UNIVERSITETET I OSLO

Det matematisk-naturvitenskapelige fakultet

Exam in: **FYS4760 Physics in Medical X-ray Diagnostics**
Day of exam: **10 October 2006**
Exam hours: **13.30 – 16.30**
This examination paper consists of 4 page(s).
Appendices: **2 appendices Note: Must be handed in with answer**
Permitted materials: Approved calculator

Make sure that your copy of this examination paper is complete before answering.

Problem 1: X-ray interaction

a) Describe which interaction processes exists between photons and tissue in general, and which are prevalent for energies relevant to diagnostic radiology.

b) Enclosed you will find equations for the kinematics of the Compton effect. A figure is also prepared to outline the energy of the incoming photon as a function of the energy of the scattered photon. Draw the requirement for Thomson's theory for classical scattering into the figure.

c) Work out and draw into the figure the special case where the scattered photon has the same direction as the incoming photon.

d) Work out which energies scattered photons with angles respectively 45 °, 90 ° and 180° approaches with high incoming photon energies (derive from enclosed equations).

e) Look at the equations and assess correspondingly for low photon energies. Sketch the curves into the figure for the three given angles of scattered photons.

f) What kinetic energy will the Compton electron acquire when a photon with an incoming energy of 10 MeV is scattered to an angle of 90°?

Problem 2: X-ray spectrum

Given an X-ray tube with Tungsten anode and inner filtering equal to 0,5mm Al.

a) Make a sketch of the X-ray tube, and describe the phenomenon bremsstrahlung. Why is the anode worn and why do X-ray suppliers struggle with solutions for cooling of the X-ray tube?

b) With a given tube voltage and tube current over the X-ray tube the bremsstrahlung spectrum looks like the figure in the appendix. How would the spectrum appear if you increase the tube voltage to 120 kV (draw into the figure)?

c) How would the spectrum appear if you halve the tube current?

d) Binding energy for electrons in Tungsten is respectively 69.5 keV in the K-shell, 12.0 keV in the L-shell and 1.8 keV in the M-shell. Explain the phenomenon characteristic radiation and draw into the figure.

e) How will the X-ray spectrum appear if you reduce the tube voltage to 40 kV.

f) You put in place additional filtering of 3mm Al. How will this affect the appearance of the spectrum for 100kV?

Problem 3: Digital detectors

a) Which four types of digital detectors are available on the marked? Explain the main features of how the different detectors work, their construction and function.

b) What do you associate with the acronyms SNR and DOE, and how are these concepts related?

c) What is the advantage of digital detectors compared with traditional film-screen systems with regards to dose and image quality?

d) What does FOV mean? What is the relationship between FOV, matrix size and pixel size? Work out FOV when pixel size is 0.38mm and the matrix is 512x512.

e) Sketch the MTF curves for a low pass and a high pass (mathematical) filter, and explain the difference in resolution in both cases.

f) Which of these types of filters would be used to study small vessels filled with contrast, and which would you use to see soft tissue objects in the liver?

Problem 4: Fluoroscopy

a) Make a sketch of an image intensifier, and explain the manner of operation.
b) How does the automatic exposure control on fluoroscopy systems work? Which exposure parameters are changed, and how is image quality affected by the different changes?

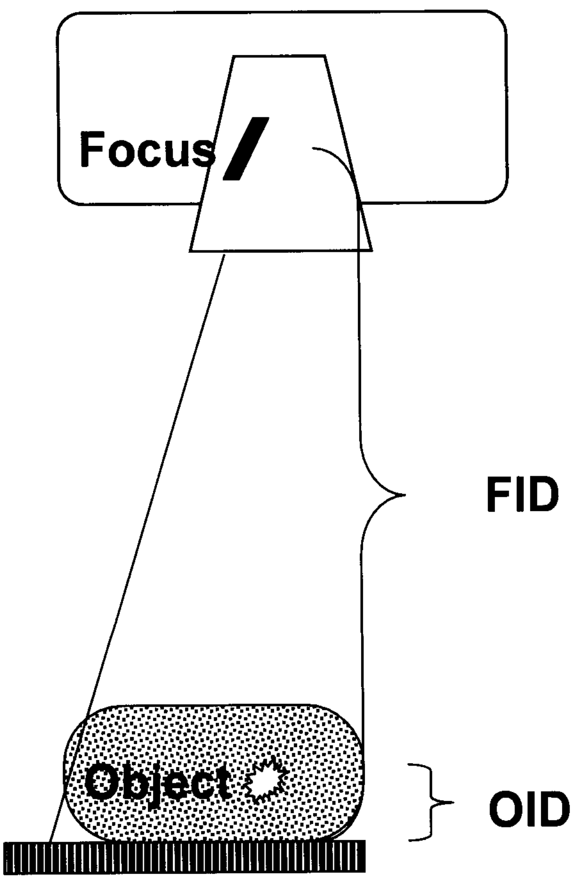
c) What is the cause of geometric distortion for large image intensifiers.

d) What is "frame averaging" and how does this technique affect noise? How large is the noise reduction when four pictures are put (merged) together?

e) What is the principle for DSA?

f) What is meant with the technique "road mapping"?

Problem 5: Unsharpness – Blurring



Three parameters affect geometric blurring.

- Distance between focus and image (registering system), FID
- Distance between the object under study and image, OID
- Focus size, FS

These parameters are related by

$$U_g = \frac{FS \times OID}{FID - OID}$$

a) Assess a mammography system that has a fixed distance between focus and registering system, FID=60cm. The object is located centrally in a breast, 3cm from the image plate, and we use 0,4mm focus (large focus).

What will the geometric blurring be?

b) We find micro calcification centrally in the object and wish to see this better with the aid of magnification technique. We will then make use of a 30cm air gap between the breast and the image plate. Draw the new situation, and work out the geometric blurring in this case.

c) We see from the images that the chalk is seen better because it is enlarged, but it has become blurred and difficult to characterize. How would you improve the visualisation of micro chalk?

Problem 6: Radiation protection

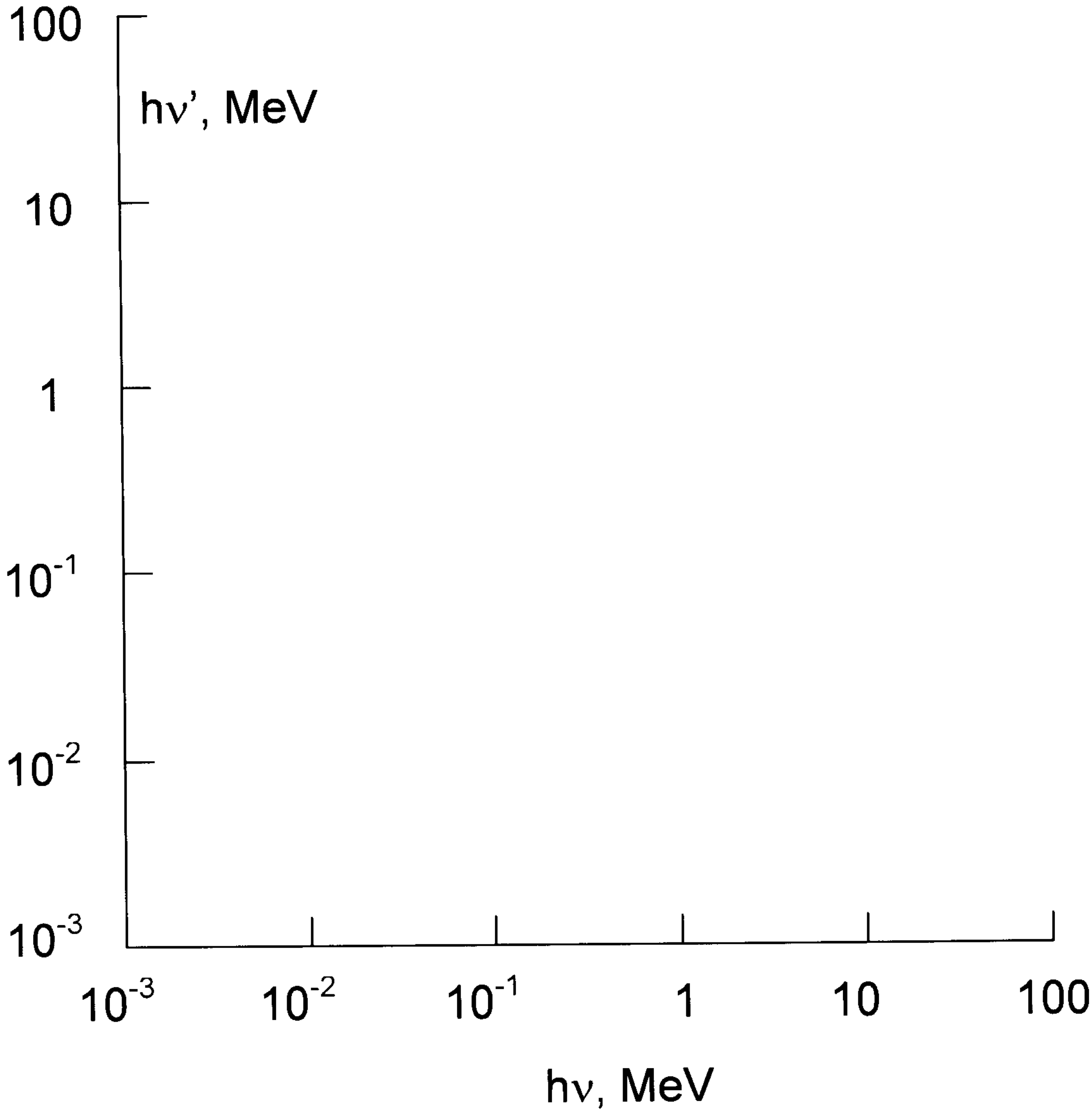
a) Describe in general terms ICRP's three main principles for radiation protection applied to respectively patient and personnel. What does the acronym ALARA stand for?

b) What is the dose limit for member of the public according to the Norwegian Radiation Protection Regulations? This dose limit is also dimensioning for X-ray laboratory shielding. If you are to check if a radiation barrier fulfils the requirement, how would you proceed?

c) Make two sketches of X-ray units with the X-ray tube placed respectively over and under the table (couch), sketch patterns of dispersed radiation around the patient, and explain which geometry gives best radiation protection for respectively personnel and patient.

Appendix 1

FIGURE and appendix to problem 1



Compton equations:

$$h\nu' = \frac{h\nu}{1 + (h\nu / m_0 c^2)(1 - \cos\varphi)}$$

$$T = h\nu - h\nu'$$

$$\cot\theta = \left(1 + \frac{h\nu}{m_0 c^2}\right)\tan\left(\frac{\varphi}{2}\right)$$

FYS4760 Physics in Medical X-ray Diagnostics **Mid semester exam 10.October 2006**

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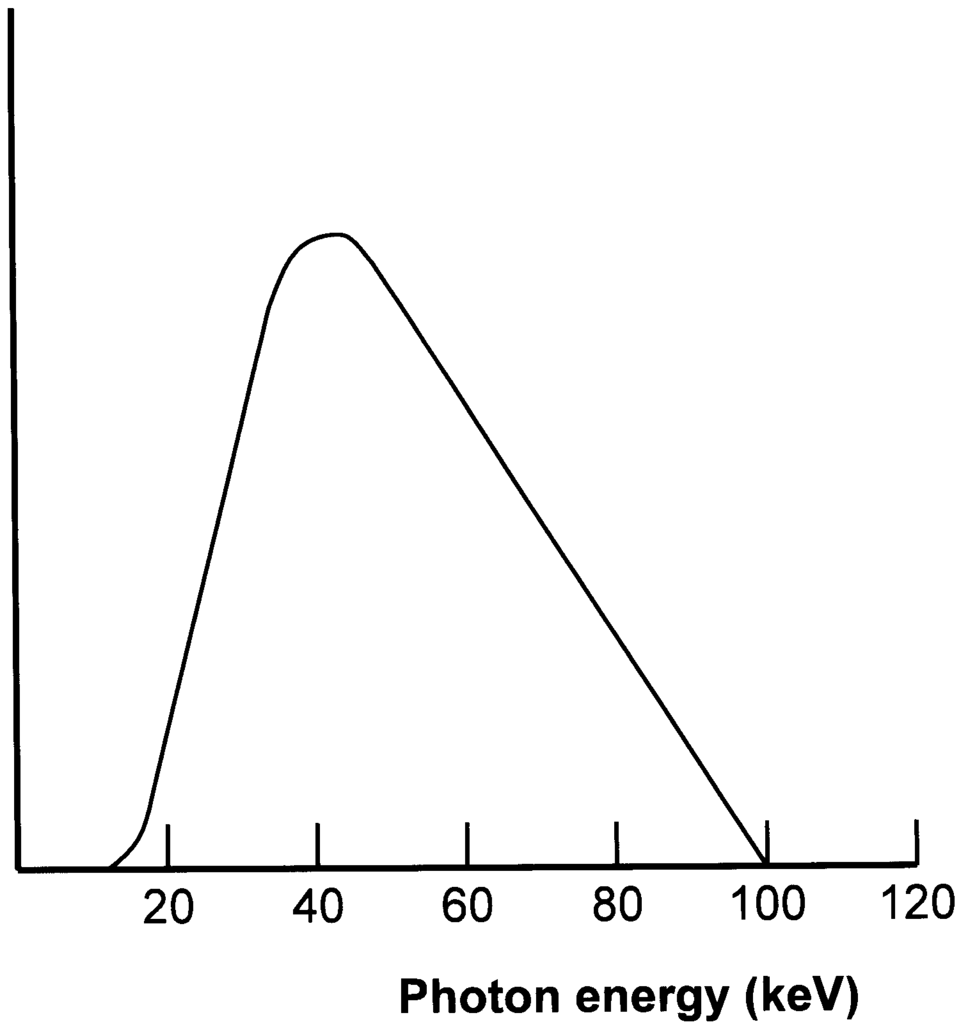
Appendix 2

FIGURE belonging to problem 2



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