Radiotherapeutic Physics Examination

Previous Radiotherapeutic Physics Examination Papers 1999 -2009

May 2009

Question 1

a) Describe the principles of operation of a 0.6cc (Farmer-type) thimble ionisation chamber when used in an x-ray beam. (2 marks)

b) Draw a labelled diagram of a re-entrant (well-type) ionisation chamber when used for HDR Iridium-192 source calibration checks. (1 mark)

c) A new HDR Iridium-192 source is delivered with a certificate of calibration from the manufacturer stating the Air Kerma Rate at 1m from the source on a particular day and time. Describe the experiment and identify factors that need to be considered to confirm the source calibration with a 0.6cc thimble ionisation chamber. (3 marks)

d) Briefly describe the use of a suitable dosimeter for each of the following tasks in a HDR brachytherapy suite.

i) Routine QA test of source position and dwell time accuracy. (1 mark)

ii) Verify that source retraction has occurred into the lead safe. (1 mark)

iii) Monitor the dose received by personnel during an emergency. (1 mark)

iv) Monitor the dose received in the control area over a period of several months. (1 mark)

Question 2

a) Figure 1 depicts an axial section through the mid-thorax, irradiated with a single lateral photon beam (6 MV, 100 cm SSD). Explain how the presence of the lung will affect the dose delivered at the points 1, 2, 3 and 4. (2 marks)

b) Figure 2 depicts an axial section through the skull, irradiated with a photon beam. Explain how the presence of the bone will affect the dose delivered at the points 5, 6, 7 and 8 in the following photon beams: (4 marks)

i) 200 kV_p, 1.5 mm Cu HVL, 50 cm SSD

ii) 6 MV, 100 cm SSD

iii) 25 MV, 100 cm SSD

c) Figure 3 depicts an axial section through the pelvis, treated using a 3-field technique, where the isodose lines are calculated with the heterogeneity correction algorithm turned OFF. The patient has bilateral hip replacements with steel prostheses.

i) Describe the effects of the steel prostheses on the CT scan image and on the calculation of the isodose distribution. (2 marks)

ii) What steps might be taken to either improve the accuracy of dose calculation or avoid the problem? (2 marks)

Question 3

a) Write brief notes on the following, including the units where appropriate:

i) recommended dose limits (1 mark)

ii) half value layer (1 mark)

iii) Compton Effect (1 mark)

iv) the Bragg peak (1 mark)

v) remote afterloader (1 mark)

vi) decay constant (1 mark)

vii) the Gamma Knife (1 mark)

viii) the Paris System (1 mark)

ix) SSD and SAD monitor unit calculation methods (1 mark)

x) field size equivalent square (1 mark)

Question 4

a) Draw an accurate diagram of the central axis depth dose curves in water, for 6 MeV, 12 MeV and 18 MeV electron beams of field size 10 x 10 cm at 100 cm FSD. Using this diagram, explain the physical reasons for the differences between each of the following clinically relevant portions of the curve

i) the surface dose (1 mark)

ii) width of the 90% dose plateau (1 mark)

iii) the dose deposited deeper than the practical range (Rp) (1 mark)

b) Draw an accurate diagram of the central axis depth dose curve in water, for a 6, 10 and 15 MV photon beam of field size 10 x 10 cm at 100 cm FSD. Using this diagram, explain the physical reasons for the differences between each of the following clinically relevant portions of the curve.

i) the surface dose (1 mark)

ii) the depth of Dmax (1 mark)

iii) the depth of D50% (1 mark)

c) Draw an accurate diagram illustrating the energy spectrum of both a ^{60}Co and a 6MV beam. Using this diagram, explain the reasons for the differences between each of the following:

i) peak energy (1 mark)

ii) mean energy (1 mark)

d) i) Draw the energy spectrum of a 6 MeV electron beam: (1 mark)

a) as the beam exits the waveguide window, and

b) at the depth of maximum dose inside the patient

ii) Explain why the beam spectrum is different in each of the cases described in d, (i) (1 mark)

Question 5

a) For each of the following applications, draw a well labeled schematic diagram of the components of a linear accelerator head in; (2 marks)

i) photon treatment mode

ii) electron therapy treatment mode

b) Describe the key function of each of the components in your diagrams. (3 marks)

c) Describe the spatial distribution of x-rays around a thin target, resulting from an electron beam incident on that target, with energies of a) 100 keV and b) 20 MeV. How has this distribution influenced the placement of targets in superficial and megavoltage radiation generators? (2 marks)

d) The attenuation of a photon beam in matter is caused by 5 major types of interactions. With the aid of diagrams, describe 3 of these interactions. (3 marks)

Question 6

a) With the aid of diagrams, describe two methods of wedge filtration commonly used in megavoltage photon treatments in clinical practice. (3 marks)

b) Consider each of the wedge filters described in your answer for part a) of question 6.

i) Discuss the physical principles involved in their design. (4 marks)

ii) Explain the similarities and differences in the dose distributions achieved in the patient. (1 mark)

c) Give two reasons why wedge filtration is used and a clinical example of each in practice. (2 marks)

October 2008

Question 1

a) Define ACTIVITY, APPARENT ACTIVITY and SPECIFIC ACTIVITY as used in radiation therapy. Provide the unit of measurement for each of these terms. (2 marks)

b) For each of the following radionuclides Caesium-137, Cobalt-60, Iridium-192, Strontium-90 and Iodine-125: (5 marks)

   i) identify the type of emissions produced, give a brief description of their energy spectrum, and state the half-life of each radionuclide.

   ii) give one clinical use for each of these radionuclides.

   iii) describe the source construction for each radionuclide which makes it suitable for the clinical use given in part (ii).

c) Describe two types of radioactive equilibrium that occur. Provide one example of each type and its practical application. (3 marks)

Question 2

a) Modern linear accelerators are operated by electronic systems that can deliver radiotherapy treatments without human intervention apart from the command to start. In a system where electronic transfer of radiotherapy data is routine, describe two potential problems that can lead to errors in radiation treatment delivery. (3 marks)

b) In 2004 the Japanese Society for Therapeutic Radiology and Oncology found that “7 out of 8 accidents were related to updated radiotherapy treatment planning (RTP) systems”. Using your knowledge of RTP systems, describe two scenarios where the inappropriate implementation of an updated system may lead to radiation incidents. (3 marks)

c) While the important radiation incidents are usually thought to be overdoses, underdosing also constitutes an incident. Explain why underdosing can be considered a radiation incident. (1 mark)

d) What steps should be taken before releasing an upgraded version of the radiotherapy treatment planning (RTP) system for clinical use? (3 marks)

Question 3

Define and write brief notes on the following terms, including the units of measurement where appropriate: (1 mark each)

a) Exposure

b) Absorbed dose

c) Equivalent dose

d) Tissue compensation

e) Wedge factors

f) Stopping power ratio

g) Inverse square law

h) Photon dose build-up

i) Anisotropy factor

j) Field size

Question 4

a) Consider a 6MV photon beam incident on a water phantom at 100cm FSD. The field size on the phantom surface is 10cm x 10cm. Draw labelled diagrams showing representative isodose curves for this beam where: (3 marks)

i) the field edges are symmetric about the central axis.

ii) an independent jaw has been used to block the beam to the central axis in one dimension.

b) Explain the differences between the dose distributions observed in part (a). (2 marks)

c) Consider a 6MV photon beam incident on a water phantom at 100cm FSD. The field size on the phantom surface is a 10cm diameter circle. Draw labelled diagrams showing Beam's Eye View representation of the beam aperture defined using: (2 marks)

i) a cerrobend block.

ii) multi-leaf collimators.

d) Describe and explain the differences between the dose distributions generated by the beams in part (c). (2 marks)

e) What differences, if any, will be observed in the monitor unit calculation equations used for the beams in part (c)? (1 mark)

Question 5

a) Consider an electron beam traversing a material. Define IONISATION and EXCITATION within that material. (1 mark)

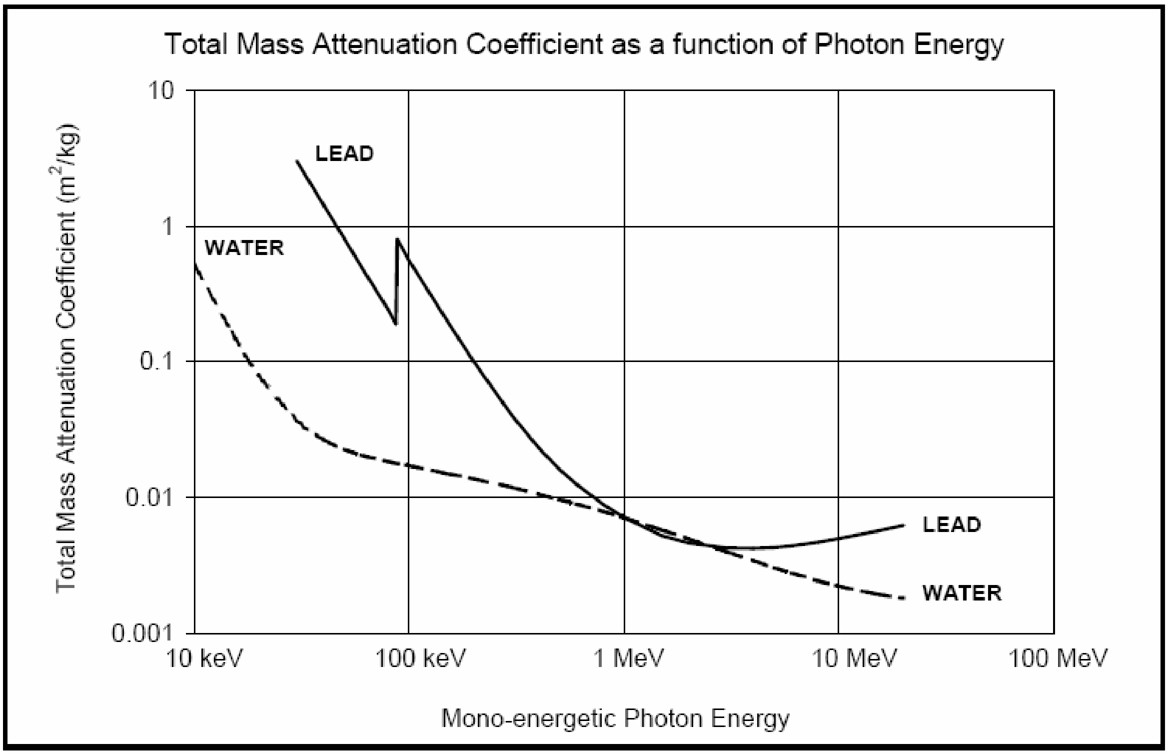
b) Consider an electron beam traversing a material. Explain BREMSSTRAHLUNG production within that material. (1 mark)

c) Provide two examples of how multiple scattering affects the shape of the electron beam dose distribution in soft tissue. (2 marks)

d) Describe the physical conditions required to produce EXPONENTIAL PHOTON ATTENUATION. Provide the equation which describes this attenuation and define each component of the equation. (1 mark)

e) Consider a photon beam traversing a material. Define the ENERGY TRANSFER COEFFICIENT. Describe its relationship to the ENERGY ABSORPTION COEFFICIENT. (1 mark)

f) Use your knowledge of the attenuation coefficients for the PHOTOELECTRIC EFFECT, COMPTON EFFECT and PAIR PRODUCTION to explain the shape of the TOTAL ATTENUATION COEFFICIENT CURVES for WATER and LEAD as shown in the accompanying diagram. (4 marks)



Question 6

a) Intensity modulated radiation therapy (IMRT) can be delivered in two ways. Describe the process of IMRT delivery based on: (2 marks)

   i) multi-leaf collimators (MLCs)

   ii) compensators

b) Describe benefits and potential problems of each method. (2 marks)

c) A superficial tumour with skin involvement is located just below the eye. The oncologist describes the PTV which is 1.0cm wide, 1.5cm long, 1.0cm deep. The superior border of the PTV lies 0.5cm inferior to the centre of the bony orbital rim.

   Give a brief description of suitable techniques, their limitations and potential usefulness in treating this tumour with the following beam modalities: (6 marks)

   i) kV photons.

   ii) MV electrons.

May 2008

Question 1

For the use of unsealed sources for radiation therapy:

a) describe the physical and radiobiological properties of Sr-89 (2 marks)

b) describe the clinical indication for the use of Sr-89 and why it is appropriate for this indication. (2 marks)

c) describe how the dose to a specific organ from administered Sr-89 is determined. (3 marks)

d) in relation to administering an injection of Sr-89, how would you manage a spill of Sr-89 during its administration to a patient? (3 marks)

Question 2

a) What is the purpose of commissioning a linear accelerator? (1 mark)

b) List two (2) activities which should be undertaken when commissioning a new linear accelerator, and for each activity describe:

i) how this activity is undertaken (2 marks)

ii) how the results are used when the linear accelerator is in clinical use (2 marks)

c) What is the purpose of performing quality assurance on a linear accelerator? (1 mark)

d) List two (2) quality assurance activities undertaken on a linear accelerator (do not repeat activities from part b), and for each activity describe: (4 marks)

i) how this activity is undertaken

ii) how often this activity is undertaken

iii) the action taken when a measurement is outside the accepted range

Question 3

a) i) Draw a percentage depth dose curve of a mono-energetic, high-energy proton beam as it passes through water.

ii) On the same diagram, draw this proton beam after it has been modified for clinical use. Explain how this modification is practically achieved. (4 marks)

b) Draw a well labelled diagram of the major components of an orthovoltage x-ray tube. Describe the processes of x-ray production by this unit for radiation therapy treatment. (2 marks)

c) Describe the effect of a combination filter on 250 kVp x-ray produced from an orthovoltage x-ray tube. (2 marks)

d) Define the term "half value layer" and explain one use of this concept on orthovoltage radiation therapy. (2 marks)

Question 4

a) Draw schematic diagrams of both a thimble ionization chamber and a parallel plate ionization chamber. (4 marks)

b) Describe how each of these dosimeters measures ionizing radiation. Identify desirable characteristics for this process. (4 marks)

c) Identify a use for each of these two dosimeters for which it is uniquely suited. (2 marks)

Question 5

a) Define percentage depth dose, tissue-air ratio (TAR), output factor (Sc,p) and tissue phantom ratio (TPR). (4 marks)

b) For each of these parameters, indicate a situation in which it is particularly useful. (2 marks)

c) Describe and briefly explain the way in which these parameters vary with change in field size and source skin distance (SSD). (4 marks)

Question 6

a) For the following radiation quantities provide a definition and the unit of measurement: (6 marks)

   i) Absorbed Dose

   ii) Equivalent Dose

   iii) Linear Energy

   iv) Air Kerma Rate Constant

b) Provide the relationship between the following sets of radiation quantities: (4 marks)

   i) Absorbed Dose

   Equivalent Dose

   Effective Dose

   ii) Stopping Power

   Linear Energy Transfer

October 2007

Question 1

A megavoltage linear accelerator is commonly used in external beam radiation therapy. Draw separate schematic diagrams for each of the following, with sufficient labelling and captions to explain:

a) how a linear accelerator produces a photon beam suitable for therapeutic use. (5 marks)

b) the changes required in the treatment head to produce an electron beam suitable for therapeutic use. (3 marks)

c) the location of the MLC in the treatment head, the structure of a multi-leaf collimator and how it generates different field shapes. (2 marks)

Question 2

A 24 week pregnant patient has been diagnosed with breast cancer and will commence radiation treatment to the breast next week. It is expected the foetus will remain outside of the primary beam during the treatment.

a) What would be the sources of the radiation dose to the foetus, if the patient is treated with a 6MV photon beam? (3 marks)
b) What steps should be taken to reduce the dose received by the foetus? (4 marks)
c) How could the radiation dose to the foetus be determined? (3 marks)

Question 3

You are given 3 radiation measuring devices: a thimble ionization chamber, radiographic film and thermoluminescent dosimeter chips and you are asked to:

I. check the isodose distribution for an electron field on the linac. (5 marks)

II. determine the *in vivo* eye lens dose outside a photon field. (5 marks)

For <u>each</u> of these clinical scenarios listed above:

a) choose the most appropriate dosimeter.

b) give reasons for your choice.

c) describe how the selected dosimeter measures ionizing radiation.

d) explain why you decided that the other two devices would be inappropriate.

Question 4

I. Discuss the advantages and limitations of lead shielding when used for:

a) protection of the teeth and gums from a 9 MeV electron (2 marks) beam treating the lower lip.

b) protection of the lens from a 6 MeV electron beam treating the lower eye lid. (2 marks)

c) defining the field size of an electron beam treating at 110cm SSD. (2 marks)

II. Electron beams have an inherent photon component, frequently termed photon contamination.

a) What causes photon contamination? (2 marks)

b) What is the maximum dose from photon contamination you would expect at a depth Rp? (2 marks)

Question 5

a) Describe a method of measuring the source strength of an Ir-192 HDR brachytherapy source. (2 marks)

b) Compare the dose distributions from a point source of Ir-192 and an actual Ir-192 HDR brachytherapy source of the same activity. (2 marks)

Previously, iridium wires have been used for interstitial implants.

c) Describe how iridium wires may be positioned to treat a planar volume. (4 marks)

d) Describe how a single Ir-192 HDR seed source is used to produce a similar isodose distribution to that in part (c). (2 marks)

Question 6

Ia) Modern external beam radiation therapy machines have an isocentre. Describe how the isocentre is defined and how its location is quality assured. (2 marks)

Ib) Describe the problems associated with the fixed SSD technique that have motivated the adoption of isocentric treatment techniques. (3 marks)

IIa) Describe the use and components of “record and verify” systems. (2 marks)

IIb) Modern "record and verify" systems can automate all movements of the linac. Discuss how this functionality can alter levels of risk during radiation delivery. (3 marks)

May 2007

INSTRUCTIONS

- There are a total of SIX questions.
- Write your answers in the book provided.
- All questions are of equal value.
- All questions are to be attempted.
- You may use diagrams, tables or lists in your answers.
- Answers should be given from a radiotherapeutic physics viewpoint.

Question 1

a) With the aid of diagrams describe the challenges associated with junctioning two adjacent radiation beams, in the case where:

   i) both fields are megavoltage photon fields

   ii) one of the fields is a megavoltage photon field and the other an electron field (5 marks)

b) When treating the craniospinal axis, a junction is required between the lateral cranial fields and the posterior spinal field (i.e. an orthogonal field junction). Again with the aid of diagrams, briefly describe two techniques than can be used to successfully junction the fields. (5 marks)

Question 2

Total Body Irradiation is a technique used for some patients being treated with bone marrow transplantation.

a) As a part of the treatment a perspex screen is placed close to the patient to reduce the skin sparing that occurs with megavoltage beams. Explain why skin sparing occurs with megavoltage beams. (3 marks)

b) One technique for delivering TBI is to use large opposed lateral fields with the patient in a semi reclined position, arms by side and knees bent. Describe the factors that might lead to dose inhomogeneity within the target volume (i.e. the body) and the methods that can be used to minimise this dose variation. (5 marks)

c) A dose uniformity of +/- 10% is acceptable for total body irradiation. Briefly describe how the dose uniformity is measured *in* (2 marks) *vivo*?

Question 3

An x-ray tube with generating potential of 200 KVp has an inherent filtration of 1mm of aluminium.

a) Draw the expected energy spectrum of such a beam on the existing tube and explain why this beam must be modified for clinical use. (2 marks)

b) Describe a suitable method of modifying the beam, using diagrams to show how the spectrum is altered. (3 marks)

c) Draw an isodose curve for the beam as modified in b) above (field defined by an open-ended cone in contact with the surface of a water phantom). Compare this with the isodose curve for a 6 MeV electron beam (field defined by an applicator at 5cm from the surface of a water phantom). (5 marks)

Question 4

A patient has been prescribed an HDR brachytherapy dose of 30Gy using an Ir192 seed source. A kink in the catheter used to insert the seed causes the seed to be positioned 26cm from the target site. The error was not discovered until the treatment had been completed.

Identify

a) the cause of the event and factors contributing to the event becoming a radiation accident (5 mark)

b) remedial action that could be taken for the patient (1 mark)

c) what remedial action should be taken for future implants to avoid this scenario? (4 marks)

Question 5

a) Explain the concept of radioactive equilibrium using Strontium 90 as an example (3 marks)

b) Strontium-90 applicators are used to treat superficial regions on the skin or eye.

  i) Explain the source construction of Strontium-90 applicators (2 marks)

  ii) Explain the processes involved to achieve the treatment dose (2 marks)

c) What precautions should be taken with handling and cleaning strontium applicators to minimise unnecessary radiation doses to personnel and to the patient? (3 marks)

Question 6

a) Describe the parameters that need to be considered in the determination of a PTV. (2 marks)

b) Describe the methods that can be used to quantify these parameters and to reduce their magnitude. (3 marks)

c) List the benefits from the use of an electronic portal imaging device in treatment verification. (2 marks)

d) Describe the ways in which the prescribed treatment is accurately delivered over a fractionated course. (2 marks)

October 2006
Time Allowed: 3 hours
INSTRUCTIONS

- There are a total of SIX questions. Each of these six questions is worth 10 marks.
- Write your answers in the book provided. You may request additional answer books from the invigilator.
- All questions are to be attempted.
- Answers should be given from a radiotherapeutic physics viewpoint.
- Hand **all** papers to invigilator, no papers are allowed to be taken from the exam room. THIS INCLUDES EXAM PAPERS

1. Consider a 12MeV electron beam incident on a water phantom at 100cm FSD. The field size on the phantom surface is 10cm x 10cm, with the final defining aperture of the applicator 5cm above the water surface.
   a. Draw a labelled diagram showing representative **isodose curves** for this beam *(2marks)*
   b. Discuss how the **dose distribution** for this beam would be affected by:
      i. decreasing the field size
      ii. increasing the phantom surface obliquity

      Your explanation should include labelled diagrams. *(4 marks)*
   c. Discuss the effect that the following would have on the **isodose curves** for this beam

i. underlying bone
ii. an air cavity *(4 marks)*

2. a. Briefly discuss the concepts of the physical, biological and effective half lives of a radionuclide. State the relationship between these concepts. *(2 marks)*
   b. List the desirable features of a radionuclide for therapeutic use as an unsealed source. *(3 marks)*
   c. Name two (2) therapeutic radionuclides that are used as unsealed sources. For each give a clinical indication. *(2 marks)*
   d. Briefly discuss how the dose to target tissues and critical organs can be estimated for radionuclide therapies. *(3 marks)*
3. a. Give an explanation for the Bragg Peak of a proton beam. *(2 marks)*
   b. Briefly explain how a proton beam can be modulated for clinical use. *(3 marks)*
   c. Stereotactic radiation therapy for small intracranial lesions can involve a single fraction (stereotactic radiosurgery) or multiple fractions (stereotactic radiotherapy), using a combination of a linear accelerator, stereotactic apparatus and multiple narrow beams. The stereotactic process includes the following four (4) steps:
      - head immobilization
      - imaging
      - target localization
      - treatment setup and delivery

      i. Describe one type of stereotactic frame. *(1 mark)*
      ii. Describe the use of the stereotactic frame in each of the four (4) steps listed above. *(3 marks)*
      iii. What is the achievable degree of accuracy (millimetres) in target localisation *(1 mark)*

4. a. ^{137}Cs tube with an activity of 45MBq and an air kerma strength of 5.00μGym^2h^{-1} was mistakenly left in the drawer of a wooden desk for 24 hours before being discovered. A female radiation oncologist occupied the desk for 8 hours at an average distance of one (1) metre from the source. Explain how the average radiation dose to the oncologist can be calculated. Compare this to the recommended dose limit. *(4 marks)*

b. Describe the ALARA principle and its application to medical practices. *(2 marks)*

c. What are the basic principles to minimise exposure when using sealed radioisotopes? Give examples of the application of these principles in clinical practice and their relative importance. *(4 marks)*

5. The photons used in clinical radiotherapy can interact with matter in one of four important processes – Photoelectric Effect, Compton Scattering, Pair Production and Photonuclear Reaction.

a) Select three (3) of these processes and for each in turn:
   i) Describe the interaction using labelled diagrams. (*4 marks)*
   ii) Comment on factors that influence these interactions. *(4 marks)*

b) Give an example from clinical radiotherapy practice which illustrates one of these interactions. *(2 marks)*

6. Write brief notes and where appropriate include the units for the following:

a. exposure
b. dose
c. equivalent dose
d. activity
e. wedge factors
f. linear stopping power
g. inverse square law
h. dose build-up
i. anisotropy factor
j. field size

(1 mark each)

May 2006

Time allowed: 3 hours
Instructions for Examination:

- There are a total of SIX questions.
- All questions are of equal value
- All questions are to be attempted
- You may use diagrams, tables or lists in your answers.
- Answers should be given from a radiotherapeutic viewpoint.

1. A superficial tumour with visible skin involvement is located just below the eye. On the planning CT, the oncologist marks the GTV and constructs a CTV which is 1.0cm wide, 1.5cm long, 1.0cm deep. The superior border of the CTV lies 0.5cm inferior to the centre of the bony orbital rim.

   d. Explain how you would determine an appropriate PTV. *(2 marks)*

   e. Choose three commonly available radiation treatment modalities and give a brief description of their limitations and potential usefulness in treating this tumour. *(8 marks)*

2. Draw on the same graph, the central axis depth dose curves, measured in water, for:

   a. A 6 MV photon beam, 10 cm x 10 cm at 100 cm FSD,

   b. A 3 mm Cu HVL orthovoltage beam, 10 cm x 10 cm at 50 cm FSD. *(4 marks)*

   Explain the shape of the 6MV curve with reference to basic interactions of ionising radiation with matter. Explain why the orthovoltage curve differs from the 6MV curve. *(6 marks)*

3. a. Consider an old 6 MV linear accelerator that is to be replaced with a new model accelerator, which produces 6 MV and 18 MV photon beams. Discuss the additional radiation interactions that need to be considered with this upgrade with regard to radiation protection requirements. Include in your answer the modifications which may need to be made to the room bunker. *(8 marks)*

   b. Define absorbed dose and effective dose, providing S.I. units. Discuss the differences between these two terms. *(2 marks)*

4. Percent depth dose data for radiotherapy beams are usually tabulated for square fields, however the majority of treatments encountered in clinical practice require rectangular or irregularly shaped fields.
   a. Describe two simple systems commonly used for equating different field shapes to square fields. *(3 marks)*
   b. Draw a diagram to illustrate the differences in dose distribution between a 10cm x 10cm open field and a half-beam blocked 20cm x 10cm field. *(4 marks)*
   c. How do Monte Carlo calculation methods provide optimal results for the situation described in 4b? *(3 marks)*
5. Write brief notes and where appropriate include the measurement units for the following:
   a. Bolus
   b. Isocentre
   c. Bremsstrahlung
   d. Linear energy transfer
   e. Attenuation
   f. Anthropomorphic phantom
   g. Effective energy
   h. Mass energy absorption coefficient
   i. Inverse planning
   j. Reference Air KERMA rate *(1 mark each)*
6. *In vivo* dosimetry is commonly requested for out of field eye lens dosimetry, where the eye is outside but close to the radiation field.
   b) Identify 2 types of dosimeters commonly used for this application. (*2 marks)*
   c) Describe the physical principles upon which the above dosimeters operate and the advantages and disadvantages of these dosimeters. *(6 marks)*
   c) Comment on the confidence you would have in the measured dose reading from each of the *in vivo* dosimeters you describe. *(2 marks)*

August 2005

1. a. Define the <u>volumes</u> which the ICRU recommends should be identified when planning and reporting a 3-D conformal radiation treatment.
   b. Discuss the advantages and potential errors associated with the use of CT and MR images to delineate the volumes defined in part (a)
   c. The position of the isocentre and other beam parameters are determined during the planning process. Briefly describe the methods employed by the treatment machine staff to ensure accurate treatment delivery on a daily basis?
2. When a linear accelerator is first installed, rigorous acceptance tests are carried out to ensure that the performance specifications are met. The machine must then be commissioned prior to clinical use.
   a. List and briefly describe the beam data that are required to commission the 6MV beam of a linear accelerator.
   b. The acquisition and verification of isodose charts and central axis depth dose data is integral to the commissioning of a linear accelerator. Describe how the beam data are measured in order to construct these isodose charts. Include in your answer a brief description of the equipment that may be used.
3. a. <u>Briefly</u> discuss the basic physical principles of brachytherapy. What are the advantages and disadvantages of brachytherapy compared with external beam therapy in clinical practice from a radiotherapeutic physics perspective*?*
   b. List the physical characteristics of the ^{192}Ir source utilised in a remote after-loading HDR unit that make it useful as a brachytherapy source.
   c. Briefly describe how the prescribed dose distribution for the treatment of cervical cancer is achieved and delivered by a single HDR source.
   d. Give the ICRU specification system when the HDR afterloading unit is used as a boost treatment for cervical cancer.
4. An elderly woman is admitted to the ward for a therapeutic dose of Iodine-131 following thyroidectomy for a thyroid malignancy. Several hours after ingesting the capsule she feels unwell and alerts the nursing staff via the intercom. On approaching the room the nurse finds the patient on the bed and a pool of vomit on the floor.

a. List the ward procedures in common use to minimise the radiation hazards associated with treating patients with radioactive isotope Iodine-131.
b. Outline an appropriate management plan for the above scenario. Include in your answer a brief discussion of any appropriate monitoring of exposed staff, giving reference to current regulations and ICRP guidelines.
c. Discuss the current radiation protection regulations relating to the discharge of a patient following administration of 4000MBq of Iodine-131. State the authority that has issued the regulations that you have discussed.

5. a. With the aid of a well labelled diagram, compare the dose deposited by an electron beam, a megavoltage photon beam and a proton beam in homogeneous tissue and how the dose changes with depth in tissue.
b. Identify one example of a suitable clinical use for each of the above beams, supporting your example with the physical characteristic you described in part a.
c. For a 6MV, 10 × 10 cm field size, 100 cm FSD photon beam, draw a well labelled diagram to illustrate each of the following:
- the percentage depth dose curve
- the isodose chart
- the profile plots for depths of 10 cm.

6. a. With the aid of diagrams, describe the physical principles of radiation beam production by a linear accelerator, a superficial X-ray machine and a cobalt 60 teletherapy machine.
b. Briefly describe the beam energy spectrum of each of these radiation beams.
c. List 2 clinical situations where application of a linear accelerator-produced photon beam would be substandard in your judgement. Give one reason to support each judgement.

February 2005

1. A chest wall tumour is to be treated with radiation therapy treatment. It extends from midline to post/lateral ribs and from clavicle to lower ribs. Describe each of the following treatment techniques with particular attention to the limitations and possible solutions:
(a) Fixed field electrons
(b) Electron arc
(c) MV photons

2. a. Draw and label a typical isodose curve for a 10cm x 10cm, 6MV photon beam incident perpendicularly to the surface of a water phantom at 100cm SSD. Discuss the clinically important features of this curve.
b. Discuss the importance of density/heterogeneity correction for CT planning in calculating the dose deposition for potentially curative treatment of lung cancer.

3. Discuss the radiotherapeutic gains and losses following the deployment of new technology for:
a. Wedging: fixed v dynamic
b. Field shape: blocks v multileaf collimator
c. Port imaging: films v electronic images

4. Modern linear accelerators employ a record and verify (R&V) system.
a. Briefly give the justification for a R&V system.
b. Describe the essential and optional features of a R&V system.
c. Discuss the ways that a modern R&V system can improve efficiency and safety in patient treatment.
d. Discuss the new errors introduced, and errors not diminished by a modern R&V system.

5. a. List the characteristics which make a material suitable for use as a phantom. Provide examples of materials commonly used in clinical practice.
b. With the aid of a diagram, outline the design principles and characteristics of a practical thimble ionisation chamber used with MV photon beams.
c. Briefly describe the procedure for absolute calibration of a clinical 6MV photon beam. Identify how the dose per monitor unit is determined for the reference conditions described. Include in your answer a description of equipment and diagram of setup.

6. Mrs Brown is being treated with High Dose Rate (HDR) brachytherapy Ir192 implant to the cervix, using an automatic afterloading technique. On completion of the treatment episode the independent radiation monitor is reporting higher than expected radiation activity in the room, although the HDR console reports that the radioactive source has been retracted.

Consider the three following scenarios:
Scenario 1 – The active source pellet is lodged within the applicator inside the patient.
Scenario 2 – The active source pellet is stuck in the transfer tube between the patient and the HDR unit.
Scenario 3 – The active source pellet escaped the tube, through a crack and is lying on the floor.
For each of the three scenarios:

a. List the resources you expect to have available (personnel and equipment) to deal with this situation.
b. What needs to be done immediately, in the short term and in the long term?
c. Who needs to perform each of these action items?

August 2004

1. You need to select an appropriate external beam to treat a thin but 3 cm wide BCC lying over the bridge of the patient's nose. Thoroughly discuss the radiotherapeutic PHYSICS issues involved in selecting the appropriate beam.
2. With reference to the Radiotherapy Photon Beam Penumbra
   - Define the term
   - Describe and discuss 3 types of penumbra, drawing on your knowledge of various photon beams, beam shielding and modifying devices and their clinical use
   - Discuss the clinical advantages and disadvantages of both large and small beam penumbra.
3. In the radical treatment of a tumour situated in the clivus (base of skull), consider the radiotherapy treatment modalities [teletherapy and brachytherapy] typically available in a modern radiotherapy department.
   Discuss the modalities you would use and those you would reject.
   Use your knowledge of the PHYSICS of each modality to justify your answer, for this particular application.
4. For the reporting of 3D conformal radiotherapy treatments, provide a detailed definition of the 6 volumes that need to be described.
   Discuss Internal Margins and Setup Margins, with particular reference to methods for reducing each margin and how these margins are used in creating the Planning Target Volume.
5. Answer ONE of the following:

A In working safely with ionising radiation

- Which factors [protection practices and physical entities] do you have at your discretion to directly minimise your dose
- Briefly identify the philosophical principles underlying the use of ionising radiation for medical practice
- Draw a plan of a typical bunker housing a >10MV linac. Give a short description of each barrier, its purpose, placement and suitable constituent material

<u>OR</u>

B This morning a radiation oncology registrar entered a >10MV linac bunker searching for a lost pager, while a patient was being set up.

Just as the pager is spotted on the floor in the far corner of the bunker, the registrar notices that they are alone in the room with the patient, the linac is producing a different sound and assumes that the beam has been turned on. The registrar yells, races out of the room challenging the radiation therapists at the console, who turned the beam on. Meanwhile the patient rolled off the treatment couch in shock.

Using your knowledge of good radiation protection practices, with reference to your local hospital protocols and procedures and the legislation in your region:

- identify the poor features of this scenario
- list the events, following this incident, in the order they should have occurred, justifying the reason for each event, quoting relevant values, markers or indicators
- discuss how this incident could have been avoided what should be done to prevent this situation re-occurring?

6. Answer ONE of the following:

A Not all radionuclides are acceptable for therapeutic use. Select three radionuclides that have essentially disappeared from clinical use. Use the radionuclides' physical features to describe why this has happened, thereby identifying characteristics which should be avoided in future novel clinical radionuclides.

OR

B Radioisotopes of Iodine are used as sealed and unsealed sources.
   a. List the specific physical features common to ALL radionuclides.
   b. Describe the radiation physics features specific to radioactive iodine, used for therapeutic purposes
   c. Provide an assessment of the advantages and disadvantages of radioactive iodine in its various clinical roles

February 2004

1. Discuss the specific physical features of a radionuclide which would make it suitable for use in patient treatment.
   Discuss separately the principles and requirements for using:
   a) Sealed and
   b) Unsealed radioactive substances.
2. A number of separate physical concepts and associated physical quantities are used in radiotherapy.
   Give at least ten examples of such concepts and their measures.
   Why are all of these necessary in day to day clinical practice?
3. (a) Sketch central axis depth dose (in water) curves for:
      (i) a 6 MV and an 18 MV photon beam, both 10 cm x 10 cm at 100 cm SSD, on the one graph
      (ii) a 5 cm x 5 cm and a 10 cm x 10 cm orthovoltage beam, both of 3 mm Cu HVL, 50 cm SSD, on the one graph
      (iii) a 6 MeV and an 18 MeV electron beam , both 10 cm x 10 cm at 100 cm SSD, on the one graph.
   Show percentage and depth scales with numerical values on each of the three graphs.
   (b) Explain the important features of the curves drawn, and comment on the clinical significance of these features.
4. (a) Discuss the use of wedge filters and compensating filters in megavoltage photon beam radiotherapy, indicating the physical principles involved in their design and application.
   (b) How can independent jaws and multileaf collimators be used to produce wedging and compensation? What are the advantages and disadvantages of using these instead of physical wedges and compensators?
5. Irregularly shaped X-ray treatment fields can be achieved using either multileaf collimators or customised shielding blocks.
   Comment on the advantages and disadvantages of each technique for:
   (a) achieving the required field shape
   (b) penumbra
   (c) dose to tissues under the shielding
   (d) treatment planning
   (e) treatment delivery.
6. Write short notes on
   (a) the physical aspects of prostatic implants using radioactive seeds
   (b) the radiation protection requirements relating to the discharge of patients undergoing treatment with radioactive substances including iodine-131, samarium-153 and strontium-89.
   Note: For Australian candidates attempting Q 6(b), either the old or the new (Sept 2002) recommendations will be acceptable.

July 2003

1. Discuss the ward procedures that should be adopted to minimise the radiation hazards associated with patients being treated with:
   (a) Sealed and
   (b) Unsealed radioactive substances.
2. Define the term “Brachytherapy” and discuss the various forms this type of treatment may take. Describe the properties of the various nuclides used in each form of brachytherapy and indicate why they are chosen for that particular mode of therapy.
3. For an orthovoltage treatment unit:
   (a) Briefly describe, with the aid of a diagram, its construction and principles of operation.
   (b) How is the quality of the beam specified and measured?
   (c) Discuss the means by which different quality beams can be obtained, and the criteria used to select the most appropriate beam for a particular clinical application.
   (d) State the range of beam qualities typically provided.
4. (a) Define percentage depth dose, tissue-air ratio, scatter-air ratio and tissue-phantom ratio.
   (b) For each of these parameters, indicate a situation in which its use is particularly appropriate.
   (c) Describe and briefly explain the way in which these parameters vary with field size and SSD.
5. Write short notes on
   (a) In vivo dosimetry.
   (b) Factors influencing surface dose in electron beam therapy.
   (c) Monte Carlo method.
6. Discuss prevention of accidents to patients undergoing radiotherapy.

February 2003

1. Describe and discuss the various processes which may occur when a beam of ionizing radiation interacts with biological matter of varying density. Distinguish between electron and X-ray beam interactions.
2. Discuss natural and artificial radioactivity. Describe the common decay processes. Define and discuss physical, biological and effective half-lives and the relationships between them. Give an example of these relationships for a radionuclide that is commonly used in radiotherapy.
3. Discuss the principles, implementation, applicability, advantages and disadvantages of the following techniques in megavoltage photon beam radiotherapy:
   (a) multiple static fields
   (b) rotation therapy
   (c) conformal (conformation) therapy.
4. Explain how and why the dose distribution produced within a patient by an X-ray beam is modified by the presence of
   (a) lung and
   (b) bone within the beam for beams of various energies. Include consideration of doses to the lung and bone constituents themselves.
5. Discuss the quality assurance measures necessary in
   (a) the planning and treatment delivery of stereotactic radiosurgery for intracranial lesions
   (b) pulse dose rate brachytherapy for cervical carcinoma.
6. (a) Define the following terms as used by the ICRU:
      i) Clinical Target Volume
      ii) Internal Margin
      iii) Set-up Margin
      iv) Planning Target Volume (PTV)
      v) Conformity Index
      vi) Internal Target Volume.
   (b) Define the penumbra of the beam. Is the penumbra considered in delineating the PTV?
   (c) Give typical values used for Set-up Margin and Internal Margin in curative conformal external beam radiotherapy of
      i) carcinoma of the prostate
      ii) carcinoma of the lung apex abutting the spinal canal.

August 2002

1. Discuss the various radiation measuring devices used in a Radiotherapy Department and their application in beam monitoring, dosimetry and Quality assurance.
2. Discuss the physical principles, design details and operational features of a modern therapy simulator. Discuss the relative roles of this equipment versus or in conjunction with the use of CT in treatment planning.
3. (a) Briefly outline the principles of the procedure for the absolute calibration of megavoltage photon and electron beams (i.e. the determination of the dose per monitor unit under reference conditions) in a radiotherapy department.
   (b) Comment on the choice of phantom material and type of radiation detector used for these calibrations.
   (c) What factors need to be taken into account in the calculation of the number of monitor units required to deliver a particular dose from a given megavoltage beam to a particular point on the axis of that beam within a patient?
   (d) How does the linear accelerator control the number of monitor units which it delivers in an irradiation?
4. (a) Discuss briefly the basic principles of brachytherapy and its advantages and disadvantages relative to external beam therapy.
   (b) Describe the sources, the method of positioning them within the tissues, and the equipment typically employed in performing prostate brachytherapy at:
      (i) high dose rate and
      (ii) low dose rate.
   (c) Comment on the choice of radionuclide for these sources.
5. Discuss methods and techniques used in avoidance and detection of dose delivery errors in external beam radiation therapy.
6. Discuss the physical advantages and disadvantages of the following treatment methods in the treatment of an unresectable parotid carcinoma invading the zygoma
   (i) static wedged pair photon beams (6MV)
   (ii) electron beam
   (iii) intensity modulated radiation therapy using 6MV photons.

February 2002

1. For the following unsealed radionuclide sources: Iodine-131, Phosphorus-32, Yttrium-90, Strontium-89, Samarium-153, give the spectra of radiation emitted, half-life, physical form in which they are used and their advantages in clinical application.
2. Discuss the various radiation measuring devices used in a Radiotherapy Department. Describe their use in beam monitoring, dosimetry and in quality assurance.
3. a) What is meant by the isocentric mounting of a linear accelerator?
   b) Explain the distinction between SSD and isocentric techniques, and discuss their relative merits.
   c) Discuss the criteria for treatment with a single photon beam, including choice of beam energy or quality.
   d) What are the advantages and disadvantages of treatment with a pair of parallel opposed fields (equally weighted coaxial beams)?
   e) How does the dose distribution of a pair of parallel opposed megavoltage fields depend on patient thickness and beam energy?
4. a) Discus the use of wedge filters and compensating filters in megavoltage photon beam radiotherapy, indicating the physical principles involved in their design and application.
   b) How can independent jaws and multileaf collimators be used to produce wedging and compensation, and what are the advantages and disadvantages of using these instead of physical wedges and compensators.
5. Write short notes on the Quality assurance measures necessary in the planning and treatment delivery of stereotactic radiosurgery using multiple arcs for intracranial lesions.

6. Write short notes on:-
   a) Potential errors and uncertainties which may arise in the incorporation of CT and MRI images into radiation therapy planning systems. How might these errors and uncertainties be minimised or avoided?
   b) ICRP dose limits for occupational and public exposure.

August 2001

1. Describe how the high speed stream of electrons generated in the wave guide of a linear accelerator may be used, manipulated and controlled in order to produce beams of: a) photons and b) electrons for clinical use. Describe how the doses in these two types of beam may be monitored and give the field sizes, the range of energies and various beam parameters attainable.
2. There are in excess of 1300 different radioactive species. Outline the special features of radionuclides that result in only a few of these being suitable for use in radiotherapy? Indicate appropriate clinical applications for these radionuclides.
3. a) Discuss the various quantities used to specify the ‘strength’ of a brachytherapy source. Give the units in each case.
   b) How can the strengths of brachytherapy sources be verified and why is it important to do this? Include in your answer an outline of the principles of operation of the measuring system used.
   c) What are the typical strengths of LDR, PDR and HDR sources? d) What are the origins of the dose outside the geometrical edge of a megavoltage x-ray beam, and how does this dose vary with field size and distance from the edge? e) What can be done to further reduce this dose, eg in case of a pregnant patient where the foetus is some distance from the irradiated region?
4. a) Describe the changes that take place in the energy spectrum, intensity and angular (spatial) distribution of the photons produced, as the energy of the electrons bombarding a metal target increases through the kilovoltage and megavoltage range.
   b) How do aspects of photon production affect the design of treatment units producing photon beams?
   c) Discuss filtration of kilovoltage beams.
5. Discuss the physical aspects of total body irradiation.
6. Discuss the types of remote afterloading equipment available for use in interstitial, intravascular and intracavitary brachytherapy. Outline the physical principles of their operation and discuss the relative advantages and disadvantages of each. Include reference to the radiation protection issues in their usage.

February 2001

1. Describe how the high speed stream of electrons which have been generated in the wave guide of a linear accelerator may then be used, manipulated and controlled in order to produce beams of: a) photons and b) electrons for clinical use.
2. Discuss the physical principles of the use of unsealed radionuclides in radiation oncology. Describe the concepts of uptake, distribution and elimination. Indicate the activities used in clinical practice and how the dose to target tissues and to critical organs is estimated.
3. a) Define percentage depth dose, tissue-air ratio, scatter-air ratio, tissue- phantom ratio and off-axis ratio.
   b) For the first four of these parameters, indicate a situation in which its use is particularly appropriate, and explain why.
   c) How and why does the off-axis ratio vary with depth?
   d) Describe and briefly explain the way in which percentage depth dose varies with beam energy, field size and SSD, for photon beams.
   e) Approximately what percentage depth dose would occur in water at 10 cm depth, 100 cm SSD, for a 10 cm x 10 cm 6 MV x-ray beam?
4. Discuss:-
   a) Phantoms and their use and limitations in radiotherapy.
   b) Half value layer and its measurement.
   c) The dose distribution which results from a central spinal cord shielding block in a 6 MV beam

5. a) Write short notes on the physical principles and clinical uses (including advantages and disadvantages) of in-vivo patient dosimetry.
   b) Compare the use of multileaf collimators to fixed shielding blocks for shielding critical normal tissues.
6 Define the following ICRU terms and explain the relationship between them:-
   - ☐ Gross Tumour Volume
   - ☐ Clinical Target Volume
   - ☐ Planning Target Volume
   - ☐ Internal Margin
   - ☐ Internal Target Volume
   - ☐ Set-up Margin
   - ☐ Conformity Index
   - ☐ Planning Organ at Risk Volume
   - ☐ Reference point

   Give an example illustrated with diagrams.

August 2000

1. Discuss the physical principles, design details and operational features of a modern therapy simulator.
2. Discuss the principles of the use of unsealed radionuclides in radiation oncology. Describe the concepts of uptake, distribution and elimination. Indicate the common radionuclides and the activities used in clinical practice and how the dose to target tissues and critical organs is estimated.
3. a) Discuss briefly the importance and practical implementation of a program of periodic quality assurance checks on radiotherapy treatment machines.
   b) List the parameters which should be so checked monthly or more frequently in the case of linear accelerators, and indicate acceptable tolerances for them.
   c) Define those parameters in your list which are properties of the radiation beam, and indicate an appropriate method of checking them.
4. Explain how and why the dose distribution produced within a patient by an x-ray beam is modified by the presence of:-
   (i) lung and
   (ii) bone within the beam, for beams of various energies.
   Include consideration of the doses to the lung and the bone constituents themselves.
5. Compare the physical and dosimetric aspects in the stereotactic radiosurgical and radiotherapy treatment of intracranial lesions using:-
   a) Gamma Knife
   b) linear accelerator
   Include an overview of the equipment and techniques used.
6. Write short notes on:-
   a) factors influencing surface dose with electron beams
   b) variation of electron beam percentage depth dose with changing field size and SSD,
   c) radiation protection considerations in the use of pulsed dose rate brachytherapy.

February 2000

1. Define the term "brachytherapy", and discuss the various forms this type of treatment may take. Describe the properties of the various radionuclides used in each form of brachytherapy and indicate why they are chosen for that particular mode of therapy.
2. Discuss the various radiation measuring devices used in a Radiotherapy Department and their application in beam monitoring, dosimetry and quality assurance.
3. a) Briefly describe the equipment and measurement procedure used to obtain a standard isodose chart for:
      (i) a photon beam and
      (ii) an electron beam from a medical linear accelerator
   b) Sketch such an isodose chart for a 6-MV photon beam producing a 10cm x 10cm field at 100cm SSD, discuss its clinically relevant features, and compare them with the corresponding features of an orthovoltage beam.

4. a) Describe the changes that take place in the energy spectrum, intensity and angular (spatial) distribution of the photons produced, as the energy of the electrons bombarding a metal target increases through the kilovoltage and megavoltage range.
   b) How do these aspects of photon production affect the design of treatment units producing photon beams?
   c) Discuss filtration of kilovoltage beams.
5. a) Discuss the physical and biological half-lives of the unsealed radionuclides Iodine-131, Strontium-89 and Phosphorus-32. Discuss the uptake and elimination of these radionuclides.
   b) How are the safe levels of activity for discharge from hospital after radionuclide administration derived?
6. Discuss the problems posed by and methods of dealing with
   a) Field junctions in craniospinal irradiation.
   b) Spinal cord shielding in head and neck cancer.

   In each case discuss the relative advantages and disadvantages of the dose distributions obtained using either:
   (i) custom made cerrobend blocks
   (ii) multileaf collimators
   (iii) independent jaws

August 1999

1. a) Describe the processes that occur in the absorption of an electron beam as it passes from air into a tissue medium and from tissue into an air cavity.
   b) Give a specific example and show how computer planning may assist in treatment strategy.

2. Discuss the ward procedures that should be adopted to minimise the radiation hazards associated with patients being treated with:
   a) Sealed and
   b) Unsealed radioactive substances.

   Discuss the limitations to the discharge of these patients.
3. a) What is meant by the penumbra of a radiation beam?
   b) Describe the components of the penumbra of a photon beam at a depth in a patient, and the factors which affect these components.
   c) What can done to i) minimise or ii) broaden the penumbra, and in what circumstances might such actions be advantageous?
   d) Describe and explain the initial dose build-up phenomenon that occurs with a megavoltage beam, and discuss its clinical significance.
   e) What factors affect the magnitude of the relative surface dose for a photon beam?
   f) What can be done to i) minimise or ii) increase the relative skin dose from a megavoltage photon beam?
4. a) Discuss the use of wedge filters and compensating filters in megavoltage photon beam radiotherapy, indicating the physical principles involved in their design and application.
   b) How can independent jaws and multileaf collimaters be used to produce similar effects?
5. a) Write short notes on the Quality Assurance measures necessary in the planning and treatment delivery of stereotactic radiosurgery using multiple arcs for intracranial lesions.
   b) Write short notes on the physical aspects of total skin electron beam therapy. Include reference to physical aspects of dose uniformity achievable, treatment technique and quality assurance.
6. Discuss what is meant by stochastic and deterministic effects with regard to the impact of ionising radiation on human beings. Give two examples of each type of effect. Outline the human data sources that have been used by the ICRP to develop the current risks of radiation exposure. What is the likely magnitude of the total detriment from radiation exposure at low doses and dose rates? What does this detriment include?

   What dose limits does the ICRP recommend for occupational and public exposure? How do these limits compare with annual dose from natural background radiation?

February 1999

1. Clearly describe how the high speed stream of electrons which have been generated in the waveguide of a linear accelerator may then be manipulated and controlled in order to produce beams of:
   a) photons and
   b) electrons for clinical use.

   Describe how the doses in these beams may be monitored and give the energy ranges and various beam parameters attainable.
2. Discuss the concepts of and give definitions of the units of kerma, absorbed dose, dose equivalent, effective dose, linear energy transfer, stopping power, integral dose, activity and specific activity.
3. a) Briefly outline the principles of the procedure for the absolute calibration of a megavoltage beam (i.e., the determination of the dose per monitor unit (m.u.) under reference conditions) in a radiotherapy department.
   b) Comment on the choice of phantom material and type of radiation detector used for this calibration.
   c) What factors need to be taken into account in the calculation of the number of m.u. required to deliver a particular dose from a given megavoltage beam to a particular point on the axis of that beam within a patient?
   d) Explain how the number of m.u. which a linear accelerator delivers in an irradiation is controlled.
4. Describe and explain how the dose distribution produced within a patient by an x-ray beam is modified by the presence of (i) bone and (ii) lung within the beam, for beams of various energies. Include consideration of the doses to the bone and to the lung themselves.
5. Write short notes on:
   a) ICRU dose specification for gynaecological brachytherapy.
   b) Usage of the Paris system in interstitial brachytherapy.
6. Write short notes on:
   a) Potential errors and uncertainties which may arise in the incorporation of CT and MRI images into radiation therapy planning systems. How might these errors and uncertainties be minimised or avoided?
   b) ICRP dose limits for occupational and public exposure.