLE XIII. QA of remote afterloading brachytherapy units.

Frequency	Test	Tolerance
Each treatment day	Room safety door interlocks, lights, and alarms Console functions, switches, batteries, printer Visual inspection of source guides Verify accuracy of ribbon preparation	Functional Functional Free of kinks and firmly attached Autoradiograph
Weekly	Accuracy of source and dummy loading (dummies used for spacing and/or simulation/verification) Source positioning	1 mm 1 mm
At each source change or quarterly	Calibration* Timer function Check accuracy of source guides and connectors Mechanical integrity of applicators (by x-ray if appropriate)	3% 1% 1 mm Functional
Annual	Dose calculation algorithm (at least one standard source configuration for each isotope) Simulate emergency conditions Verify source inventory	3%, 1 mm

\*It is worthwhile at source change to calibrate both new and old sources to establish and document reproducibility of calibration method.

\*Tolerance for deviation in a light field for a CT sim 2mm

This question should be simulator rather than CT sim, Table 3 TG40, 2mm for field size indicator and light to rad is 2 mm or 1%

According to TG-66....something about distance in mm an iso can be off in a simulator 2mm or 1% (only 2 mm in TG66)  
This question should be simulator rather than CT sim, Table 3 TG40, 2mm for field size indicator and light to rad is 2 mm or 1%

\*Two 2x20 conjuncted rectangles, 10% high in the conjunction area. 3mm penumbra for each rectangle.  
ask what is the position error.

my try: penumbra is defined width between 20% to 80% dose, 3mm --> 0.25mm for every 5% dose --> 0.25mm position error ()

$$3/60\% \times 5\% = 0.25 \text{ mm off for each rectangle ()}$$

50. Tolerance for deviation between light and radiation field according to TG-40.

2 mm or 1% on a side (TG40, table 2, )

(24) TG40 how often do you check well chamber leakage. A. 2 years, B. Every use, C....(TG40 Table X)

For all the chamber, leakage test is recommended to be check for every use, not just well chamber, 0.1% uncertainty, but not mentioned the uncertainty for well chamber

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

(TG40) leakage, collection potential, redundancy check (only for local standard chamber)(Table IV)

### Shielding:

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 4 mm apart. Provided with a graph of  $R/(mA \cdot min)$  at iso on vertical axis (log scale) vs concrete shielding thickness (cm) on horizontal scale – with the log scale, the plot was reasonably linear.

McGinley, p126, Ch8 gave a good example, we simply follow the  $B = Pd^2/(WUT)$  to get the B transmission in  $R/(mA \cdot min)$  at 1 m, and then find the required concrete shielding thickness. There is no need to project the  $R/mA \cdot min$  at iso, coz B is already defined as 1 m.

The distance from target to the people sitting position is  $(12 - 4) \text{ ft} \times 0.3 + 0.3 + 1 \text{ m} = 3.7 \text{ m}$

$B = 2 \text{ mR/wk} \times 3.7^2 / (800 \text{ mAmin/wk}) \times 1/4 = 0.14 \text{ mR/(mAmin)} = 1.4 \times 10^{-4} \text{ R/(mA \cdot min)}$  then find the concrete thickness based on B ()

T87. If space is not restricted, concrete may be used in preference to lead for primary shielding in an 18 MV linac installation for all of the following reasons, except:

- A. Concrete is less expensive.
- B. Concrete is more efficient than lead for neutron shielding.
- C. Lead is more difficult to install than concrete.
- D. Lead would weigh too much.

$$0.02 \text{ mSv/wk}$$

$$1 \text{ Sv} = 100 \text{ Rem}$$

$$2 \text{ mR/10k}$$

**T87. D** Using concrete for primary shielding will also shield for neutrons. Lead is not a good attenuator for neutrons because of its high-Z value, and must be supplemented by additional neutron shielding, typically borated polyethylene.

- T88.** A patient treated with 6 MV breast tangents requests a lead apron to shield her ovaries. All of the following are true, except:
- The ovaries are far enough away from the breast tangents that they would receive no measurable dose.
  - 6 MV head leakage has an HVL of about 12 mm of lead.
  - A typical lead apron contains about 0.5 mm of lead, which would have negligible shielding effect.
  - The lead apron is ineffective against internal scatter.

**T88. A** The ovaries would receive about 0.5% of the dose to the tangents, or about 25 cGy. The portion due to internal scatter cannot be shielded against. To shield against head leakage and collimator scatter would require a substantial amount of lead on a sturdy bridge over the patient. These bridges are sometimes fabricated for pregnant patients, but are not used routinely.<sup>4</sup>

**O** The linac is only capable of producing 20 MeV, 15 MeV, 10 MeV and 6 MeV electrons, no photon beams are available for this linac. The patient load is 20 per day... What is the workload that should be used in shielding calculations for such a vault.

The question is most likely about the "intraoperative electron beam therapy (IORT)". Good references are Int. J. Radiat. Oncol. Biol. Phys. 33, 725 (1995) and 18, 1215 (1990)

The pt. for IORT is usually treated with 1 fx (20 Gy). The patient load is normal 20 pt/month rather than per day (pls see the 2nd reference). The e beam exiting from the treatment cones is completely absorbed within patient so the x-ray contamination is the primary safety shielding concern. The neutron is also the concern but it is generated by the x-ray and 2 order of magnitude lower than the conventional linac due to lower electron beam current. For the board exam, I will just consider x-ray contamination for the highest electron energy

**X** Workload / wk = 20 pts/4 wk x 20 Gy x 5%~~(x-ray contamination)~~ = 500 cGy, the 100 Gy electron workload is consistent with the 2nd reference. ()

According to NRC-151, what is the most important factor for shielding of pregnant women to be treated for breast cancer?

- (A) Block (B) Distance (C) Dose prescribed (D) Fetus period

Distance AA

Not in NCRP151 but possible explanation in TG36,

In my opinion, reducing the field edge to the fetus area is more important than the just using block

\*Using photon mode in the linear accelerator , which one from the following materials have the highest cross section for neutron production: high photon energy, does it relate to high Z material as well

Besides being produced in the linac head, photoneutrons are also produced in the patient and in the bunker walls, floor and ceiling. The production in the linac head is particularly important because of the presence of a large amount of high-Z materials and their large photo- neutron production cross sections. Furthermore, these high-Z materials have low neutron capture cross sections and the generated photoneutrons will escape from the linac head.

Since this question asks the material, I therefore put possible choice as reference :

1. Tungsten W(鎢), 74, 2. Lead Pb 82, 3. Copper, Cu 29, 4. Aluminium, Al 13. ()

\*A treatment room has no office on the top of it. The dose rate is 40 mSv/week. If an office to be established over that room and the dose rate to be 2 mSv/week. What is the thickness of the steel layer that should be added to the concrete ceiling? Both TVLs for concrete and steel are given. $10^{(-n)}=2/40$ ,  $n=1.3$  TVL

\*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

1 HVL is added to the larger of the 2 barrier thickness (NCRP 151 p34 )

14. which survey meter is best for simulation room survey? (GM counter? Scintillation survey meter? hand-held ion chamber, as well as different size of ion chamber 1, 10, or 100 cc)  
McKinley (p147)

\*What measurement device is best for a simulation room survey? ion chamber, ion chamber w/ electrometer, GM, scintillation counter? Ion chamber Kahn 3rd p415 ()

\*Concrete is used for neutron shielding for what reason?

slow down the neutron to thermal

The hydrogenous makeup of concrete causes it to have a much higher neutron cross section than say lead or steel. JPS

Q \*The NRC requires HDR shielding to be surveyed: daily, weekly, monthly, annually, after source change (from 2002 recall).

After every source change before it is used. Must check the housing shielding with the source in it, and check the walls with the source exposed. From 10CFR35. KMW

From 2002 recall, "after source change" is actually a choice, so it can be the answer ()

[http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1556/v9/index-old.html#\\_1\\_79](http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1556/v9/index-old.html#_1_79)

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

The correct paper can be Kersey R. (1979) Medicamundi 24, 151. The question should be TVD (tenth value distance) rather than TVL. The TVD for neutron according to Kersey is 5 m (McGinley p69-74)()

Linear Accelerators for Radiation Therapy by David Greene, P.C. Williams, Page 208: For a maze with a cross sectional area of 6 m^2, the first TVL is approximately 3 m and subsequent TVLs are 5 m (the first TVL is less because the neutrons have not slowed down very much at this point) (HL)

Kersey's original paper (1979) also cited in NCRP 151 Page 43-44 stated 5 m as TVD/or TVL(tenth-value length). However, in 1991, they think 5 m is a conservative way so they used modified Kersey method  $TVD = 2.06 \sqrt{S1} = 3.4$  if 6 m^2 cross sectional area. But I think this question may ask the TVD from Kersey's 1979 paper if there is no maze cross sectional area provided ()

Q The largest contributor to dose at a point behind the gantry stand is patient scatter, head leakage, neutrons from (gamma,n) in the walls (from 2002 recall)?

My vote is the "Leakage radiation from source", because for MV linac, leakage photon energy is higher than scattered photon. (Kahn 4th p363, & Metcalfe p779) ()

Q \*According to NCRP-49, what is the max allowed exposure/dose for films in a storage area?

Sufficient film shielding must be in place to reduce the radiation level to stored film to  $< 0.1 \text{ mGy}$  over the storage period of the film. Once films are loaded into cassettes, radiation exposure levels should be  $< 0.5 \text{ µGy}$ . (HL) ([http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/safety-code\\_35-securite/section-b1-eng.php](http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/safety-code_35-securite/section-b1-eng.php))

\*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.

$$66''/13.6'' = 4.85 \text{ TVL} = N_{\text{conc}} + N_{\text{steel}} - (1)$$

$$N_{\text{conc}} * 13.6 + N_{\text{steel}} * 3.8 <= 36'' - (2)$$

solve (1) & (2) and  $N_{\text{steel}} = 3.05 \text{ TVL}$  (AA)

\*36 inch space is available for 6 TVL shielding. Given Pb TVL (2 inch) and Concrete TVL (18 inch), what is the minimum thickness of Pb needed?

TVL of lead x, TVL of concrete y,

$$x + y = 6$$

$$2x + 18y = 36, \text{ so } x = 4.5, 4.5 \times 2 = 9 \text{ in of lead}$$

\*Question on how to calculate TVLs, Blx, Bsx for shielding needs. On one, the patient scatter area was 20 sq cm rather than 40 sq cm.

Q \*Retrofit a linac to perform IMRT... how much shielding do you need to add?

Leakage will be the concern due to 2 - 10 fold higher MU from IMRT compared to conventional linac (NCRP 151), 5 fold higher MU can be an appropriate number to consider IMRT leakage. Leakage will mostly affect the 2nd barrier than the

primary barrier. If the leakage is increased by factor 5, we will need additional  $2.3 \text{ HVL} = 0.5^{\text{th}}(2.3) = \frac{1}{5}$  to bring the leakage down to the original dose limit ()

- O Retrofitting a machine to perform IMRT. What is the increase in workload? Given 65% IMRT, Ratio of MU IMRT/no IMRT = 4, average PDD = 60%, 200cGy/patient, 30 pt/day.  
 $W_L = 4 * 0.65 + 0.35 = 2.95$ ; so the workload for secondary leakage shielding was increased by a factor of 2.95  
(leakage workload increase but not the regular workload on the iso. NCRP 151, )

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.

$$B = (0.02 \times 1^2 \times 5^2 \times 400/400) / (0.001 \times 500 \times 1000), B = 0.001, \text{ assuming } T = 1 ()$$

37. IMRT shielding: how much more shielding needed? All wall + TVL; Primary + TVL; Secondary + HVL; Secondary + TVL; etc. Leakage: Secondary + HVL or TVL depending on the % of the leakage workload changing ()

T25.

As the x-ray energy increases from 1 MV to 20 MV, the half-value layer, in lead:

- A. Increases.
- B. Decreases.
- C. First decreases, then increases.
- D. First increases, then decreases.
- E. Stays nearly constant.

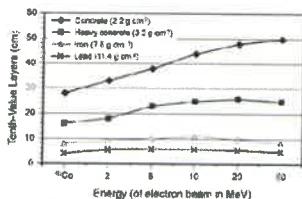


Fig. A.1.b. Primary TVLs for materials (expanded from Figure A.1.a.).

D: NCRP 151

T78.

When designing shielding for a 6 MV linear accelerator, the tenth-value layer (TVL) for concrete (density  $2.35 \text{ g cm}^{-3}$ ) is about 33 cm. The TVL in lead (density  $11.35 \text{ g cm}^{-3}$ ) would be about \_\_\_\_\_ cm.

- A. 3.3
- B. 5.7

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

$$Pd^2 \rightarrow 0.1 \text{ mSv}$$

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

Exposure rate constant for Ir-192 is  $4.69 \text{ R cm}^2/(\text{mCi hr})$ , and the formula can be written as  $10 \times 10^3 \text{ (mCi)} \times 4.69 \text{ R cm}^2/(\text{mCi hr}) \times 100/60 \text{ (hr/wk)} \times 1/(200)^2 \times B = 0.01 \text{ R/wk}, B = 5 \times 10^{-3}$ , ()

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

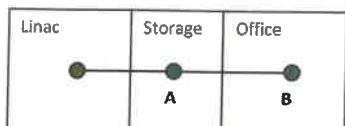
I think  $X_p$  is the dose limit we would like to achieve after the barrier,

$$600 \times 3600 \text{ (mAs/wk)} \times \frac{1}{4} \times 1/9 \times 0.01 \text{ R/mAs} \times B = 0.01 \text{ (R/wk)}, s = 4.78 \text{ TVL} ()$$

\*Scatter and leakage shielding thickness calculations are equal. The shielding that should then be used is? TVL+HVL  
 If the thicknesses of the two barriers differ by at least three HVLs, the thicker of the two will be adequate. If the difference is less than three HVLs, one HVL should be added to the larger one to obtain the required secondary barrier. Khan P363  
 NCRP151 added 1 HVL ()

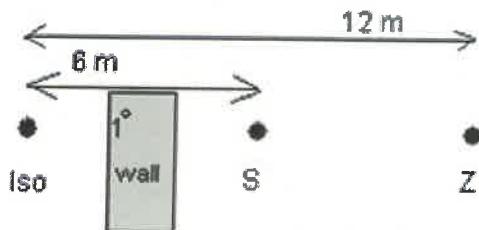
$$1 \text{ mrem} = 0.01 \text{ mSv}$$

\*Distances given: Linac to A=6m, Linac to B=12m. Survey meter measures 0.6 mrem/hr at point A. 200 cGy delivered at each treatment is also given. How many patients can be treated to limit the exposure at point B to below 2 mRem/wk



\*The distance from isocenter to point S is 6m, and iso to point Z is 12m. Point S is in a store room and point Z is in a room being considered as new office space. A survey meter measures 0.2? cGy/hr at point S. A beam is aimed toward this primary wall for 30 seconds per treatment. For a maximum dose of 0.08? cGy/week at point Z, what is the maximum number of patients you can treat per day? Consider only photon interactions.

236. Shielding: the distance from isocenter to point S is 6m, and iso to point Z is 12m. Point S is in a store room and point Z is in a room being considered as new office space. A survey meter measures 0.2? cGy/hr at point S. A beam is aimed toward this primary wall for 30 seconds per treatment. For a maximum dose of 0.08? cGy/week at point Z, what is the maximum number of patients you can treat per day? Consider only photon interactions.



$$(6+1)^2/(12+1)^2 = 0.29 \cdot 0.2 \text{ cGy/hr} * 0.29 = 0.058 \text{ cGy/hr at Z}; 0.08/0.058 = 1.38 \text{ hr} \rightarrow 1.38 * 60 / 0.5 = 165 \text{ patients/wk} \rightarrow 33 \text{ patients/day...}$$

considering it's primary beam so the distance from target to s and to z are 7 and 13 m, following the inverse square law, the dose at point z is reduced from 0.2 cGy/hr to  $0.2 \times 49/169 = 0.058 \text{ cGy/hr}$   
The maximum accumulated dose at point z is 0.08 cGy/wk, it means  $0.08 \text{ cGy}/0.058 = 1.38 \text{ hr/wk}$ . The machine only can operate for 1.38 hr /wk, total patient amount is  $1.38 \times 60 / 0.5 = 165 \text{ pt/wk}$  so  $165 \text{ pt}/5 \text{ days} = 33 \text{ pts/ day}$

\*If the thickness of a shielding barrier was calculated as per the 6 MV beam and the Exposure level was given at particular point. Calculate the exposure level if 18 MV beam is used for the same thickness. TVLs given.

O Neutron dose equivalent (mSv) outside field per photon Gy at isocenter for 20MV beam.

Measurements have shown that in the 15 - 25 MV x-ray therapy mode the neutron dose equivalent along CAX is approximately 0.5% of the x-ray dose-equivalent and falls off to about 0.1 % outside the field. (Hendee, p351)  
 $0.1\% \times 1 \text{ Gy} = 1 \text{ mSv}$

\*How many TVL's in a linac head?

<0.1% head leakage requirement means 1/1000 attenuation so  $\Rightarrow 3 \text{ TVL AA}$   
(Green p195, 0.1% that our leakage fraction for shielding calculation)

\*Weekly dose limit for unrestricted area. 0.02mSv/wk

\*Give a dose limit at Im, and the secretary office distance, ask the shielding calculation by ALARA principle. Office area U = 1, uncontrolled area 0.02 mSv/wk, hourly limit 0.02 mSv/hr

O \*Energy at which theoretically neutrons can be produced a neutron in LINAC  
8 MV is more accurate (NCRP151 and AAPM2011 review course, )

\*Using lead and concrete to shield Primary wall. From the inside, what is the order of the materials?

From NCRP151 or AAPM 2011 review course (p25), it suggested lead and then concrete, because photoneutron can be produced in the lead itself, so concrete can then absorb neutron. ()

\*Shielding: Electron only machine has 4 electron energies, each with 3.5%, 2%, 1.5%, and 1% X-ray contamination. Workload 200 Gy/week, what is weekly workload for photon contamination? simple average? anyone? The workload is the sum of the 4 electron energies since the information is limited, I used  $200 \text{ Gy}/4 \times (0.035 + 0.02 + 0.015 + 0.01) = 4 \text{ Gy}$  ()

\*What is the dose rate at 1m from a patient receiving external beam treatment?

Shouldn't it be  $0.1\% = 0.001$ ? if we consider 90 degree scatter 1 m away from patient (Kahn sec 16.6B, ) the rule of thumb is that the dose scattered laterally from a megavoltage beam has a max photon energy of about 500 keV and the dose at 1 m is about 1/1000th of the dose at the isocenter.

\*A lead pig with 2 cm wall thickness is inside a 30cm diameter polyurethane foam shipping drum. HVL of lead was given ( $=5.5\text{mm}$ ). Exposure rate constant of 192  $\text{Ir}$  was given ( $0.32 \text{ mR/mCi hr}$  at 1 meter). Calculate max activity to keep exposure rate below 50mR/hr on the drum surface.

$0.32 \times X / (0.17^2) \times (0.5)^2 \times (20/5.5) = 50 \rightarrow X = 56.4 \text{ mCi}$  I would think the distance be 15cm instead of 17cm  $\Rightarrow$  radius of drum is 15. Am I wrong?? I used 15 cm as well and I got 43 mCi ()  $0.32 \times X / (0.15^2) \times (0.5)^2 \times (20/5.5) = 50$

I agree

Q 163. Given Kersey's formula and the distances and ratio of maze areas, neutron dose at isocenter (m Sv) per photon cGy at isocenter, what is neutron dose (mSv) at door per photon cGy at iso. given TVL of maze for neutrons is 5m.  $H_{n,D} = H_0 \times (S_0/S_1) \times (1.41/d_1)^2 \times 10^{(-d_2/5\text{m})}$

In Kersey's formula,  $d_0$  is actually 1.41 m from target (NCRP151, p44 eq.2-18, )

$$H_{n,D} = (H_0) \left( \frac{S_0}{S_1} \right) \left( \frac{d_0}{d_1} \right)^2 10^{-\left( \frac{d_2}{5} \right)} \quad (2.18)$$

In this application of Kersey's method,  $H_0$  is the total (direct plus room-scattered plus thermal) neutron dose equivalent at a distance  $d_0$  (1.41 m) from the target per unit absorbed dose of x rays at the isocenter ( $\text{mSv Gy}^{-1}$ ) (see Table B.9 in Appendix B for measured values of  $H_0$ ). The ratio  $S_0/S_1$  is the ratio of the inner maze entrance cross-sectional area to the cross-sectional area along the maze (Figure 2.8). These are usually different primarily because of their different widths, though the height may change also due to the use of lintels above the inner maze entrance. Distance  $d_1$ , which is shown in Figure 2.8, is the distance from the isocenter to the point on the maze centerline from which the isocenter is just visible (A). For a maze with one bend as illustrated,  $d_2$  is the distance in meters from A to B. In the case of a maze with two bends,  $d_2$  is the distance from A to C plus length C to D. Note that for this method the maze has a TVD of 5 m for the attenuation of neutrons in the maze.

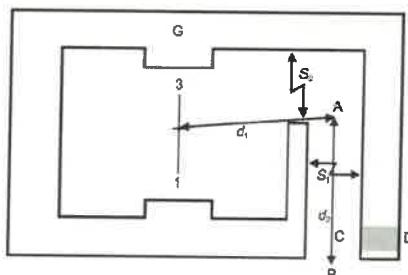


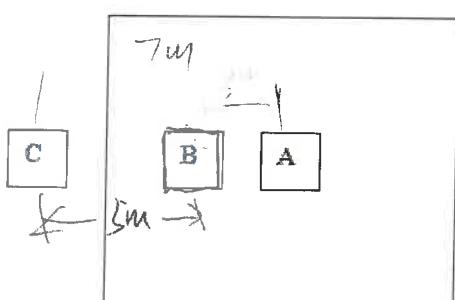
Fig. 2.8. Room layout for calculating neutron capture gamma-ray and neutron dose equivalents at the maze door.

$H_{n,D}$  is neutron dose equivalent in  $\text{mSv/Gy}$ , the  $d_0$  is the 1.41 distance from target not the SAD!!

\*Shielding: What's peak energy of photons near door? 200 keV, 500 keV, etc.  
511 KeV 90 degree Compton scattering see Kahn 3rd Fig. 16.3, p412

Q Which will give the highest portion of the photon dose at the door of the maze: is it from the head, or from wall between the door and the accelerator or from the scattering wall facing both the accelerator and the door?

\*Point A and B are candidates for machine isocenter. Point C is outside the primary shielding and distances AC( $=7\text{m}$ ) and BC( $=5\text{m}$ ) are given. If isocenter is set at A, measurement at C is within the MPD specification. If isocenter is changed to B, how much more shielding (TVL) is needed for the wall to maintain same reading at C, given TVL. A) 4.7 TVLs (B) 3.7 TVLs (C) 2.7 TVLs (D) 1.7 TVLs



$$\frac{8^2}{6^2} \times 10^{(-n)} = 1$$

$$\frac{7^2}{5^2} \times 10^{(n)} = 1 \rightarrow 0.3$$

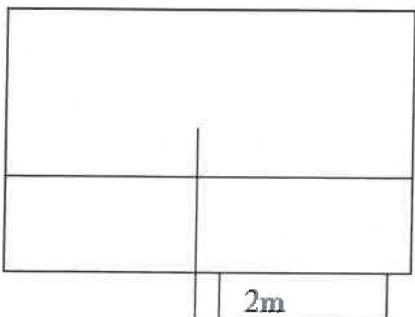
The distance for primary beam should be "target" to the point of measurement from NCRP151, so in this case it should be more accurately using  $8^2/6^2 \times 10^{-n}$  and  $n = 0.25$  TVL. To LSK107 comment, we have 5 choices, so (E) may be our answer. ()

\*Given primary workload, distance to office, and TVL, calculate shielding thickness to achieve 1/10 of MPD. U, T, MPD were not given.

$$U = \frac{1}{4}; T=1; MPD = 0.02 \text{ mSv/wk}$$

$W \times U \times T \times 10^{-(n/TVL)} \times (1/d^2) = 1/10 \times MPD$  (just feel weird the design goal even 1/10 for uncontrolled area) (NCRP151,) MPD for public frequent exposure is 1mSv/yr, so 0.02 mSv/wk

\*HDR shielding question. How much thickness for 10 patients per week, 5 days a week, 500cGy/patient. The drawing showed a distance of 2 meters (I think that's what it meant).



$$500 \text{ cGy} \times 10 \times 10 \times \frac{1}{4} \times 10^{-n} = 0.02 \text{ mSv}$$

For a Workload of 10 patients for week we get : 5000 cGy/wk or 50,000mGy/wk, Weekly limit P = 0.02 mSv/wk,  $d=2\text{meters}$   $B = Pd^2/WUT = 0.02^2/(4)/50,000 \Rightarrow 5.79 \text{ TVLs}$

For HDR, we still use 0.02 mSv/wk as the dose limit

$$500 (\text{cGy}) \times 10 \times 10 \times (1/4) \times 10^{-(n)} = 0.02, 5.79 \text{ TVL} ()$$

\*Given density of lead and mass atten coeff. for a random energy... what is TVL?  
 $\mu/\rho \times \rho = \mu$ ;  $TVL = \ln 10 / \mu$   
 $\text{or } \exp(\mu/\rho \times \rho \times d) = 1/10 \Rightarrow d = \ln 10 / (\mu/\rho \times \rho)$  (3.3 HVL)

\*200 keV beam. The density of copper is given in g/cm<sup>3</sup>, and the  $\mu/\rho$  for copper is given in cm<sup>2</sup>/g. If 3 mm of copper attenuates the beam to 63% of its original intensity, what is the TVL for copper?

$$\text{density of copper} = 8.92 \text{ g/cm}^3; \mu/\rho = 0.1559 \text{ cm}^2/\text{g} \rightarrow \mu = 1.39 \text{ cm}^{-1} \rightarrow HVL = 4.5 \text{ mm}$$

$$TVL = \ln 10 / \mu, \text{ so } TVL = 1.65 \text{ cm} ()$$

$$\frac{W}{2} + \frac{W}{2} \times 5 = 3 \text{ in} \\ 3 \times 10 =$$

\*A Shielding calculation was performed assuming no IMRT. If you will now be doing 50% IMRT, how much additional shielding will you need to add?

Increased MU usage for IMRT will only affect the secondary shielding for leakage, but I'm not sure what factor we need to apply to the workload when doing calculation.

Assume the original work load = W, and the IMRT factor = 5, so the total leakage workload  $WL = W/2 + W/2 \times 5 = 3W$  which means the point behind the secondary barrier-dose will receive 3 fold higher dose than without IMRT implemented. We need  $3 \times 10^{-(n)} = 1$ ,  $TVL = 0.47 ()$

$$3 \times 10^{-n}$$

5. storage room 6m away from iso in primary direction reading 0.06mSv/hr for 6MV beam, if add 18MV beam and wanted the office next to storage room and 12m away from iso, if want the reading at office below 0.02mSv/hr, how many patient can treat everyday. Beam on time for each patient on this direction is 30 sec.

$$TVL(6X) = 13.7 \text{ inches}, 18X = 17.8 \text{ inches}, 6X:18X = 70\%:30\%$$

For this question, I assumed the thickness of the wall is given, because in practical situation, we should know the thickness of the wall. Let's assume the thickness is 5 TVL for the wall. Therefore, the wall thickness is  $5 \times 13.7 \text{ in} = 68.5 \text{ in}$ .

Now, we want to add 18x, and the beam usage is 6x: 18x = 0.7: 0.3, so the workload for 6x and 15x are 0.7W and 0.3W. The wall penetration for 18x becomes  $10^{(-68.5/17.8)} = 10^{(-3.84)}$ , and we can calculate the dose at the storage room 6 m away as:

$$[0.7 + (0.3/10^{(-5)}) \times 10^{(-3.84)}] \times 0.06 = 0.3 \text{ mSv/h} \rightarrow \text{at 12 m away using inverse square law } 0.3 \times [(6+1)/(12+1)]^{1/2} =$$

0.08 mSv/h

$0.02/0.08 = 0.25 \text{ h}$ ,  $0.25 \times 3600/30 = 30 \text{ pts}$ ; I suspect the question giving the dose limit is weekly 0.02 mSv/wk (from other recalls). Nevertheless, shielding needs to satisfy the hourly and weekly dose limit. In this question, weekly dose limit is more stringent than the hourly limit. 1 wk we can treat 30 pts, so 6 pts per day (this number is related to the assumption of wall thickness) ()

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

According to NCRP151, for varian machine 15MV H<sub>0</sub> = 0.79-1.3mSv/Gy; for 18MV H<sub>0</sub> = 1.02-1.6mSv/Gy, so it could be 1 or 2, anyone?

From AAPM review course, Peter Biggs shielding handout, page 24 "At 10 MV, the production of neutrons is quite low, and by 15 MV, neutron production increases by a factor 10, and by 18 MV, a further factor of 2. Therefore, I will vote for 2. ()

\*TVL is related to HVL by A: TVL = ln10/ln2 HVL, link by the attenuation coeff.

3.3

### Radiation safety:

A radiation therapist's whole body monitor reads 15 mR in one month. The *most likely* source for this exposure is:

- A. Treating 35 patients a day on a dual energy (6/18 MV) linac.
- B. Delivering four vaginal cylinder treatments each week with HDR, using a new 10 Ci source.
- C. Removing vaclocks and adjusting masks for patients about to be scanned in a PET-CT scanner.
- D. Carrying packages of Pd-103 seeds to be used for prostate implants from the mail room to the hot lab.
- E. Loading I-125 seed into cartridges prior to sterilization.

C

Therapists should receive no measurable dose from treating patients on a linac, or at the treatment console of an HDR unit. Modern HDR units are well shielded, and even older models should not exceed 2 mR in an hour at 1 m from the safe. I-125 and Pd-103 seeds emit low-energy photons, which are easy to shield, both for transport and loading; only the hands receive a very small dose from loading. Patients who have had FDG injected for a PET scan emit fairly energetic 0.51 MeV photons from positron-electron annihilation. Although the dose at 30 cm from the patient would be low (typically 8 mR/hr one hour after the injection), prolonged therapy simulation/setup procedures could result in close contact with the patient, and should if possible be completed *before* the patient is injected with FDG, to minimize staff exposure.

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. Area survey requires the highest dose rate and the largest field size, so A is correct. (NCRP 151, p100, ) The chamber wall for the survey meter is already adequate for leakage radiation measurements for energy as high as 25MeV(Mckinley p147)

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.

this is equivalent to 0.02mSv/hr, so it's ok. We may also need to consider weekly dose limit ()

T78. Average dose to a member of the U.S. population from natural background radiation (excluding radon).

T79. Average dose to a member of the U.S. population from medical x-rays.

The average annual dose to members of the public is about 1.6 mSv, excluding the dose from radon. Medical x-rays, cosmic, internal, and terrestrial radiation each contribute 0.3 to 0.4 mSv, and nuclear medicine contributes about 0.14 mSv.

0.02 mSv/wk  
hr

If a technologist were to stand 2 m away from a patient during fluoroscopy (outside the primary beam), the dose received by the technologist would be mainly due to:

- A. Compton electrons.
- B. Photoelectrons.
- C. Compton-scattered photons.
- D. Characteristic x-rays generated in the patient.
- E. Coherent scatter.

C

Even at low kV, coherent scatter contributes only a small part of the total scatter. The characteristic x-rays created by photoelectric interactions within the patient are of very low energy (because of the low Z of tissue) and have an extremely small range. Compton electrons and photoelectrons also have a short range and are unlikely to leave the patient's body.

Compton scattered photon is the highest energy among these choices!!!

T92. The dose to a resident's hands from a brachytherapy procedure is 25 mSv (2.5 rem). The number of procedures that the resident can perform per year without exceeding the recommended dose limit is:

mSv/yr, so the answer is 500/25 = 20

The annual dose limit to radiation worker is 500

○ All of the following types of radiation contribute about equally to the average annual dose equivalent received by a member of the U.S. population, *except*:

- A. Internal.
- B. Terrestrial, other than radon.
- C. Medical x-rays.
- D. Nuclear medicine.
- E. Cosmic.

T85. D Out of a total of about 1.6 mSv, nuclear medicine contributes about 0.14 mSv, and the others all contribute about 0.3 to 0.4 mSv each.

nuclear medicine is

lower than others.

- T70.** Regarding radioactive package labeling, which is *false*?
- Yellow III has a higher dose rate at 1 m than Yellow II.
  - Yellow II has a higher dose rate at 1 m than White I.
  - The Transport Index (TI) is the dose rate on the surface of the package. (A) 1 m
  - The type of label implies a maximum dose rate on the surface and at 1 m.

**C**

31. The Transport Index represents the exposure rate.... (choices included "on the surface" and "at one meter")  
At one meter from surface. (reference: <http://www.nrc.gov/reading-rm/basic-ref/teachers/unit5.html>)

Transport index of 1 is Exposure of 1mR/hr @ 1 meter from the surface of the package. JPS

Although the package required for transporting radioactive material is based on the activity INSIDE the package, the label required on the package is based on the radiation hazard OUTSIDE the package.

Radioactive material is the only hazardous material which has three possible labels, depending on the relative radiation levels external to the package. Also, labels for radioactive material are the only ones which require the shipper to write some information on the label. The information is a number called the Transport Index (TI), which, in reality, is the **highest radiation level at 1 m from the surface of the package**.

The 3 labels are commonly called White I, Yellow II, and Yellow III, referring to the color of the label and the roman numeral prominently displayed. A specific label is required if the surface radiation limit and the limit at one meter satisfy the requirements shown on the "Labeling" transparency.

- T80.** The U.S. Nuclear Regulatory Commission considers a reportable "medical event" to be based on both dose thresholds and percent differences from prescribed doses. Which of the following would be considered a medical event?
- 0.05 Sv overdose with an 11% difference in total dose.
  - 0.55 Sv overdose to an organ or tissue with 22% difference in total dose.
  - 0.55 Sv overdose to an organ or tissue, with a single fraction difference of 22% and a total dose difference of 2%.
  - 0.05 Sv overdose with a 22% difference in total dose.

B. NRC, 10 CFR 35.3045:

Medical event includes an absolute dose error: Total dose errors of 0.5 Sv to an organ, tissue, or skin and a percentage difference from the prescribed dose

or percentage error: 20% errors in total delivered dose (or 50% in 1 fx) are reportable. (Errors of 10% are recordable.)

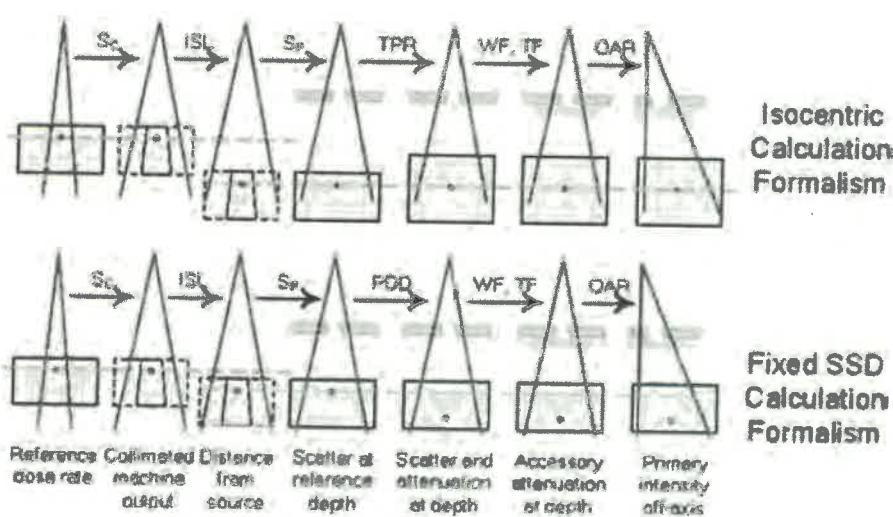
\*Dose limits for the public for frequent and infrequent exposure is \_\_\_\_\_

\*What is the highest dose to Public?

Public frequent 1mSv/year

Infrequent 5mSv/year infrequent (Therapy review course radiation protection in radiotherapy)

**Dose/MU Calc:**



$$MU = \frac{D}{D'_0 \cdot S_c(r_c) \cdot S_p(r_d) \cdot TPR(d, r_d) \cdot OAR(d, x) \cdot TF \cdot WF(d, r, x) \cdot CF} \cdot \left( \frac{SPD}{SSD_0 + d_0} \right)^2$$

$$MU = \frac{D \cdot 100\%}{D'_0 \cdot S_c(r_c) \cdot S_p(r_{d_0}) \cdot PDD_M(d, r_{d_0}, SSD) \cdot OAR(d, x) \cdot TF \cdot WF(d, r, x) \cdot CF} \cdot \left( \frac{SSD + d_0}{SSD_0 + d_0} \right)^2$$

Be careful of the inverse square law correction for PDD function of SSD. It does not always require!! only SSD changed!

Be careful of the inverse square law correction for TPR not function of SSD. So when only SPD changed not at ISO, we will need to correct using inverse square law.

15. A given dose rate in air at 40" from the superficial x-ray source 125KvP,  
10R/mA-s. What is the dose rate at 2cm depth (Pdd= 0.6, BSF=1.15, fmed=0.9)

The dose rate at 2 cm depth =  $10 \text{ R/mA-s} \times 0.9 \text{ (cGy/R)} \times \text{BSF} \times \text{PDD}$

$$= 9 \times 1.15 \times 0.6 = 6.21 \text{ cGy/(mA-s)}$$

$$\cancel{400 \times 10 \text{ R/mA-s} \times 0.6} \\ \times 1.15 \times 0.9$$

18. Patient is being treated with SAD setup with iso at 9 cm depth, calculate the exit dose giving the PDD or TMR at 9 and 18 cm depth.

Using SAD setup, TMR(d=9) and TMR(d=18), and prescription dose D is known

$$MU = D / (TMR(9)) \rightarrow SAD$$

$$\text{Exit Dose} = D / TMR(9) \times TMR(d=18) \times (118/100)^2$$

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.

Assuming 6x and output at SSD=100 cm + dmax 1.5 as 1 cGy/MU, when we move to SSD 125 cm, the output becomes 1  $\times (101.5/126.5)^2 = 0.64 \text{ cGy/MU}$



$$\text{rayword} \left( \frac{SSD_2+d_{max}}{SSD_1+d_{max}} \right)^2 \left( \frac{SSD_1+d_0}{SSD_2+d_0} \right)$$

Output Needs updated

If we want to use PDD

$$PDD2(\text{SSD}=125, d=10, FZ) = PDD1(\text{SSD}=100, d=10, FZ) \times (125+1.5/125+10)^2 \times (100+10/100+1.5)^2 = 1.03 \times PDD1$$

$$MU = 300 / (0.64 \times PDD2(\text{SSD}=125, d=10, FZ)) = 300 / (0.64 \times 1.03 \times PDD1)$$

If we want to use TMR

$$\text{The output at SAD 100 will be } 1 \text{ cGy} \times (101.5/100)^2 = 1.03 \text{ cGy/MU}$$

$$MU = 300 / (1.03 \times TMR(d=10, FZ) \times (100/135)^2) = 300 / (1.03 \times 0.55 \times TMR, ()$$

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).

I assuming the output is actually measured in air S cGy/min

$$\text{Time} = D / (S \times \% DD(10, FZ) \times BSF (FZ)), () \text{ Kahn sec. 9.4 ex: 3}$$

32. 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.