Ollscoil na hÉireann, Gaillimh
National University of Ireland, Galway

GX 918

Semester II Examinations, 2002/2003

Exam Code(s) 4EL4, 4BS2

Exam(s) Fourth Year BS

Module Code(s) 4EL4-AX402-6, 4BS2-AX409

Module(s) EP437: Radiation, Environmental and Medical Physics

Paper No.

Repeat Paper Special Paper

External Examiner(s) Professor E. Kennedy

Internal Examiner(s) Professor P.W.Walton
Dr. M. A. Byrne
Dr. W. van der Putten

Instructions: Answer three questions

Duration 2 hrs

No. of Answer books 1

Requirements:

Handout

MCQ

Statistical Tables

Graph Paper

Log Graph Paper

Other Material

Q.1 Answer <u>three</u> of the following parts (all parts carry equal marks; 3.3 each):

a. Using a diagram describe the operation of a gamma ray sterilization plant.

b. An organ of the body has a mass m kg and contains q.Bq of a beta emitting radioisotope. Derive the equation for the instantaneous dose rate ($Sv.h^{-1}$) to the organ in terms of the usual parameters.

c. Describe the principles of operation of a transaxial emission computerised tomography (ECT) camera as used in nuclear medicine.

d. Discuss the origins and nature of the population exposure to radon gas. Mention methods used in the reduction and remediation of this problem.

Q.2. Answer all parts.

a. In nuclear medicine imaging outline the reasons why gamma rays in the energy range of 100 keV to 300 keV are used. (2 marks)

b. Outline the principles of a technetium-99m generator and include an energy level diagram of the $^{99}Mo/^{99m}Tc$ decay scheme. (3 marks)

c. Using a cross sectional diagram, describe the operation of the detector used in a gamma scintillation camera (Anger camera). (3 marks)

d. Describe the salient features of a pinhole collimator and of a parallel hole collimator. (2 marks)

Q.3. Two types of fluoroscopy systems are in clinical use. One with the X-ray tube under the table (undercouch system) and one with the X-ray tube over the table (overcouch system) (see Figures 1 & 2)

In the undercouch system, the typical focal spot to image intensifier distance is 0.8 meter, whereas it is 2.00 meter for the overcouch system. Patient thickness is 30 cm, whereas other relevant dimensions are indicated in the figures.

a. Assuming that in both systems the image intensifier requires the same entrance dose, which system will result in the lowest patient entrance dose? Please quantify your answer. (2 marks)

b. Which system can be expected to give the highest staff dose? Explain. (2 marks)

c. Assume that a very small clinical detail is located midway in the patient who is 30 cm thick. With a focal spot size of 2 mm, calculate the blur size on the image intensifier for both systems. Assume that the clinical target is much smaller than the focal spot size. (3 marks)

d. With the diameter of the image intensifier equal to 40 cm, in case of either imaging system, specify the optimal resolution (pixel matrix) if we have a digital imaging system. Focal spot size is as in section c. By optimal resolution we mean the size of the pixel matrix which matches best the resolution obtainable with the x-ray systems. (3 marks)

Figure 1

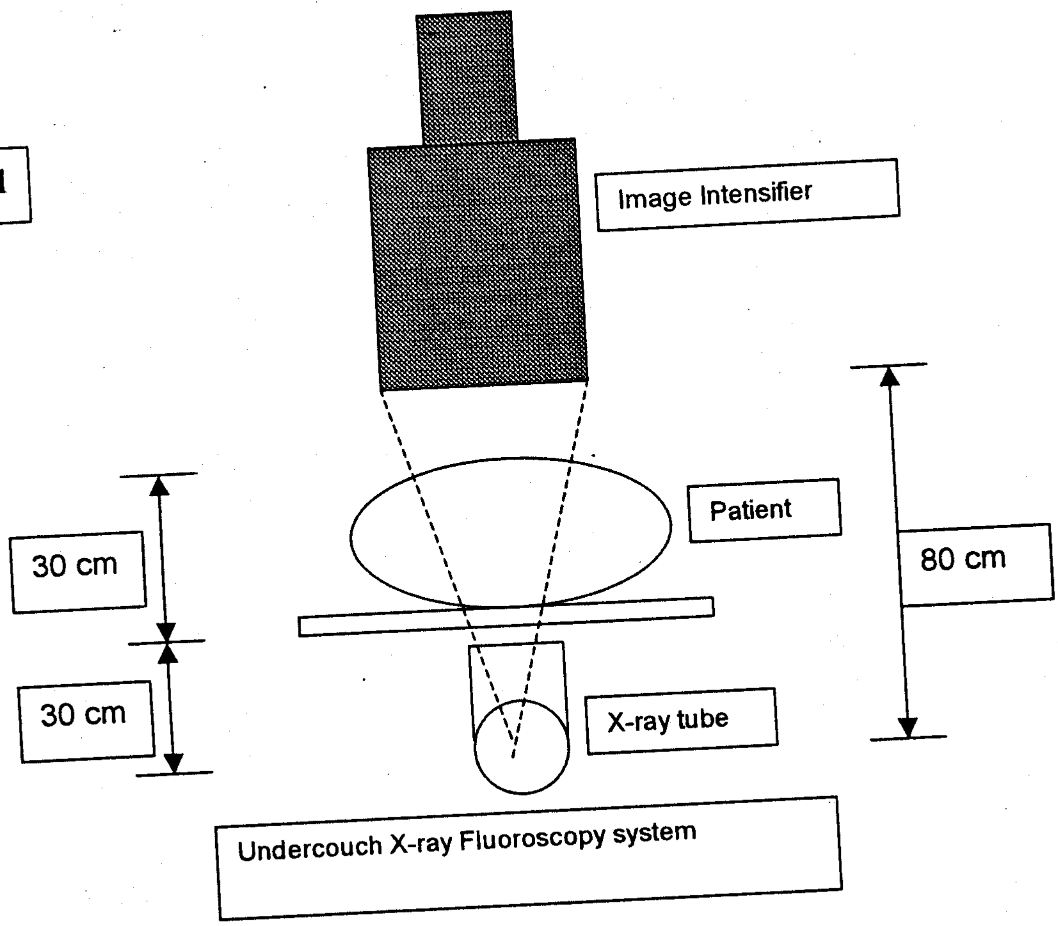
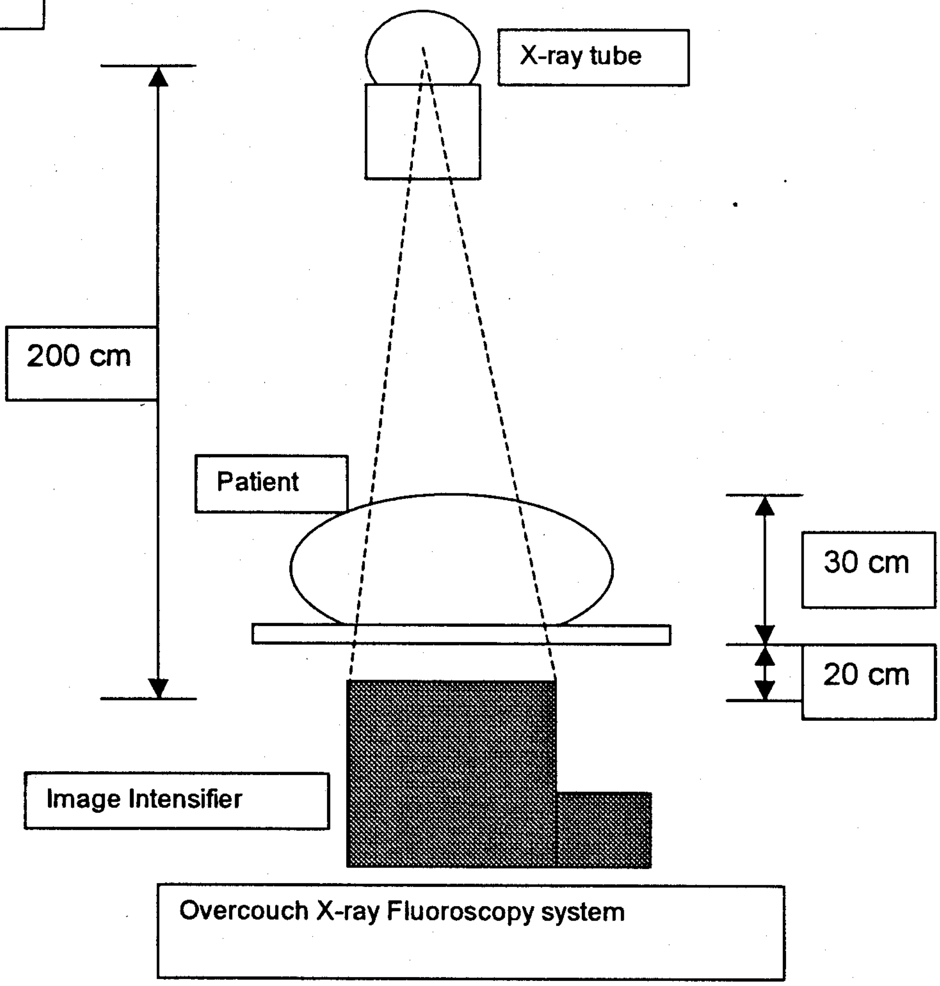


Figure 2


X-ray tube
200 cm
Patient
30 cm
20 cm
Image Intensifier
Overcouch X-ray Fluoroscopy system

Q.4 What are the units of Reynolds Number? What is the largest value of Reynolds Number that is valid when (a) describing laminar fluid flow around an aerosol particle and (b) describing laminar fluid flow through a pipe? (3 marks)

In 1883, the Krakatoa volcano erupted, injecting particles 32 km into the atmosphere. Fallout from the eruption continued for 456 days. If the settling velocity of the particles was constant, what was the minimum particle size present? Assume that the particles had a density of 2.7×10^{3} kg m^{-3} and that the viscosity of air was 1.81×10^{-5} $Nm^{-2}.s$ (4 marks)

Calculate the Cunningham slip correction factor for a 0.15 μm spherical particle (density 2.5×10^3 kg m^{-3}), if its terminal settling velocity is 3.6×10^{-6} ms^{-1}. The viscosity of air is 1.81×10^{-5} $Nm^{-2}.s$ (2 marks)

Explain what is meant by the term *aerodynamic diameter.* (1 mark)

Q.5 Distinguish between the terms *dust* and *fume.* (1 mark)

Calculate the mass median diameter (MMD) of a log-normally distributed aerosol, with a count median diameter (CMD) of 3.5 μm and a geometric standard deviation (GSD) of 2.2 (4 marks)

The aerosol mass concentration in a cement factory, where the air is well-stirred and the ceiling is 3m high, is measured as 30 mg m^{-3}. The aerosol is composed of cement dust particles, with an aerodynamic diameter of 5 μm, suspended in air. If the aerosol mass concentration is measured one hour later, without further addition of aerosol particles, what value will be obtained? Assume that the viscosity of air is 1.81×10^{-5} $Nm^{-2}.s$ (5 marks)