# UNIVERSITETET I OSLO

## Det matematisk- naturvitenskapelege fakultet

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| **Exam in:** | **FYS4760 Fysikk i medisinsk røntgendiagnostikk** |
| **Day of exam:** | **Wednesday December 13 2006** |
| **Exam hours:** | **12.00 – 15.00 o'clock** |
| **This examination paper consists of** | **5 (five) pages** |
| **Appendices:** | **3 (three) appendices** |
| **Permitted materials:** | **approved calculator** |

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

*Task 1 – 5 are valued equally and you may obtain totally 10 points for each. Max achievable number of points for each part question are stated in brackets.*

### Task 1: Five questions from syllabus

a) You have taken an X-ray image of the pelvis in AP projection with 70 kV and 40mAs. In the specifications you find the dose yield from the X-ray tube to be 61 μGy/mAs at 1m distance. What is the dose at 70 cm distance? Would you measure the same if the dosimeter was placed in the X-ray entrance field on patient at the same distance ?*(2 points)*

b) How has the ICRP defined the quantity "effective dose"? Explain the philosophy behind effective dose and collective dose. *(2 points)*

c) A 10 cm long ionisation chamber is placed freely in air along the rotational axis of a CT. An axial rotation with total collimation 4x2.5mm at 120kV and 180 mAs (head FOV) is performed. A value of 5.73 mGy is read off the electrometer. Calculate CTDI normalised to the mAs product for given radiation quality and collimation. *(2 points)*

d) Describe the main elements in a Monte Carlo program for simulation of photonic interaction with a slab of water in the energy range of diagnostic radiology. *(2 points)*

e) Describe the principle for thermoluminescence dosimetry (TLD). Which advantages and disadvantages are there for using TLD as a personal dosimeter? *(2 points)*

**Task 2: Quality control – Optimisation (10 questions of 1 point each)**

a) What is constancy control, and why is it important to perform such controls on x-ray equipment?

b) Mention at least 3 test which should be done in connection with status control of exposure equipment.

c) What does the acronym HVL stand for, and what is the minimum recommended value for HVL in conventional X-ray diagnostics?

d) How and why is perpendicularity measured?

e) What is a line raster and which picture quality parameter is evaluated with a line raster? Which measuring results would you expect for respectively mammography and CT?

f) What does the acronym DAP stand for, and what kind of measuring equipment do you associate with DAP?

g) Which relation is it between representative doses and national reference values for diagnostic x-ray examinations, and how are these established?

h) Which three occupational groups in a diagnostic environment should at the minimum be represented in an optimisation process.

i) Describe in short terms what should be incorporated in an optimisation process, what equipment is needed and what considerations you will need to do.

j) What is DQE, SNR and what is the relation between these quantities?

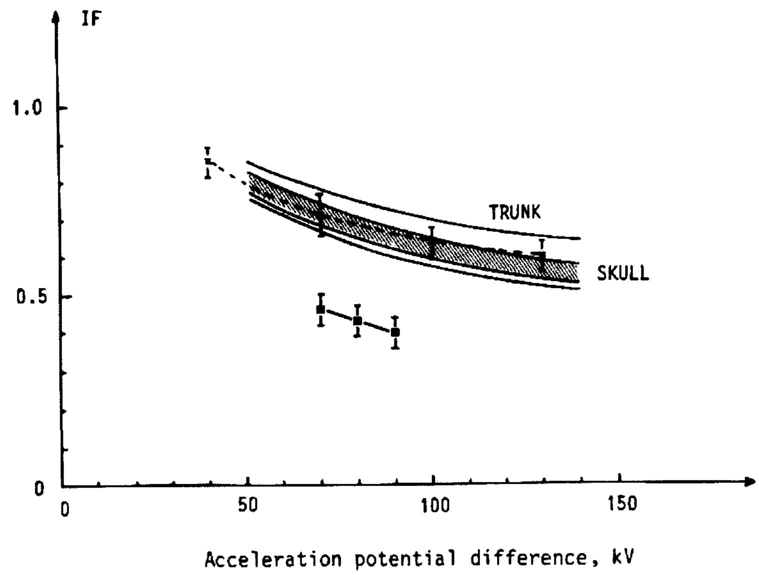
**Task 3: Energy imparted – effective dose**

A patient has had a radiograph taken of the abdomen. The image was taken in anterior – posterior (AP) projection with a tube voltage of 100 kV. Total filtration on the x-ray tube is 3 mm Al. The patient weighs 75 kg, total read dose-area product is 10 Gy·cm$^2$.

a) Derive and explain the equation below by looking at fraction of incoming radiation energy deposited in the patient, so called "imparted fraction" (IF). *(3 points)*

$$\frac{\varepsilon}{\int_A K_{c,air} \cdot dA} = \frac{IF \cdot \overline{\cos\theta}}{\overline{(\mu_{en}/\rho)}_{air}}$$

b) The figure below shows "imparted fraction" (IF) as a function of tube voltage (use solid-drawn line for "trunk" to simulate our abdominal examination.) Assume that the x-ray spectrum has an effective energy which corresponds to a mass-energy absorption coefficient of $\overline{\mu_{en}/\rho}=6{,}83\cdot10^{-2}$ cm$^2$/g. Calculate deposited energy in the patient, and from this the average absorbed dose. *(2 points)*




c) Use the figures in Appendix 1 to calculate effective dose to the patient from measured DAP value. Comment on the difference between calculated average dose to the patient in a) and effective dose. *(2 points)*

d) Imagine the examination took place in the upper abdomen, such that it covers the area from over the pelvis to the lower edge of the lung (thorax), but that the DAP value is the same (10 Gy·cm). How will this affect the values of effective dose? *(3 points)*

**Task 4: CT technique** *(10 questions of 1 point each)*

a) What is a Hounsfield Unit, and what is the definition on CT-number?

b) Given a 64 channel CT with a slice thickness of 0.5mm and table movement of 30mm per rotation, calculate the pitch.

c) Define $CTDI_w$ , $CTDI_{vol}$ and DLP and explain their mutual relation (draw a figure, if you please).

d) Make a sketch of a slice sensitivity profile, and mark FWHM in the figure. Indicate what the nominal slice thickness is. Discuss what can happen to the profile with increasing pitch.

e) What is flying focal spot and why is this used?

f) Mention at least 4 scan parameters that are important for the image quality and the dose to patient, and substantiate how these parameters make an influence.

g) What is the definition of contrast, high contrast resolution and low contrast resolution? Give some examples of high contrast objects and low contrast objects in patient images.

h) What is the relationship between noise and slice thickness in CT?

i) Given a homogenous liver with 50 HU. We need to visualise an object with 5mm extension in the patients longitudinal direction. With 5 mm slice thickness we measure 60 HU over the object. What will we measure if we increase the slice thickness to 10mm?

j) What connection is there between the reconstruction filter and the system's MTF?

**Task 5: CT image quality and dose**

a) A sketch of module CTP515 in the image quality phantom Catphan is provided in Appendix 2. We have made CT recordings of the phantom with different tube currents and rotation times while other scan parameters are kept constant. In ROI placed centrally in the image of CTP515 the following values are read:

| mAs | 100 | 200 | 400 |
|---|---|---|---|
| Mean (HU) | 49,0 | 48,7 | 49,7 |
| Sd (HU) | 9,2 | 6,7 | 4,9 |

When we read mean and sd in ROI, what do they refer to? Use the readings to show the relation between image noise and dose in CT. *(2 points)*

b) In images of CTP515, ROIs are placed in the largest object in each group of "supra slice" objects. The following values are then registered:

| | Supra slice 1.0% | Supra slice 0.5% | Supra slice 0.3% |
|---|---|---|---|
| Mean (HU) | 58,6 | 53,9 | 51,5 |

Use the information to assess correlation between nominal and measured contrast for the objects in the different supra slice groups. *(2 points)*

c) A low dose lung screening protocol shall be developed for a CT lab where a four channel Siemens Volume Zoom is installed. 120 kV 30 mA and 0.8 sec rotation time, 1mm slice thickness and pitch 1.5 will be used. Which table movements are necessary to set? *(2 points)*

d) Impact dose calculator is used to calculate effective dose to the patient, and the glandular tissue dose to female breasts (see print-out in Appendix 3). For this scanner the following values for CT dose index can be looked up ("body" SFOV): CTDI (air)=17,5 mGy/100mAs, CTDI(center)=4,6 mGy/100mAs and CTDI(pherip)=9,7 mGy/100mAs. Show that the values for $CTDI_w$, $CTDI_{vol}$ and DLP will be like in the print-out. *(2 points)*

e) For comparison the glandular tissue dose from a screening mammography will also be around 2 mGy. Discuss how effective dose from mammography still will be much lower than when screening a lung with CT. Discuss shortly the justification for possible lung screening in Norway. *(2 points)*

The figures come from the report NRPB-R262 (Hart, D. Jones, D.G. and Wall, B.F. *Estimation of effective dose in diagnostic radiology from entrance surface dose and dose-area product measurements*. National Radiological Protection Board, NRPB-R262, London: HMSO, 1994).

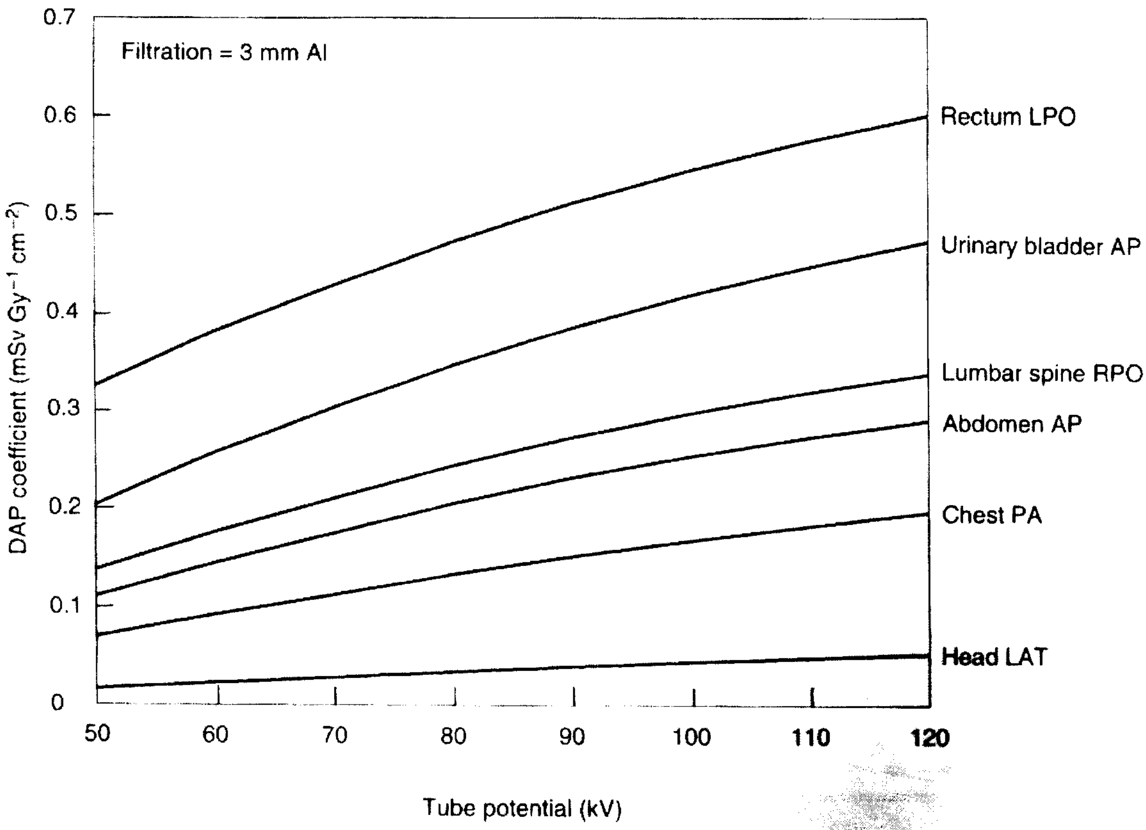
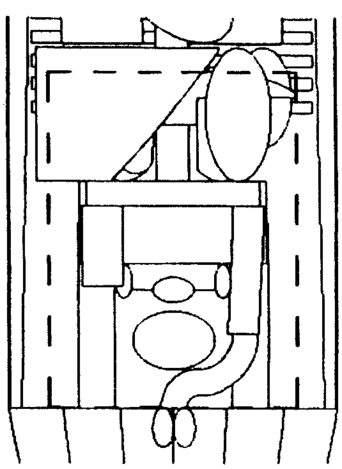


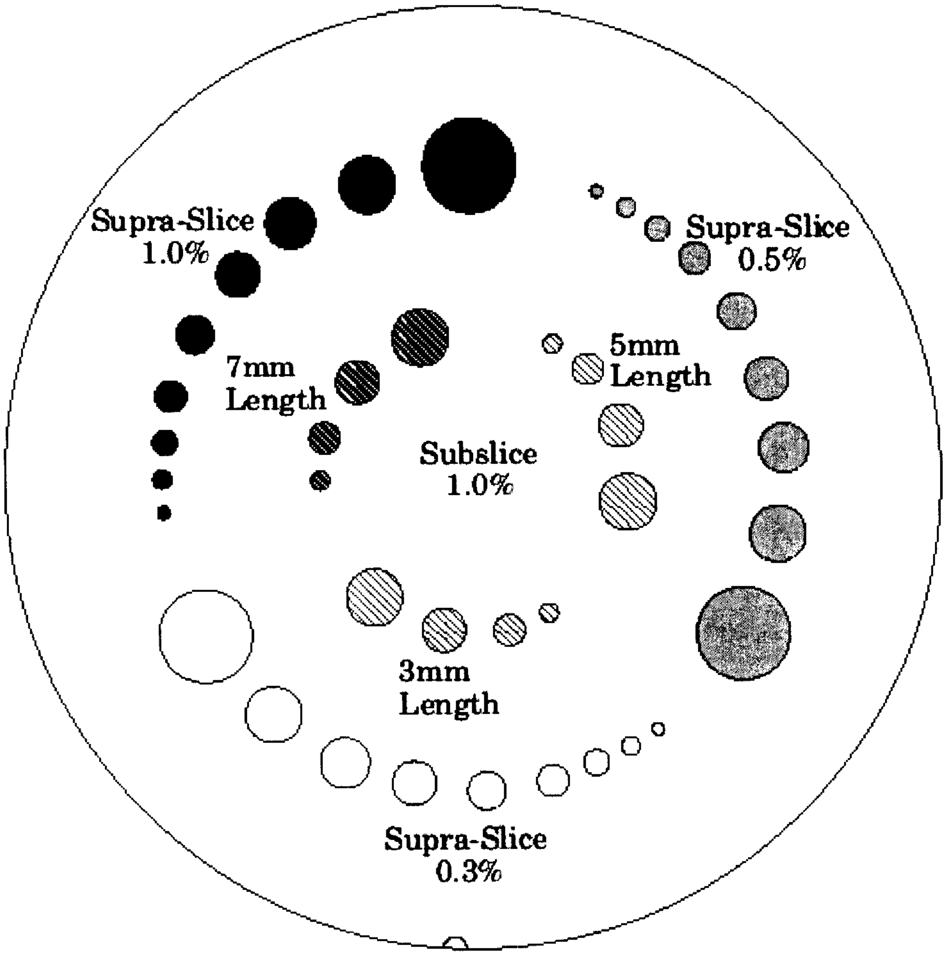

**FIGURE 7 Dose–area product conversion coefficients [illegible] potential**

Figure 7 in NRPB-R262 shows the conversion coefficients between dose-area product and effective dose as function of tube voltage in different body regions.

**Abdomen AP**



Part of Figure 6 in NRPB-R262 shows which entry field is used for the Monte Carlo simulations to obtain conversion coefficients between dose-area product and effective dose.




*Sketch of Catphan CTP515 Low contrast module.*

[redacted]

| Scanner Model: | | | |
|---|---|---|---|
| Manufacturer: | Siemens | | |
| Scanner: | Siemens Volume Zoom, Access | | |
| kV: | 120 | | |
| Scan Region: | Body | | |
| Data Set | [redacted] | Update Data Set | |
| Current Data | [redacted] | | |
| Scan range | | | |
| Start Position | 43 | cm | Get From Phantom Diagram |
| End Position | 68 | cm | |
| Patient Sex: | | | |

| Acquisition Parameters: | | | |
|---|---|---|---|
| mA | | 30 | mA |
| Rotation time | | 0.8 | s |
| mAs / Rotation | | [redacted] | mAs |
| Collimation | | 4 | mm |
| Slice Width | | 1 | mm |
| Pitch | | 1.5 | |
| Rel. CTDI | Look up | 1.23 | at selected collimatic |
| CTDI (air) | Look up | 21.5 | mGy/100mAs |
| CTDI (soft tissue) | | [redacted] | mGy/100mAs |
| $_nCTDI_w$ | | 9.8 | mGy/100mAs |

| Organ | $W_T$ | $H_T$ | $W_T.H_T$ |
|---|---|---|---|
| Gonads | 0.2 | [redacted] | [redacted] |
| Bone Marrow (red) | 0.12 | | |
| Colon | 0.12 | | |
| Lung | 0.12 | | |
| Stomach | 0.12 | | |
| Bladder | 0.05 | | |
| Breast | 0.05 | | |
| Liver | 0.05 | | |
| Oesophagus (Thymus) | 0.05 | | |
| Thyroid | 0.05 | | |
| Skin | 0.01 | | |
| Bone Surface | 0.01 | | |
| Thymus | 0.025 | | |
| Remainder 2 | 0.025 | | |
| Total Effective Dose (mSv) | | | |

| Remainder Organs | $H_T$ |
|---|---|
| Adrenals | [redacted] |
| Brain | |
| Upper Large Intestine | |
| Small Intestine | |
| Kidney | |
| Pancreas | |
| Spleen | |
| Thymus | |
| Uterus | |
| Muscle | |

| | |
|---|---|
| $CTDI_w$ (mGy) | [redacted] |
| $CTDI_{vol}$ (mGy) | |
| DLP (mGy.cm) | |

| Scan Description / Comments | Protokoll for lungescreening |
|---|---|