Equivalent skin dose of the patient - answers

Table
Typical values of the equivalent dose rate (in mSv per mAs) at a distance of 1 meter from the focus of the X-ray tube, for different values of tube voltage and filter thickness.

tube voltage	**thickness aluminum filter**		
	1 mm	**2 mm**	**3 mm**
50 kV	0.07	0.05	0.03
70 kV	0.15	0.09	0.05
90 kV	0.20	0.13	0.08

Excercise 1

a read Table at 70 kV and 2 mm aluminum → 0.09 mSv/mAs at 1 meter
mAs value = 5 mA × 0.15 s = 0.75 mAs
equivalent dose at 1 meter = 0.09 mSv/mAs × 0.75 mAs = 0.068 mSv
equivalent dose at 30 cm = 0.3 m → 0.068 mSv × $(1\text{ m} / 0.3\text{ m})^2$ = 0.76 mSv

b read Table at 50 kV and 2 mm aluminum → 0.05 mSv/mAs at 1 meter
the yield of the X-ray tube is a factor 0.09 / 0.05 = 1.8 smaller than for the previous tube setting
to keep the same density, the mAs value must, therefore, increased by a factor of 1.8
since the tube current remains unchanged, the exposure time must be increased by a factor of 1.8 → 1.8 × 0.15 seconds = 0.27 seconds

Excercise 2

a read Table at 50 kV and 2 mm aluminum → 0.05 mSv/mAs at 1 meter
mAs value = 5 mA × 0.27 s = 1.35 mAs
equivalent dose at 1 meter = 0.05 mSv/mAs × 1.35 mAs = 0.068 mSv
equivalent dose at 30 cm = 0.3 m → 0.068 mSv × $(1\text{ m} / 0.3\text{ m})^2$ = 0.76 mSv

b read Table at 70 kV and 2 mm aluminum → 0.09 mSv/mAs at 1 meter
the yield of the X-ray tube is a factor 0.09 / 0.05 = 1.8 larger than for the previous tube setting
to keep the same density, the mAs value must, therefore, decreased by a factor of 1.8
since the tube current remains unchanged, the exposure time must be decreased by a factor of 1.8 → 0.27 seconds / 1.8 = 0.15 seconds

Effective dose of the patient - answers

The tissue weighting factors for salivary glands and thyroid are:
- $w_{salivary\ glands} = 0.01$
- $w_{thyroid} = 0.04$

Excercise 3

a $H_{salivary\ glands} = H_{skin} = 1$ mSv
contribution of two salivary glands
→ $(2 / 6) \times w_{salivary\ glands} \times H_{salivary\ glands} = (2 / 6) \times 0.01 \times 1$ mSv = 0.0033 mSv
rule of thumb → $H_{scatter} = H_{skin} / 1000 = 1$ mSv / 1000 = 0.001 mSv at 1 meter
distance exposed skin to thyroid is 10 cm = 0.1 m
$H_{thyroid} = H_{scatter} \times (1\ m / 0.1\ m)^2 = 0.001$ mSv × 100 = 0.1 mSv
contribution of the thyroid
→ $w_{thyroid} \times H_{thyroid} = 0.04 \times 0.1$ mSv = 0.004 mSv
effective dose = contribution of the one salivary gland + contribution of the thyroid
= 0.0033 mSv + 0.004 mSv = 0.0073 mSv ≈ 7 μSv

Excercise 4

a $H_{salivary\ glands} = H_{skin} = 2$ mSv
contribution of the one salivary gland
→ $(1 / 6) \times w_{salivary\ glands} \times H_{salivary\ glands} = (1 / 6) \times 0.01 \times 2$ mSv = 0.0033 mSv
rule of thumb → $H_{scatter} = H_{skin} / 1000 = 2$ mSv / 1000 = 0.002 mSv at 1 meter
distance exposed skin to thyroid is 10 cm = 0.1 m
$H_{thyroid} = H_{scatter} \times (1\ m / 0.1\ m)^2 = 0.002$ mSv × 100 = 0.2 mSv
contribution of the thyroid
→ $w_{thyroid} \times H_{thyroid} = 0.04 \times 0.2$ mSv = 0.008 mSv
effective dose = contribution of the one salivary gland + contribution of the thyroid
= 0.0033 mSv + 0.008 mSv = 0.0113 mSv ≈ 11 μSv

Rules of thumb - answers

Rule 1: for the scattering factor

At a distace of 1 meter and for an irradiated area of 10 cm by 10 cm, the dose is about 1/1000th of the entrance dose at the irradiated object.

Rule 2: for scatter radiation due to intra-oral photos

The dose due to scatter radiation at 1 meter from the patient amounts to 1 µSv per intra-oral photo.

Excercise 5

a irradiated skin area = 4 cm × 5 cm = 20 cm^2
equivalent dose due to scattering according to rule of thumb 1
→ $H_{scatter} = H_{skin} \times 0.001 \times$ skin area / (10 cm × 10 cm)
$= 1\ mSv \times 0.001 \times (20\ cm^2 / 100\ cm^2)$
$= 1\ mSv \times 0.001 \times 0.2 = 0.0002$ mSv per X-ray image at 1 meter

b number of X-ray photos per year is N = 1000
all X-ray images contribute to the scatter radiation
→ $E_{dentist} = N \times H_{scatter} = 1000 \times 0.0002$ mSv = 0.2 mSv per year

Excercise 6

a equivalent dose due to scattering according to rule of thumb 2
→ $H_{scatter} = 1$ µSv = 0.001 mSv per X-ray image at 1 meter

b number of X-ray photos per year is N = 1000
all X-ray images contribute to the scatter radiation
→ $E_{dentist} = N \times H_{scatter} = 1000 \times 0.001$ mSv = 1 mSv per year

Shielding - answers

Excercise 7

a an intra-oral X-ray device in the dental practice is subject to registration
outside of the dental practice a dose constraint of 10 μSv per year applies

b use the rule of thumb for scatter radiation
→ 1 μSv per X-ray image at 1 meter from the patient
all X-ray images contribute to the scatter radiation
equivalent dose for 1000 images = 1000 × 1 μSv = 1000 μSv at 1 meter
equivalent dose at a distance of 3 meters = 1000 μSv × $(1\ m / 3\ m)^2$ = 110 μSv
read Figure 1 at 70 kV and 6 mm glass → T ≈ 0.4
effective annual dose on the street = 110 μSv × 0.4 = 44 μSv
annual limit for device subject to registration = 10 μSv
→ insufficient shielding

Excercise 8

a for visitors and workers in the dental practice, a legal limit of 1 mSv per year applies

b read Table at 70 kV and 2 mm aluminum
→ 0.09 mSv/mAs at 1 meter
only half of the images contribute to the direct beam
equivalent dose for 1000 / 2 = 500 images
→ 500 × 0.09 μSv = 45 mSv at 1 meter
equivalent dose at a distance of 2 meters = 45 mSv × $(1\ m / 2\ m)^2$ = 11 mSv
read Figuur 1 at 70 kV and 12 mm plaster → T ≈ 0.4
effective annual dose in the waiting room = 11 mSv × 0.4 = 4.4 mSv
annual limit = 1 mSv
→ insufficient shielding
(besides that ALARA must be applied)