Lec 6: X-ray tube, attenuation photoelectric effect

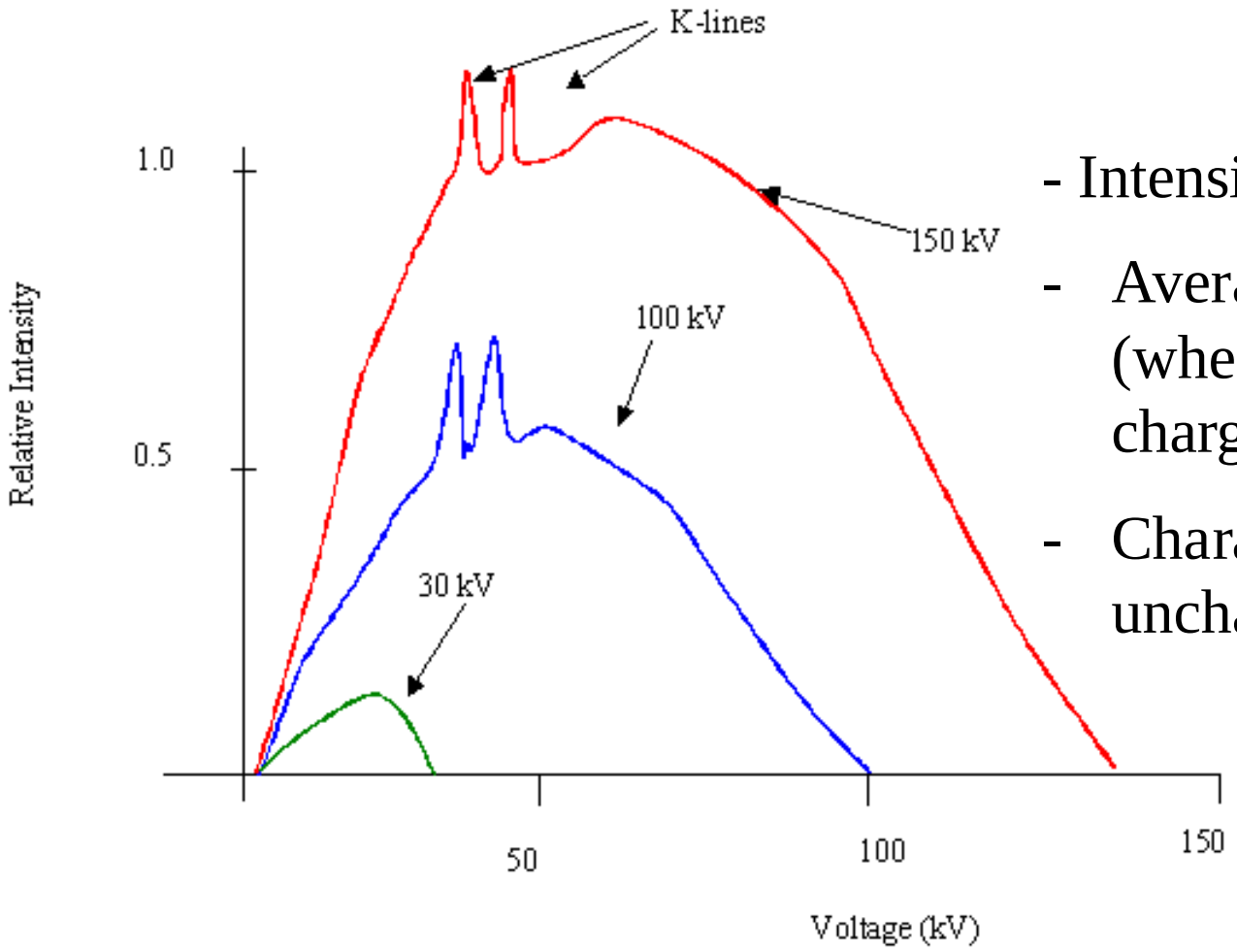
How does the x-ray spectrum change when the tube parameters are changed?

Think about what will happen to

1. Intensity
2. Average energy
3. Characteristic peaks

Increase in tube voltage

Increase in tube voltage



- Intensity goes up.
- Average energy goes up (when we operate in space charge limited region).
- Characteristic lines are unchanged

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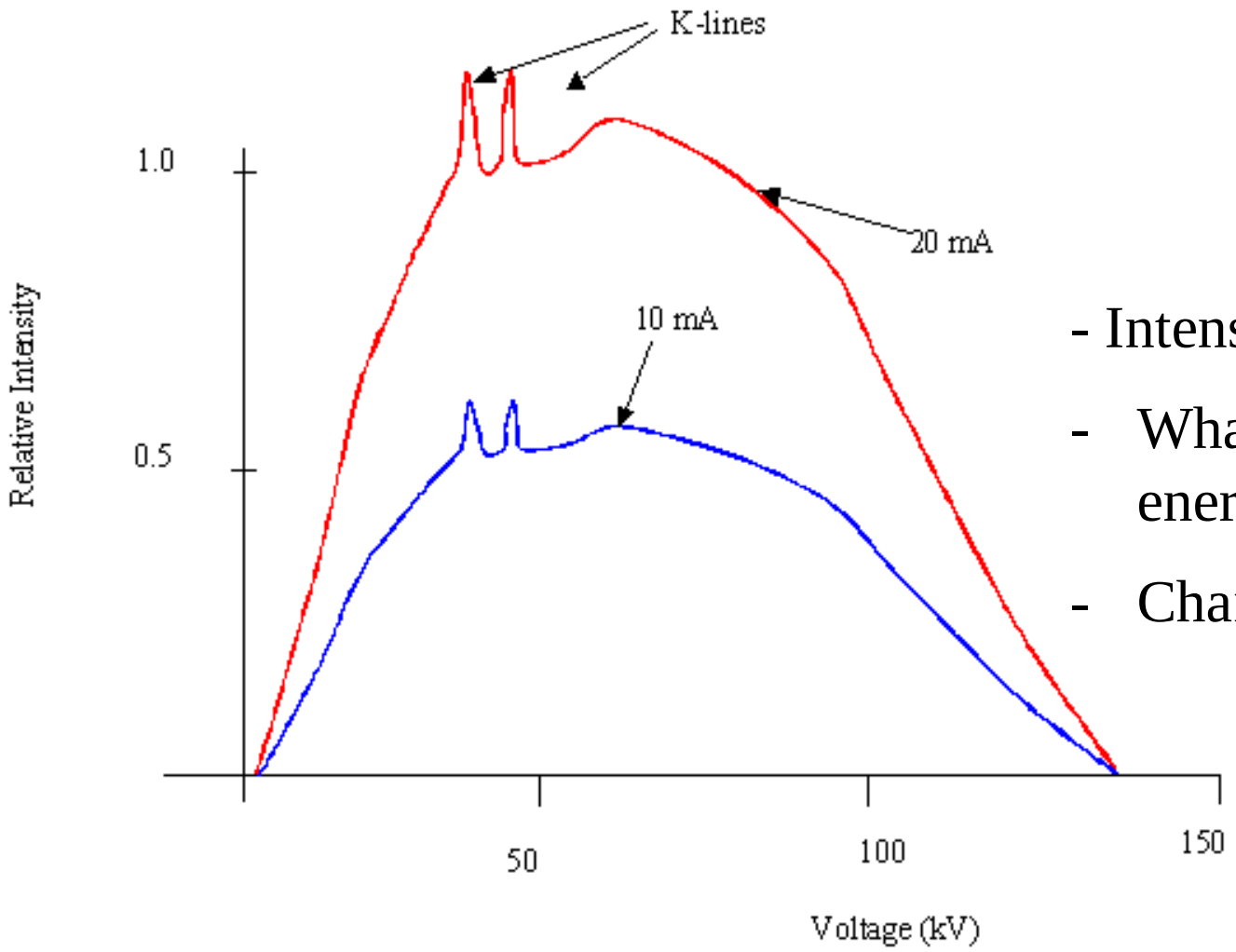
Increase in tube current

Increase in tube current



- Intensity goes up.
- What about average energy?
- Characteristic peaks?

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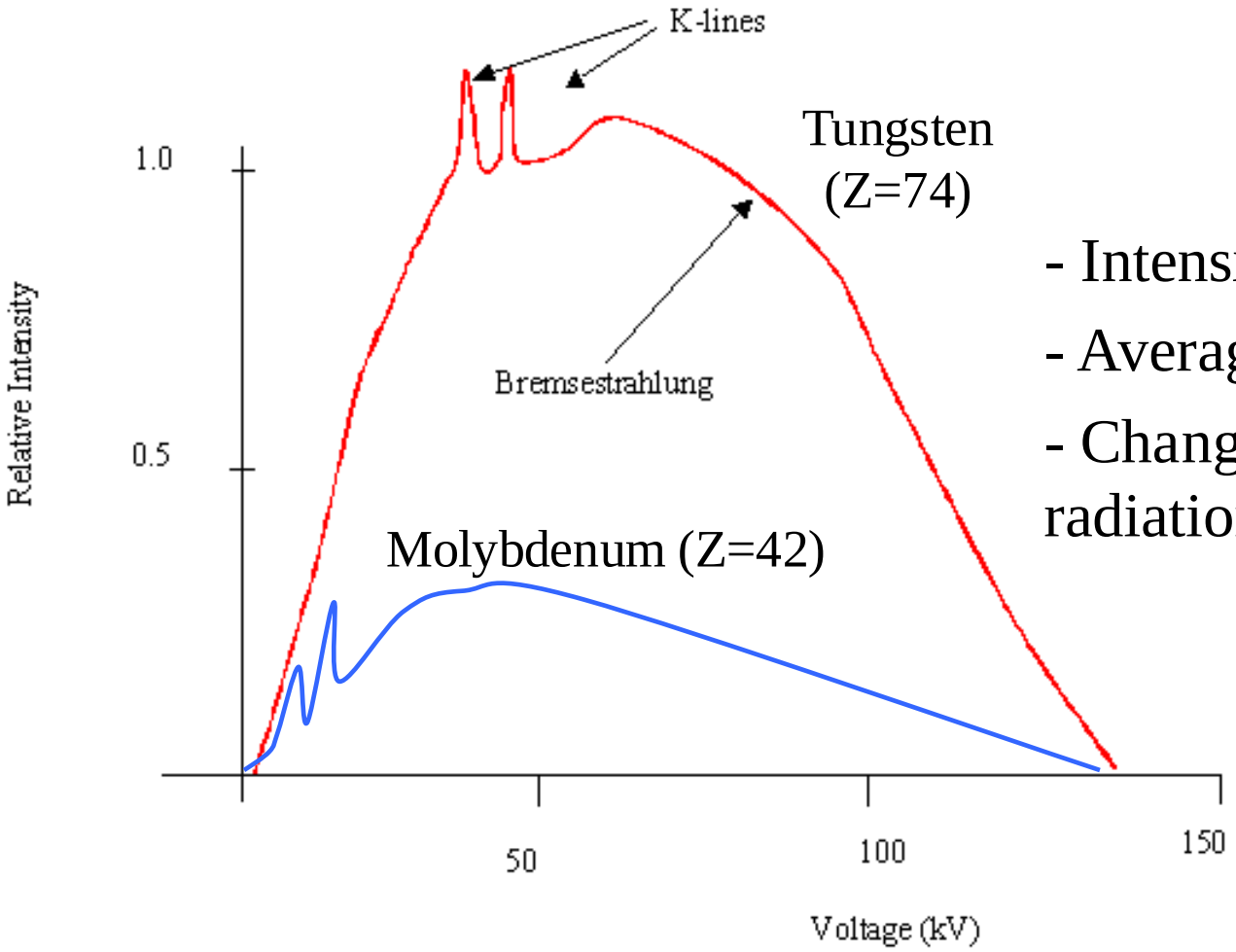
Increase in target (anode) material Z

Increase in target (anode) material Z



- Intensity goes up.
- Average energy goes up.
- Change in characteristic radiation.

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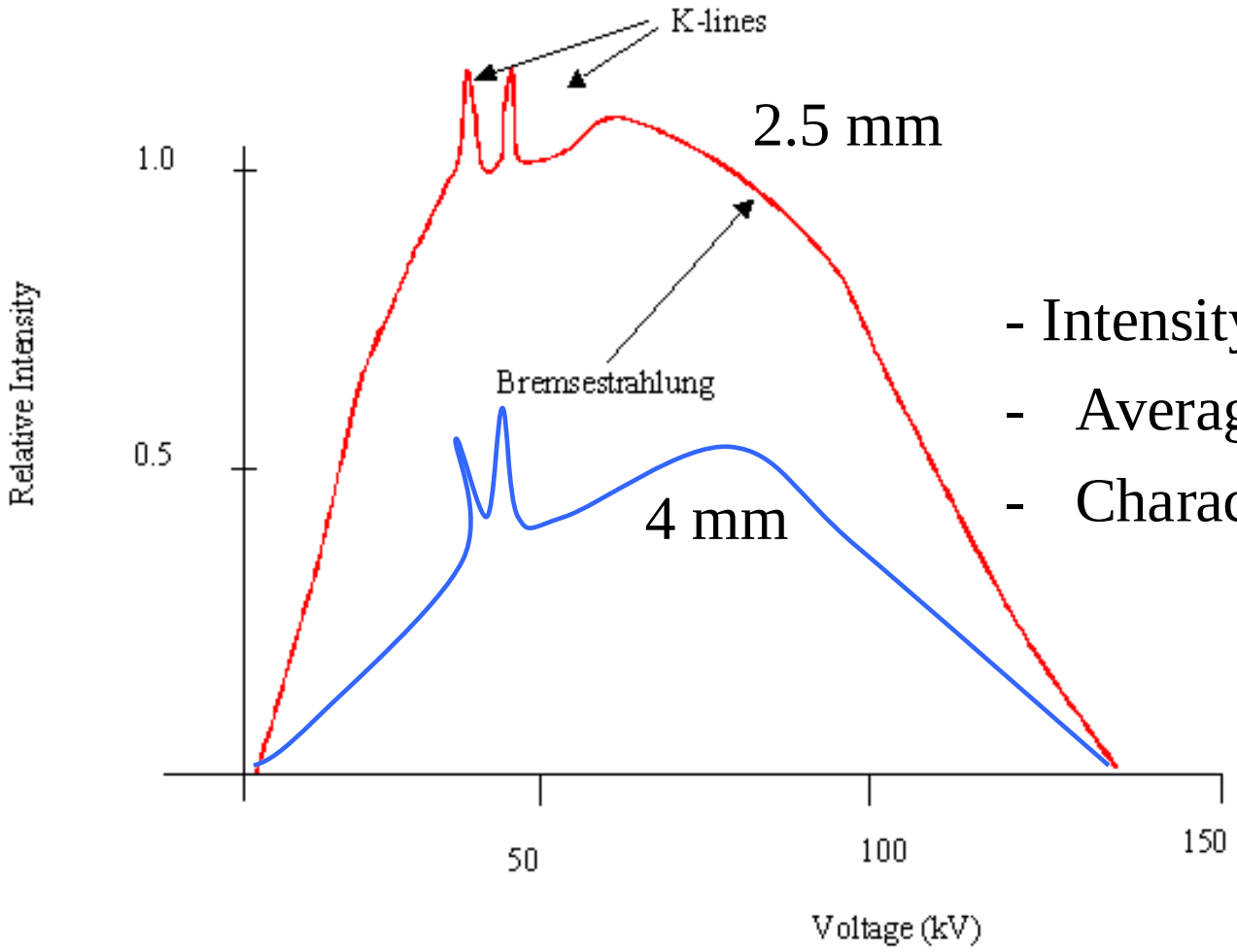
Increase in filter thickness

Increase in filter thickness



- Intensity goes down.
- Average energy goes up.
- Characteristic peaks?

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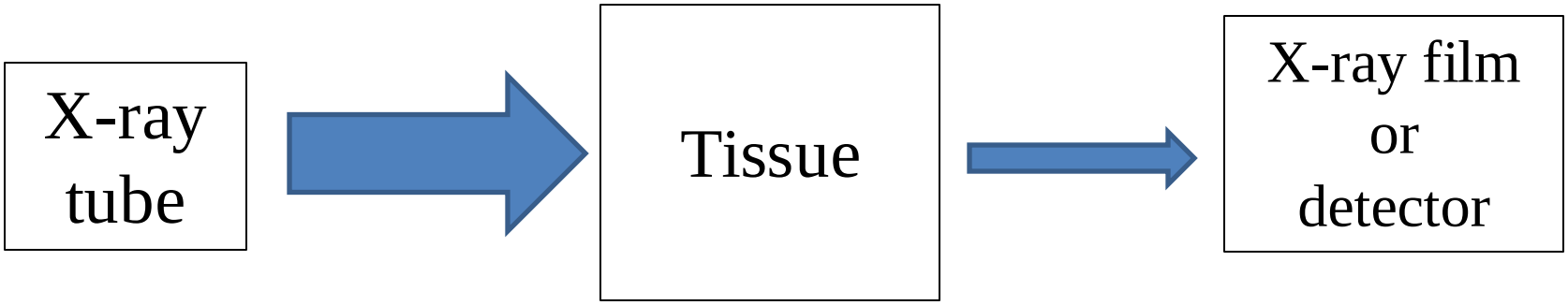
Interaction of X-rays with tissues

Interaction with tissues leads to x-ray attenuation



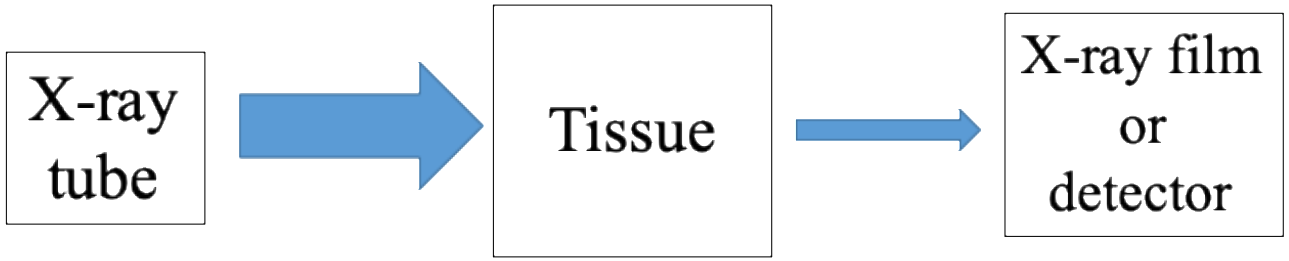
Hendee, chapter 7

Smith and Webb, chapter 2

Attenuation mechanisms: absorption and scattering

Absorption: removal of x-ray photons from the beam

Scattering: change in direction of the photon, usually with reduced energy



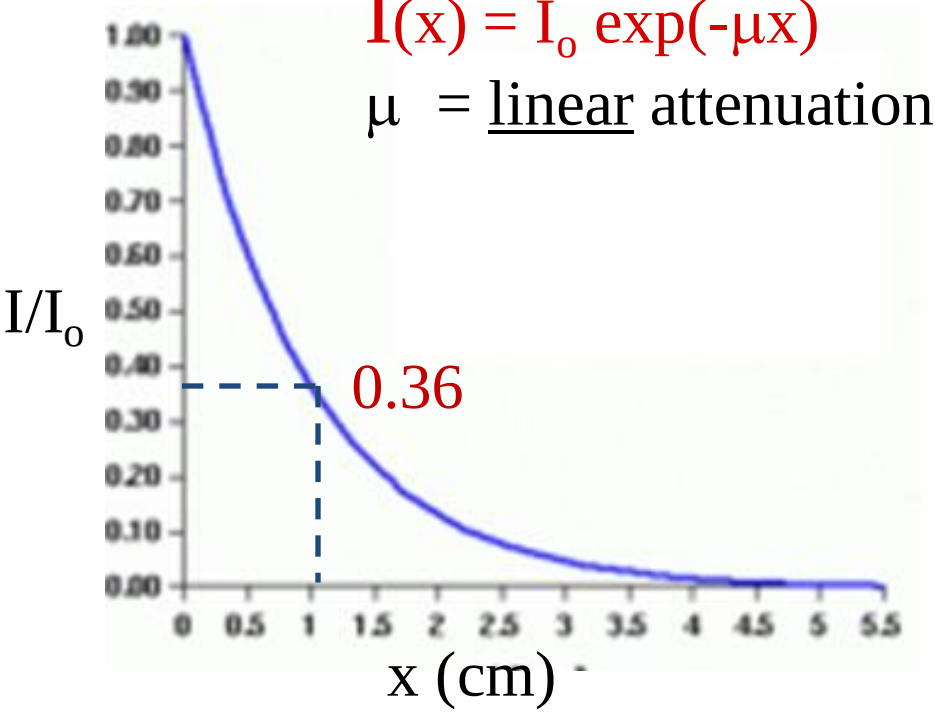
Attenuation and contrast?

High contrast needs sufficiently high **differential attenuation** of x-rays in various tissues.

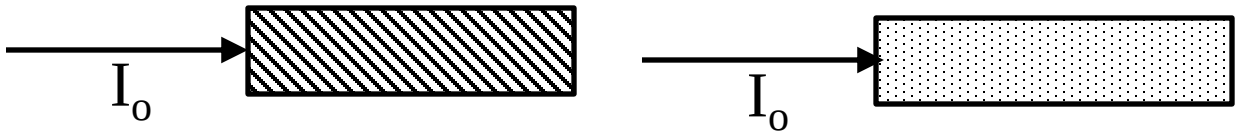
X-ray attenuation

$I(x) = I_o \exp(-\mu x)$

μ = linear attenuation coefficient; unit of μ : 1/distance



How would you compare attenuation in two tissues?



Linear and mass attenuation coefficients

Linear (μ) μ: 1/cm

Mass ($\mu_m = \mu/\rho$) μ_m: cm^2/gm

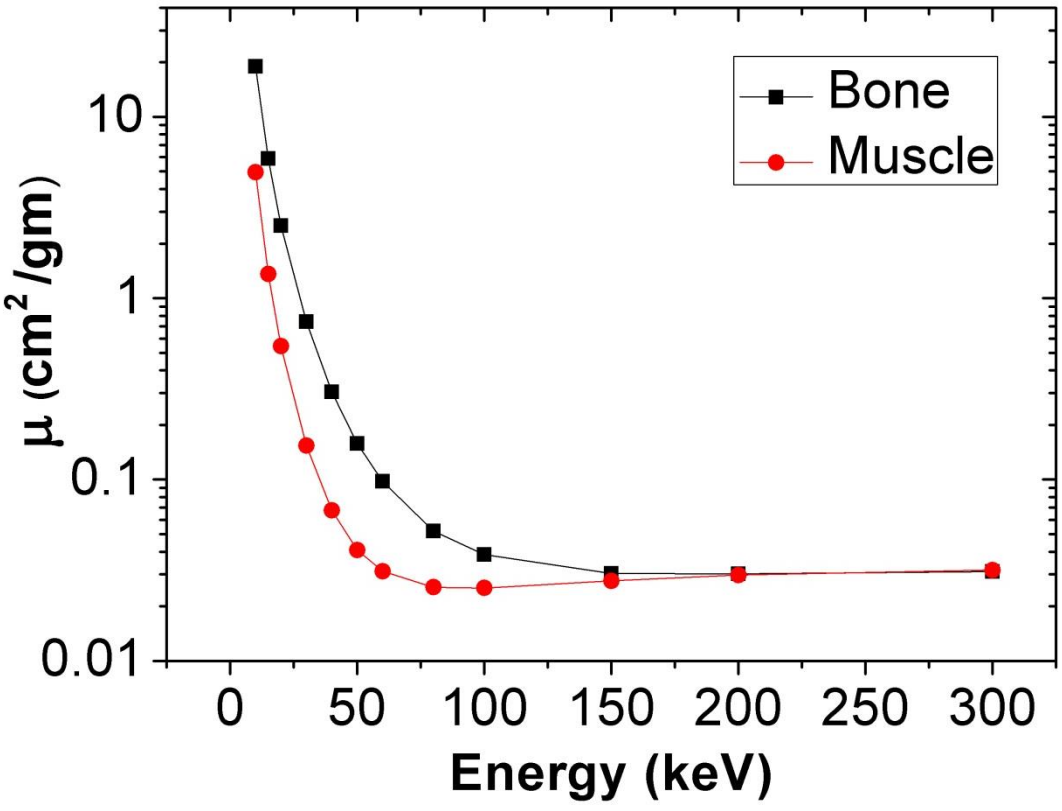
$$I(x) = I_o \exp(-\mu x)$$

$$I(x) = I_o \exp(-\mu_m \rho x)$$

Watch out when solving problems!

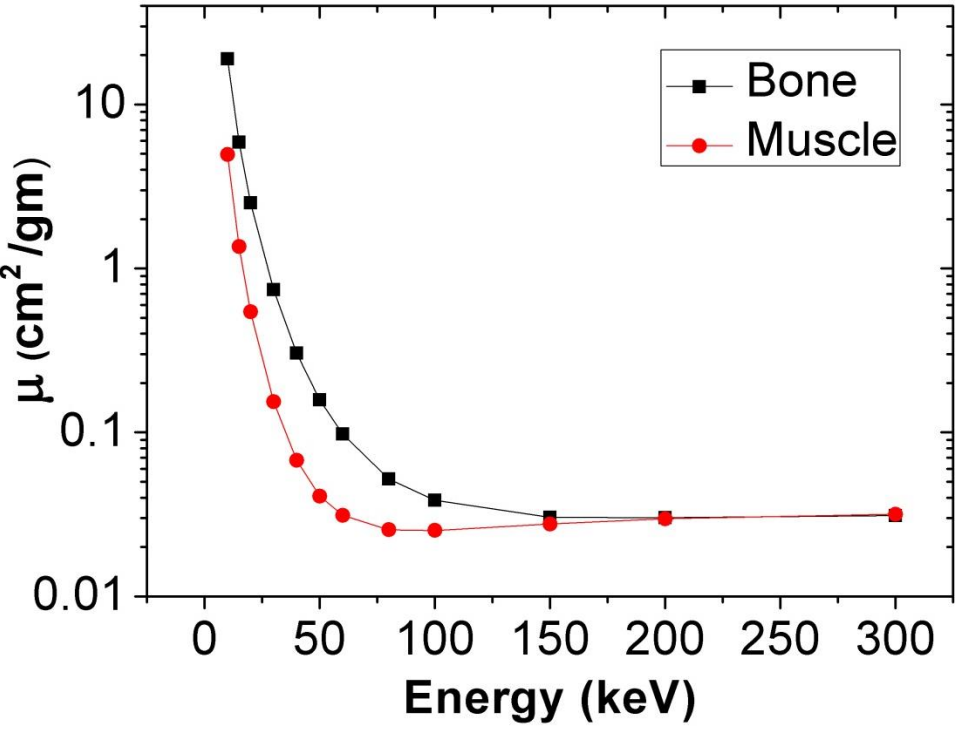
Value of μ depends on x-ray energy

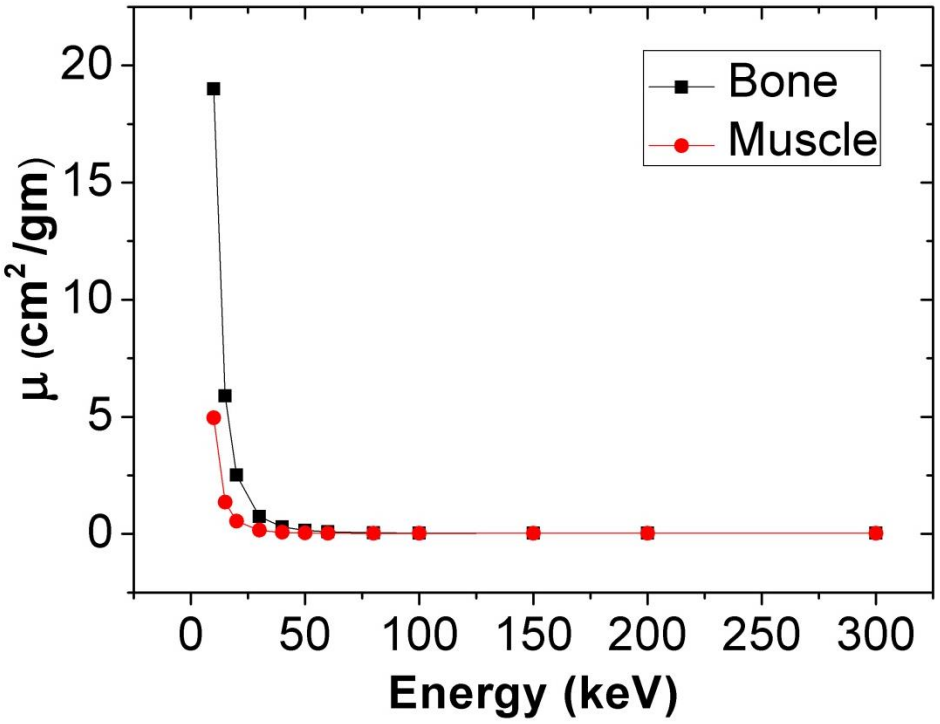
X-ray photon energy (keV)	Mass attenuation coefficient (cm^2/g)	
	Compact bone	Muscle
10	19.0	4.96
15	5.89	1.36
20	2.51	0.544
30	0.743	0.154
40	0.305	0.0677
50	0.158	0.0409
60	0.0979	0.0312
80	0.0520	0.0255
100	0.0386	0.0252
150	0.0304	0.0276
200	0.0302	0.0297
300	0.0311	0.0317



Which energy range should we choose for better contrast?

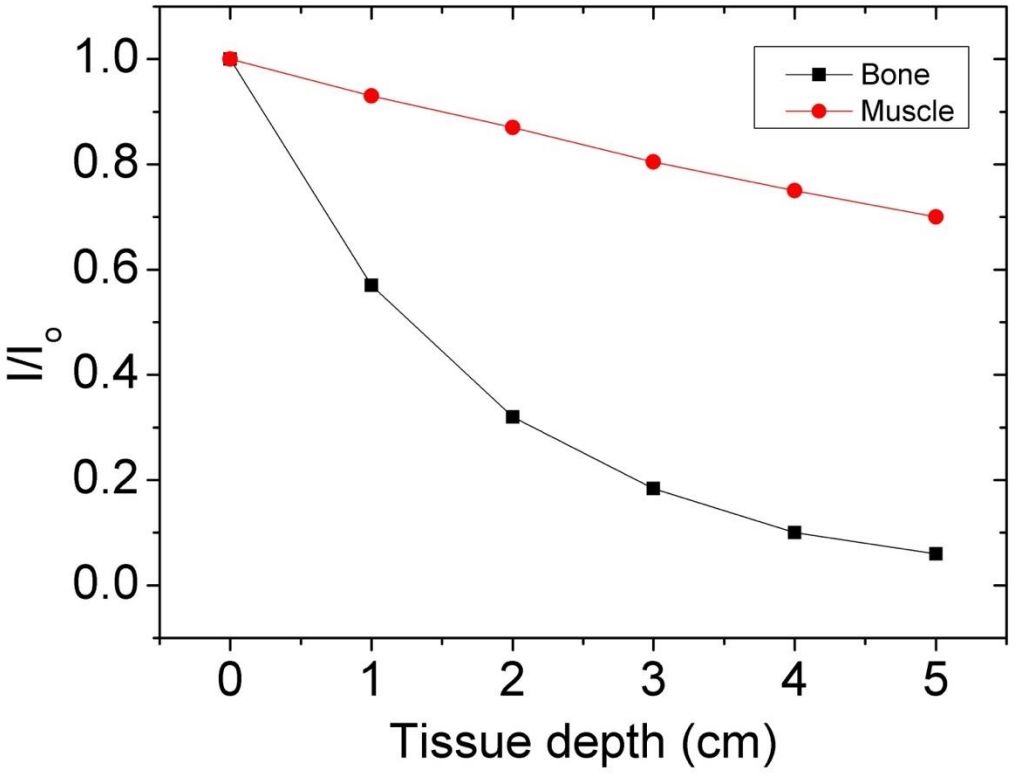
Let's take a look at the y-axis scales…





Plot x-ray intensity in bone and muscle as it progresses in x direction. Assume a tissue depth of 5cm.

Tissue	Density (g/cc)	Effective atomic number
Muscle	1.06	7.4
Fat	0.91	6.9
Bone	1.85	13.8



Recap: Value of μ depends on x-ray energy

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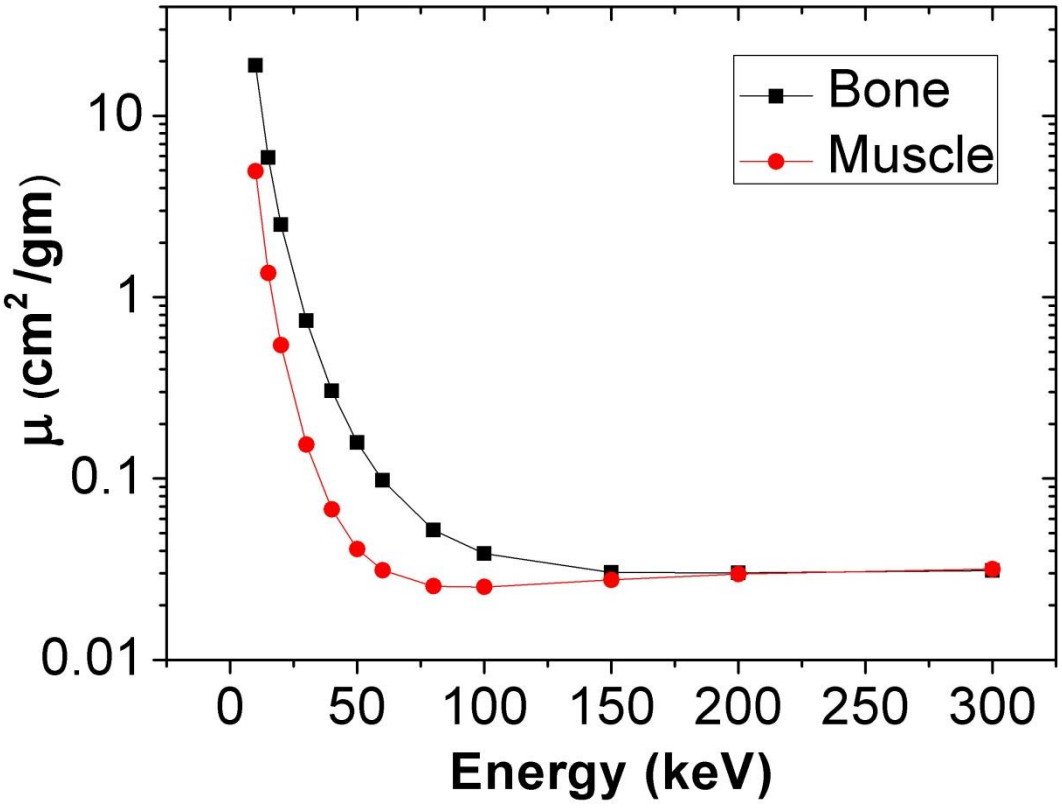
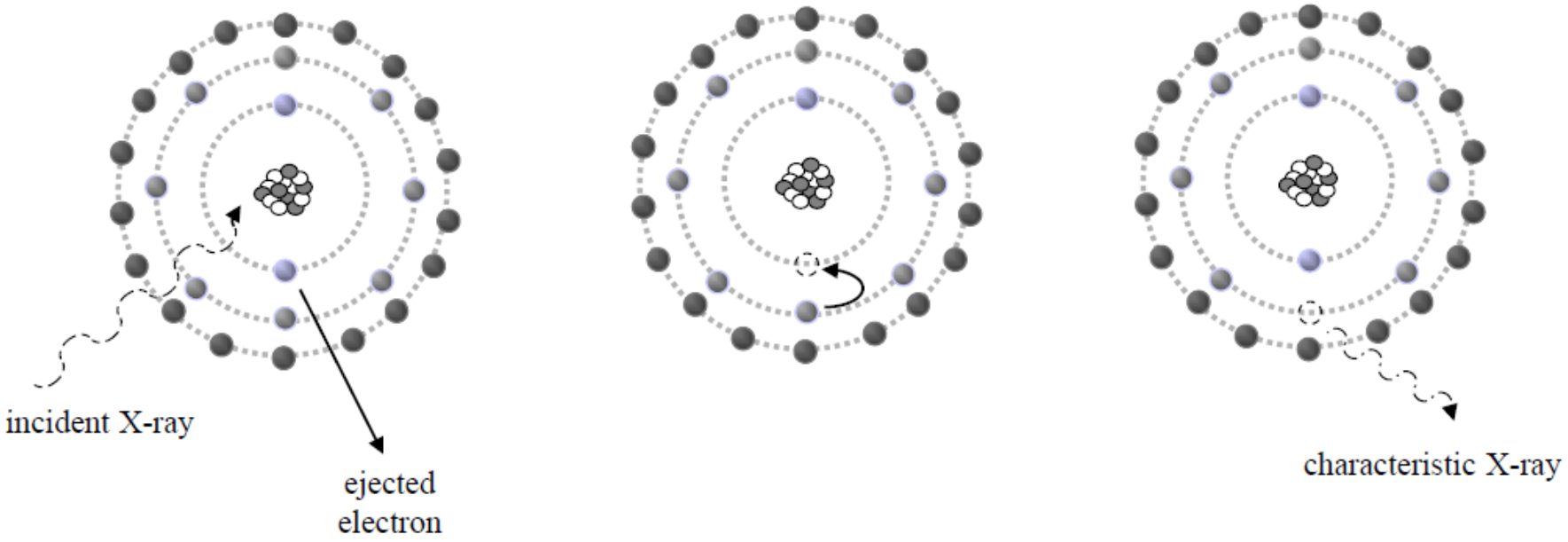


Which energy range should we choose for better contrast?

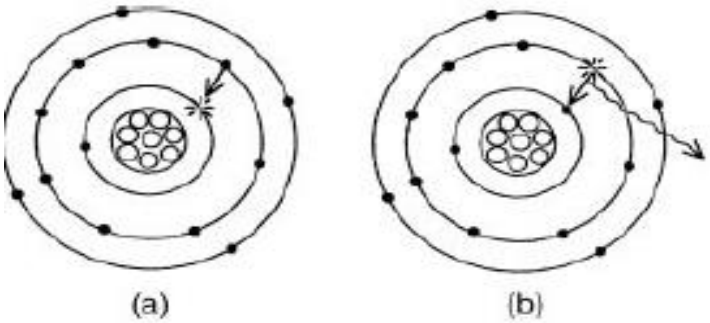
Photoelectric effect



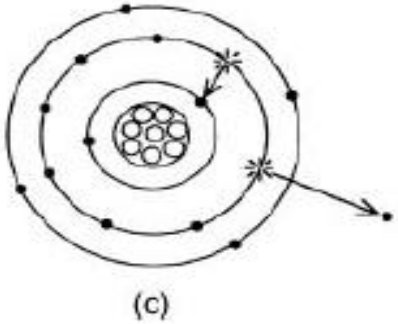
- Photon loses <u>all</u> its energy in one interaction with the tissue
- Watch out- the schematic diagram looks very similar to generation of characteristic x-rays.
- Inner shells

Auger electrons in photoelectric effect

X-ray photon ejects electron



Transition of electron from higher to lower level emits another photon



Auger transition ejects another electron instead of photon

- Transition from higher (say, L) to lower energy shell (say, K) ejects another electron (usually from the same higher energy shell).
- Causes ionization of tissue.

$$K.E._{Auger} = E_{Bi} - 2E_{Bo}$$

Hendee, Pg. 16