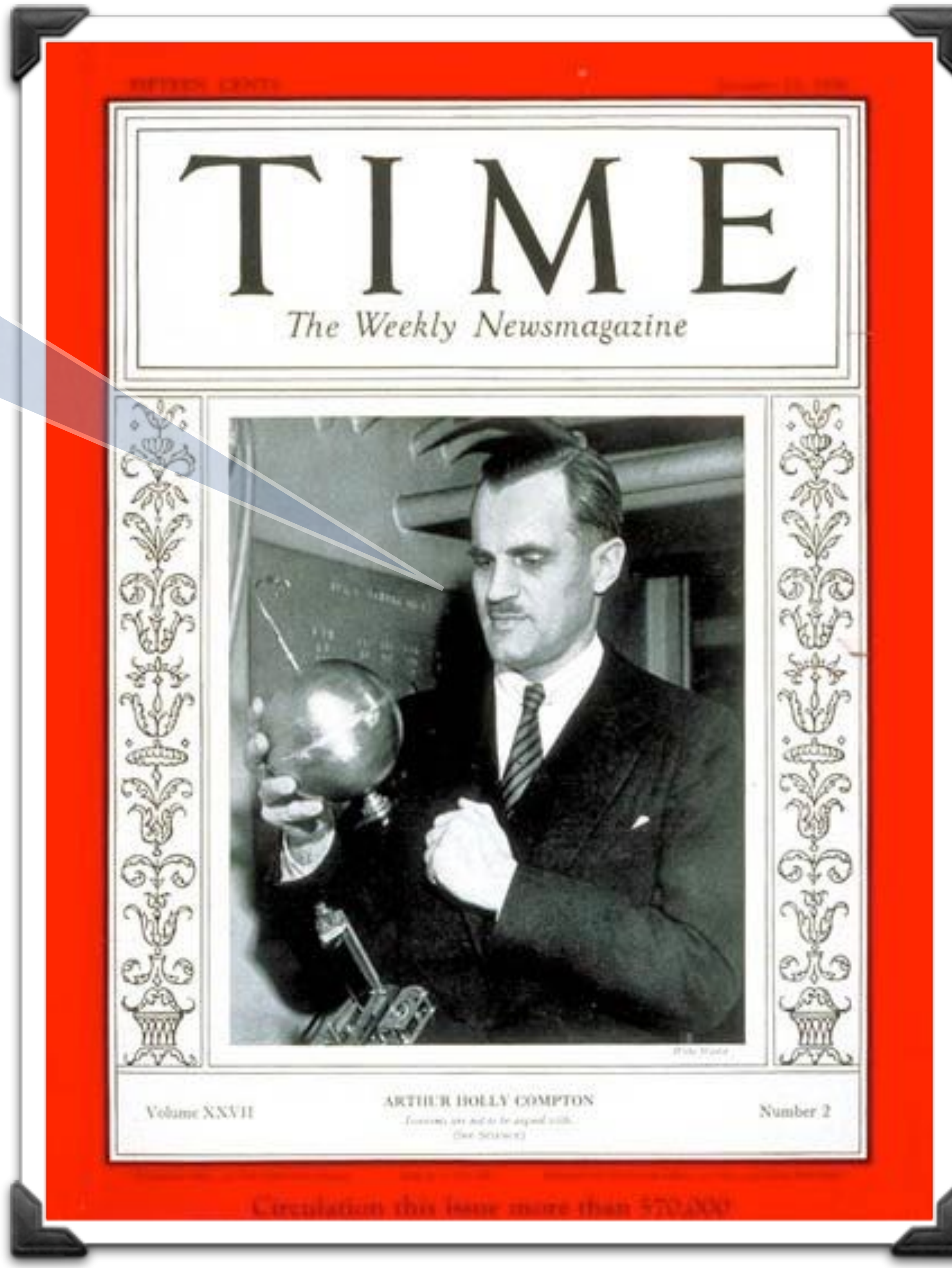
Welcome back to PHY 3305



Today's Lecture:

X-ray Production

Compton Scattering

Pair Production

Arthur Compton
1892 - 1962

Meeting of the Texas Section of the American Physical Society

When: Fri-Sat Oct 20-21
Where: UT Dallas

APS
AMERICAN PHYSICAL SOCIETY

- **Physics majors are expected to attend, and present any research project if applicable.**
- **See the email from Dr. Dalley about registration (deadline Sept 27).**
- **See Michele Hill (Physics office) well <u>before</u> the meeting to get set up for registration and banquet fee reimbursement.**

ANNOUNCEMENTS

- Reading Assignment:
  Chapter 3.6; 4.1 - 4.2
- Problem set 5 is due Tuesday, Sept. 26th at 12:30 pm.
- Regrade for problem set 4 is due Tuesday, Sept 26th at 12:30 pm.
- Midterm exam 1 covering chapters 1-2 and related material will be in class on Thursday, Sept 21st. There will be a seating chart.

REVIEW QUESTION 1

In a photoelectric effect experiment, if the intensity of the incident light is doubled the stopping potential will:

a) Double

b) Double, but only of if the light's frequency is above the cut-off

c) Half

d) $\boxed{\text{Remain unchanged}}$

Current between the electrodes stops when the opposing potential energy difference equals the maximum KE of the photoelectrons.

$$KE_{max} = hf - \phi$$

Electrons are accelerated in television tubes through a potential difference of 10.0 kV. Find the lowest wavelength of the electromagnetic waves emitted when these electrons strike the screen. What kind of waves are these?

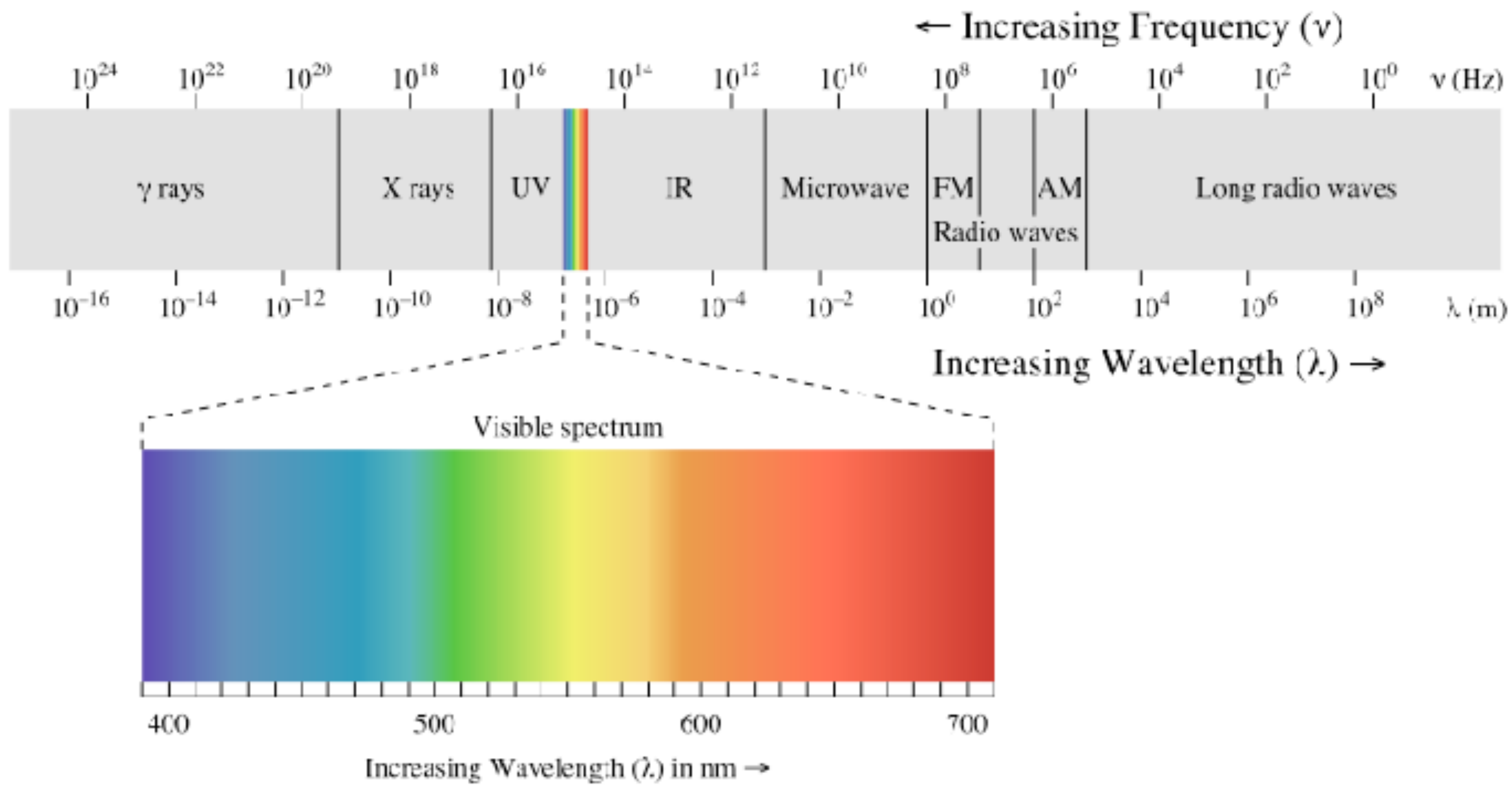
From the lecture video (and your textbook):

$$E = \frac{hc}{\lambda_c}$$

$$\lambda_c = \frac{hc}{E} = \frac{1240\ eV \cdot nm}{10 \times 10^3\ eV} = 0.124\ nm$$

What wavelength is this?

And back to the final part of our question …



0.124 nm is in the x-ray spectrum.

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X-rays? Should I be worried?

X-rays given off from TV tubes are low doses of radiation. It's not enough to be dangerous and in fact, if you watch your television for several hours a day all year, you're getting less radiation than you would from a single medical x-ray and less radiation than you get from the radioactivity that's just naturally within your body. So, it's something that we can measure, but it's not something that's harmful.

In addition, LCD and plasma TVs don't give off any radiation at all. They do not use accelerated electrons to produce images.

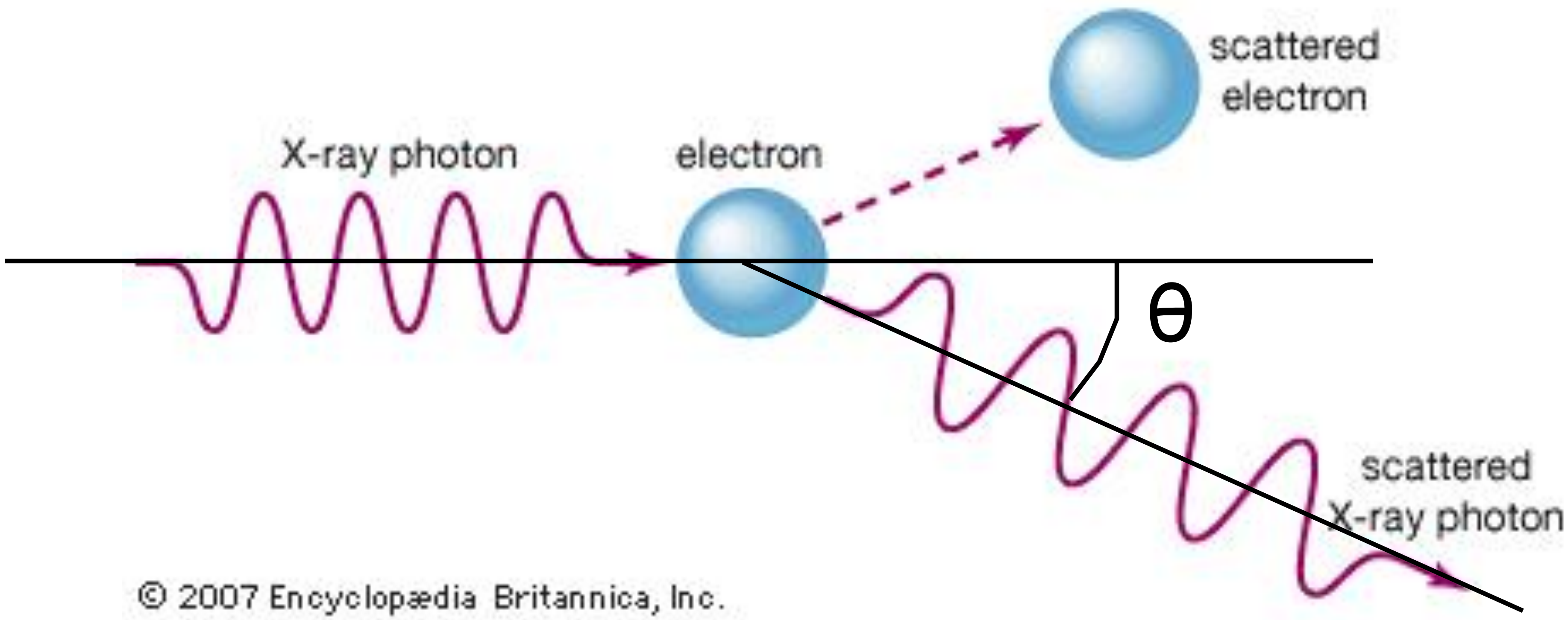
Suppose we produced x-rays by smashing protons instead of electrons into targets. If the accelerating potential difference used were the same for both, how would the cut-off wavelength of the two spectra compare?

They would be the same. Set the KE equal to the energy of one photon. Since the proton and electron have the same kinetic energy, the cut-off wavelength is the same. (Note the proton is more massive, so it would be moving slower — but that doesn't matter for the cut-off wavelength.)

$$E = \frac{hc}{\lambda_c}$$

Video Lecture:

The Compton Effect:



$$\lambda_{after} - \lambda_{before} = \frac{h}{m_e c}(1 - \cos\theta_{scatter})$$

Of the following, Compton scattering from electrons is most easily observed for:

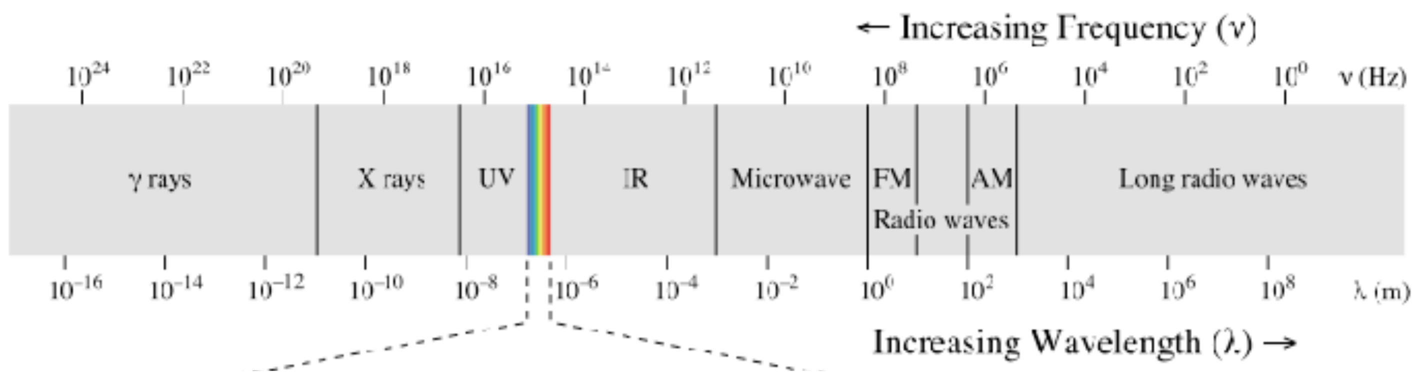
a) Microwaves

b) Infrared light

c) Visible light

d) Ultraviolet light

e) X-rays



$$\lambda_{after} - \lambda_{before} = \frac{h}{m_e c}(1 - \cos\theta_{scatter})$$

maximum Δλ for scattering off an electron (180°)
= 0.00495 nm

X-rays of wavelength 10.0 pm are scattered from a target.

a) Find the wavelength of the x-rays scattered through 45 degrees.

Start with the equation for Compton Scattering:

$$\lambda_a - \lambda_b = \frac{h}{m_e c}(1 - \cos\theta)$$

$$\lambda_a = \lambda_b + \frac{h}{m_e c}(1 - \cos\theta) = \lambda_b + \frac{hc}{m_e c^2}(1 - \cos\theta)$$

$$= 10.0 \times 10^{-3}\ nm + \frac{1240 eV \cdot nm}{511 \times 10^3\ eV}(1 - \cos 45)$$

$$\boxed{\lambda_a = 0.0107\ nm = 10.7\ pm}$$

X-rays of wavelength 10.0 pm are scattered from a target.

b) Find the maximum wavelength present in the scattered x-rays.

The maximum wavelength occurs when θ= 180 degrees.

$$\lambda_{a_{max}} = \lambda_b + \frac{hc}{m_e c^2}(1 - \cos\theta)$$

$$\lambda_{a_{max}} = 10.0 \times 10^{-3}\ nm + \frac{1240\ eV \cdot nm}{511 \times 10^3\ eV}(1 - \cos 180)$$

$$\boxed{\lambda_{a_{max}} = 0.0148\, nm = 14.8\, pm}$$

X-rays of wavelength 10.0 pm are scattered from a target.

c) Find the maximum kinetic energy of the recoil electrons.

The maximum kinetic energy is equals the difference in energy before and after the collision.

$$KE = E_b - E_a \;= hf_b - hf_a$$

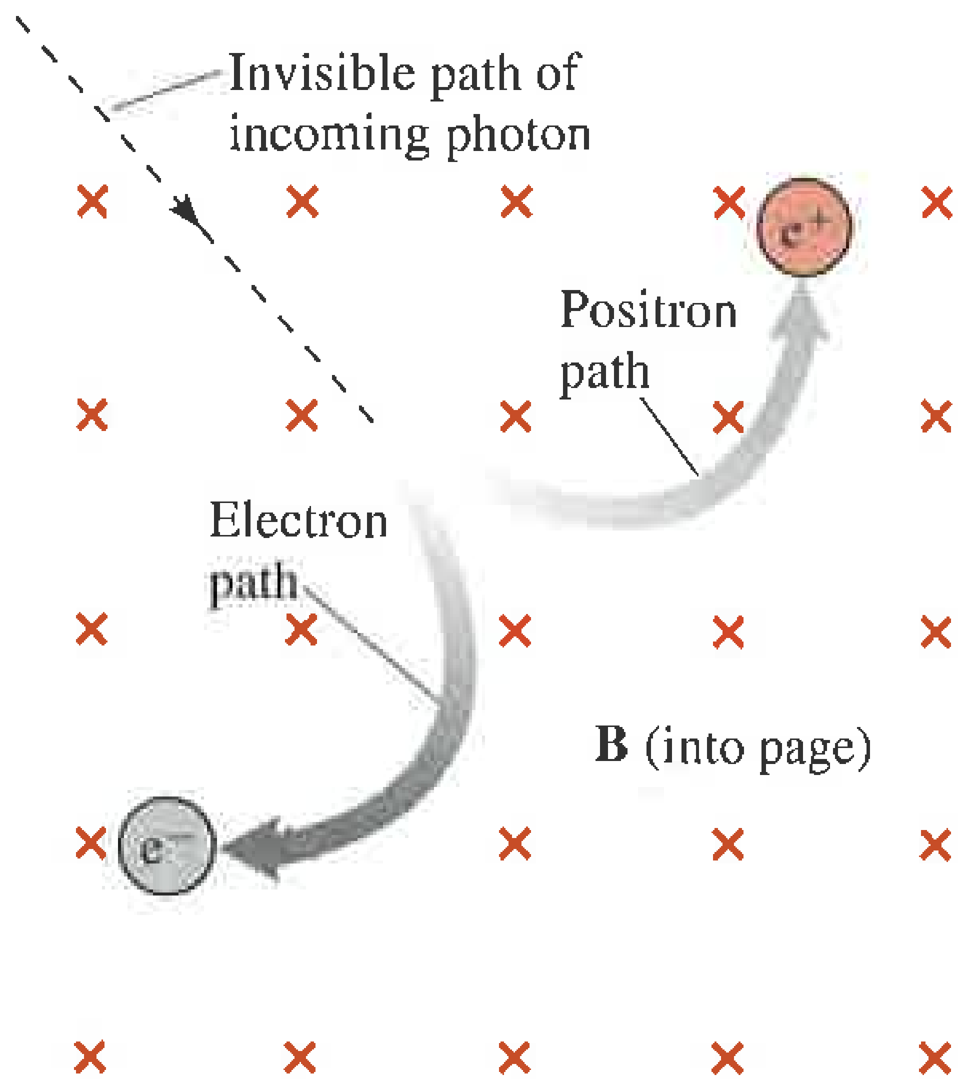
$$= hc(\frac{1}{\lambda_b} - \frac{1}{\lambda_a})$$

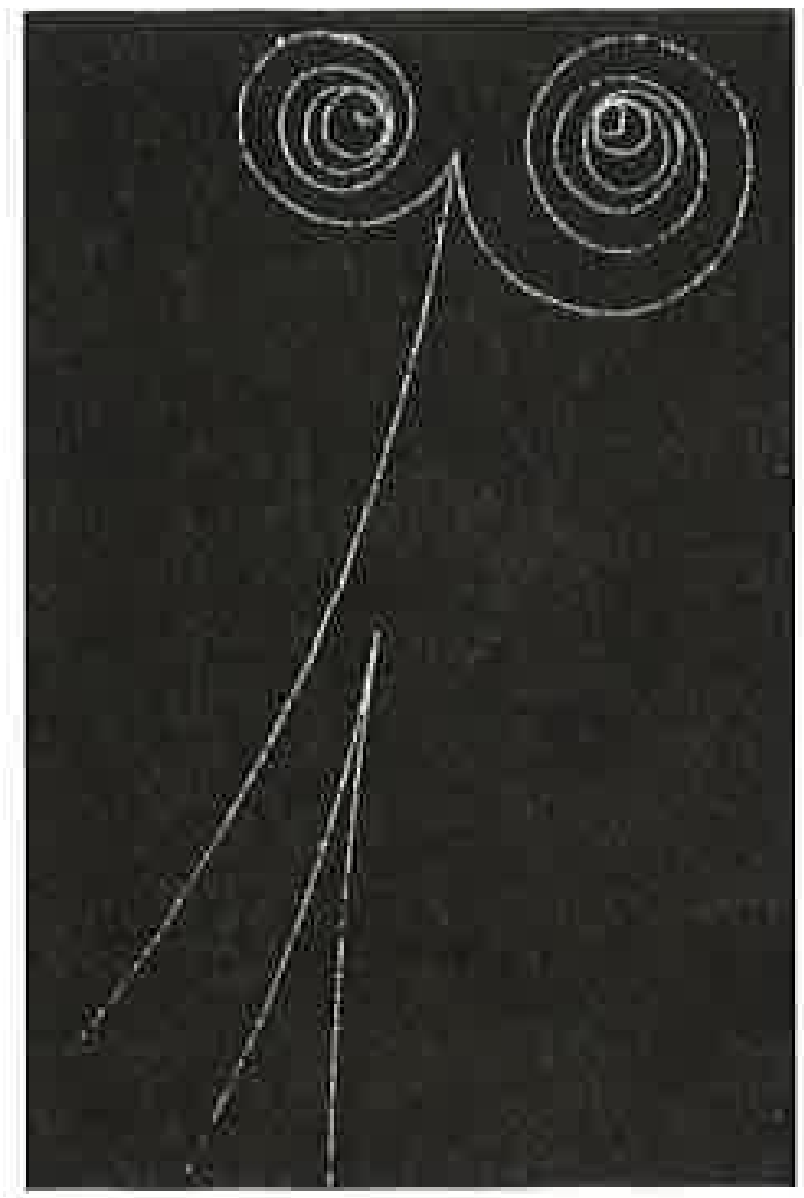
$$= 1240\ eV \cdot nm(\frac{1}{10.0 \times 10^{-3}\ nm} - \frac{1}{14.9 \times 10^{-3}\ nm})$$

$$\boxed{KE = 40.2\ keV}$$

PAIR PRODUCTION

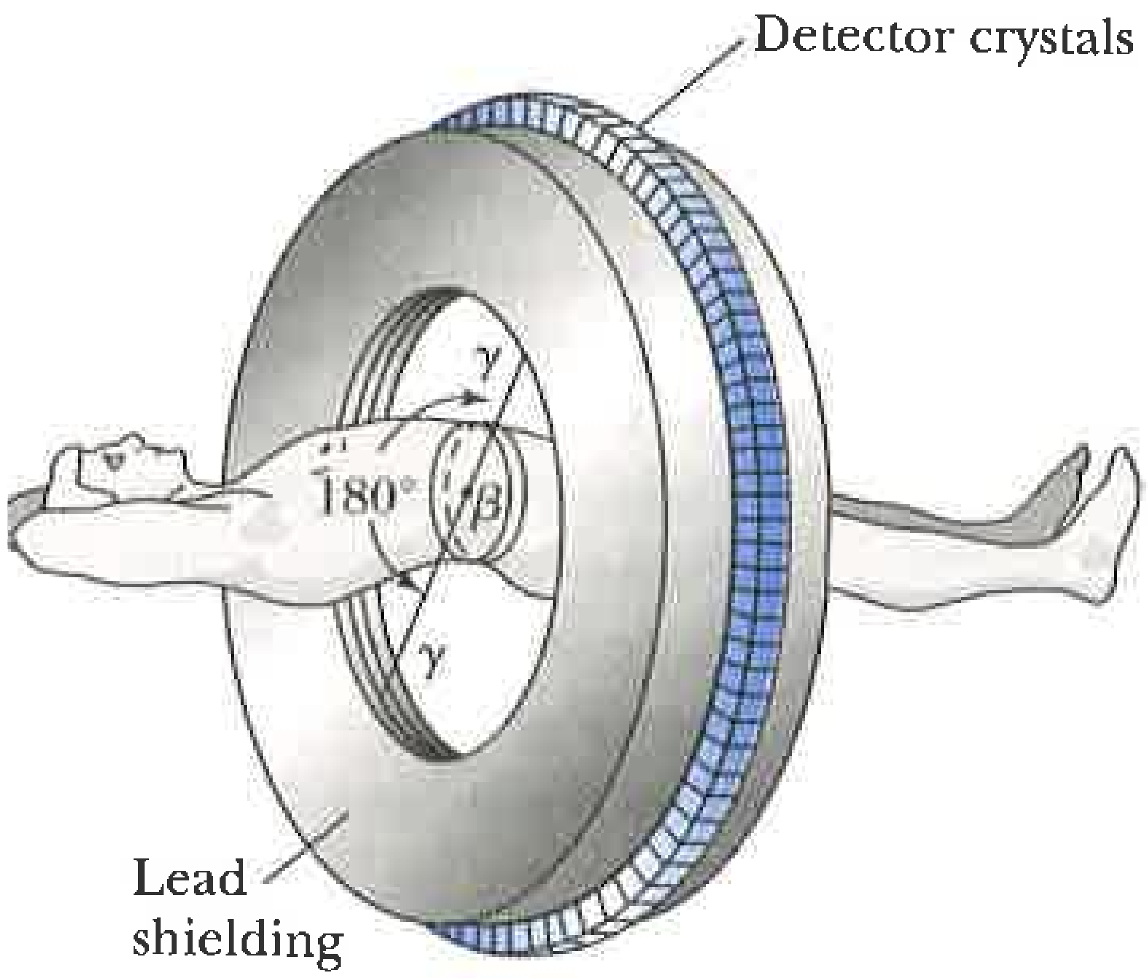
- 1932 Carl D. Anderson discovered "electrons" that curved the wrong way while studying cosmic rays.
- High energy photons create positrons through pair production.





PET SCANS

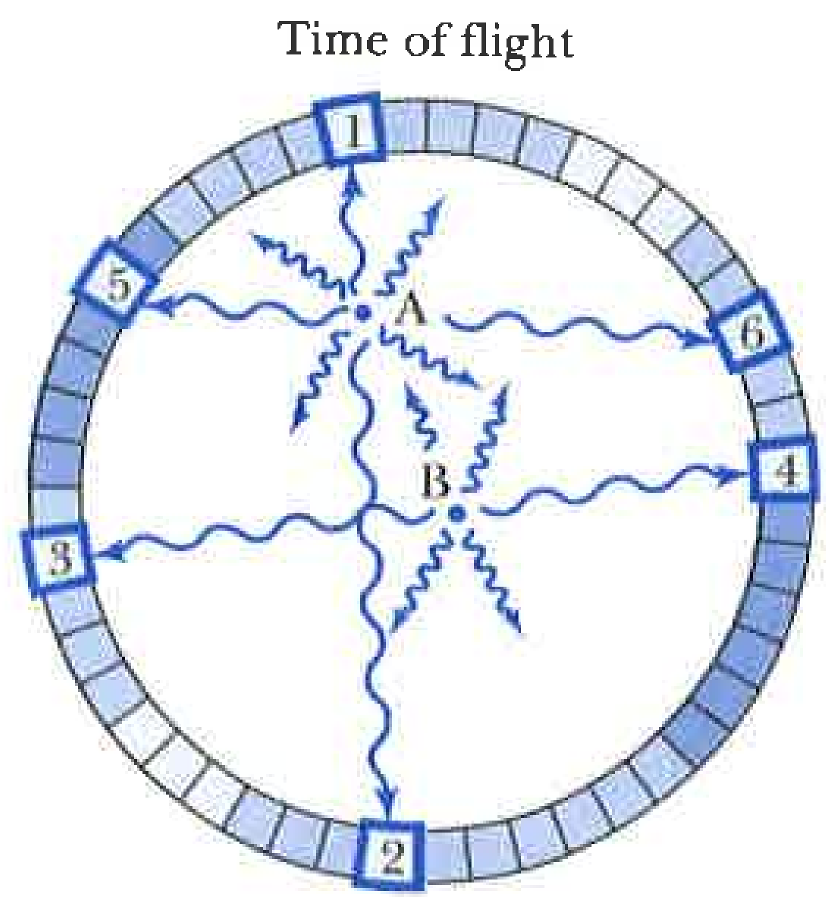
- A positron-emitting radioisotope chemical (containing a nucleus such as ^{15}O, ^{11}C, ^{13}N or ^{18}F) is injected into the body.
- Patient is put in a machine with detector with a ring of detector crystals.



(a)

Modern Physics by Thorten, Rex, 4th ed.

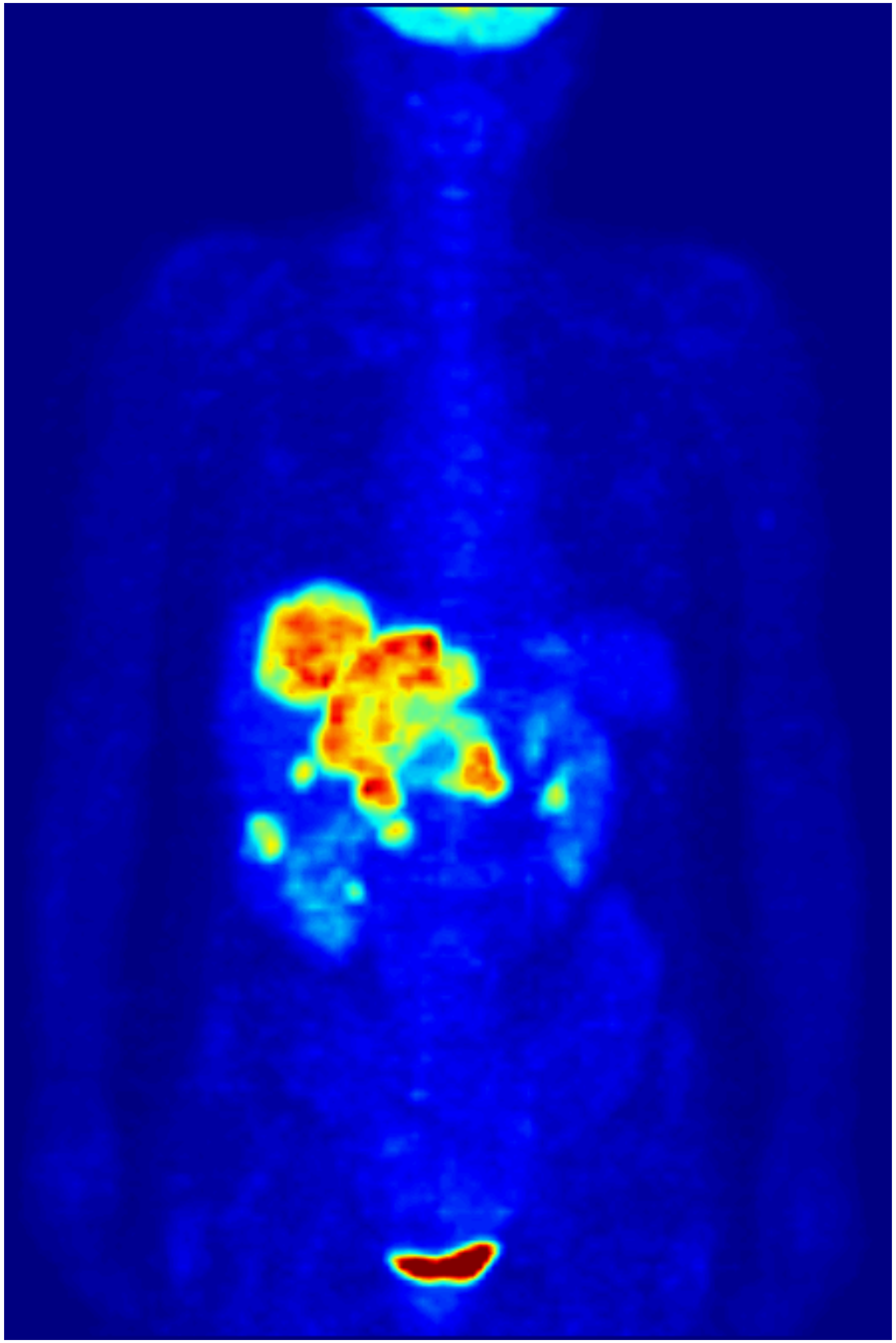
- Two characteristic annihilation photons are emitted from points where the chemical has been concentrated by a physiological process.
- Location in body is identified by measuring the direction of the two emitted photons.

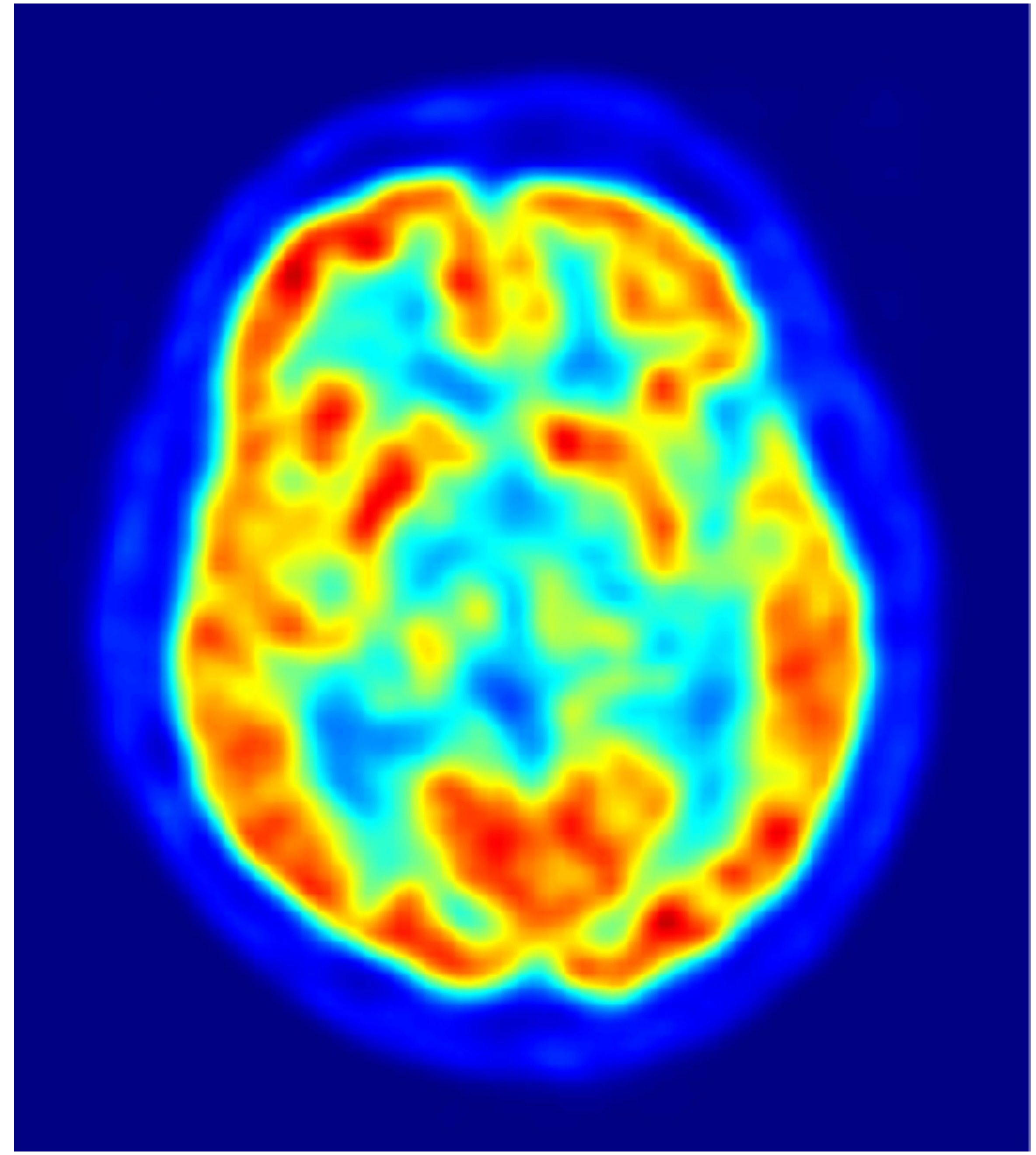


(b)

Modern Physics by Thorten, Rex, 4th ed.

https://en.wikipedia.org/wiki/Positron_emission_tomography





Above: PET Scan normal human brain. Left: Whole body PET Scan

PET SCANS

In a PET scan an electron and a positron annihilate and two photons of characteristic energy are detected. What is the energy and and what is the corresponding wavelength of the resulting photons?

Assuming that we are in the rest frame where e^+ and e^- are at rest, there is only rest mass energy.

$$E_{tot} = 2m_ec^2$$

Since the interaction must obey the conservation of energy

$\boxed{E_\gamma = 0.511\ MeV \text{ for each photon}}$

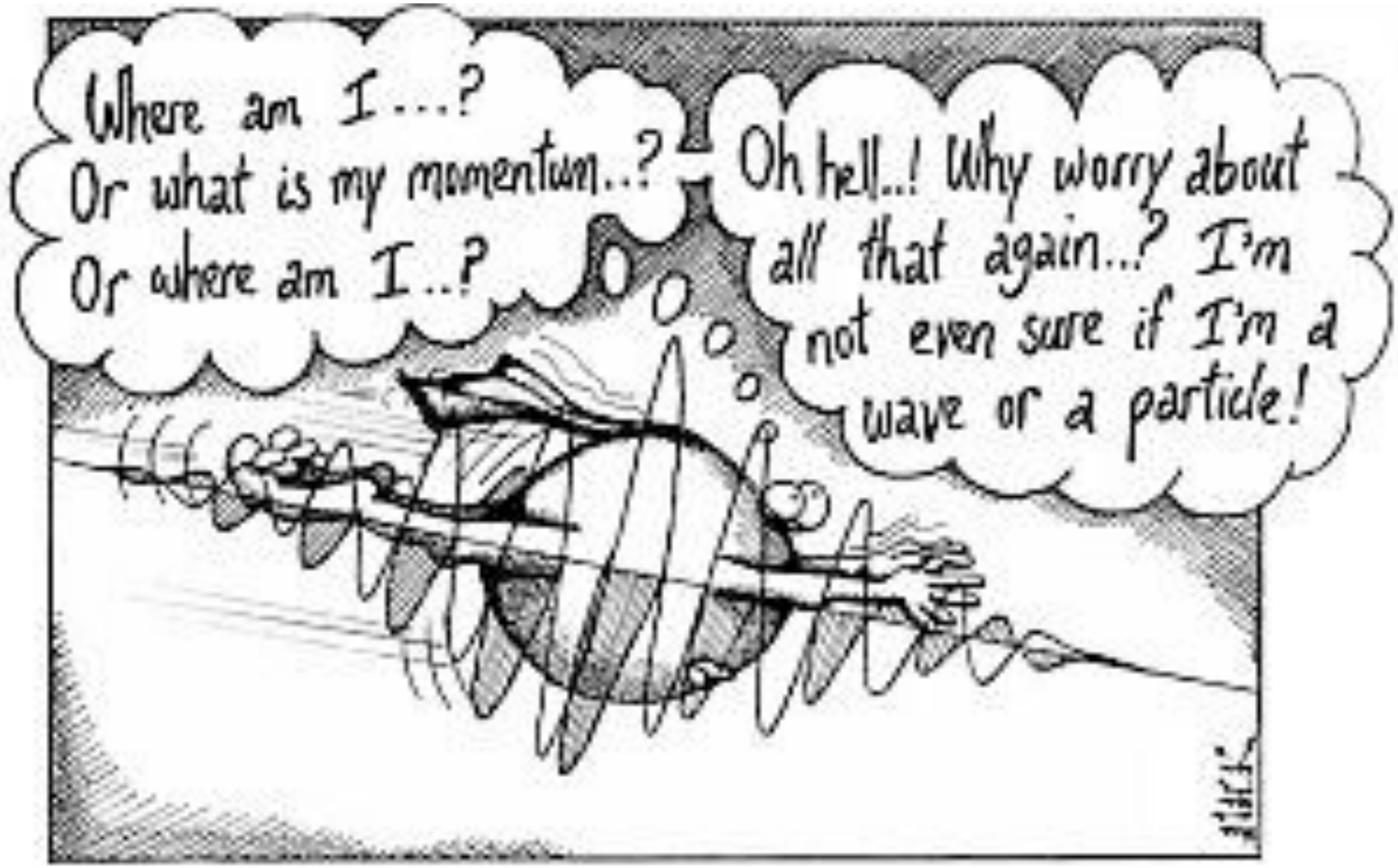
The wavelength of the photon is given by

$$E = \frac{hc}{\lambda} \quad \longrightarrow \lambda = \frac{hc}{E}$$

$$= \frac{1240\ eV \cdot nm}{0.511 \times 10^6\ eV}$$

$$\boxed{\lambda = 2.42 \times 10^{-3}\ nm}$$

THE END (FOR TODAY)



Photon self-identity problems.