PARTICLE PROPERTIES OF WAVES

1. Electromagnetic Waves.
2. Blackbody Radiation.
3. Photoelectric Effect.
4. What is Light?
5. X-Rays.
6. X-ray Diffraction.
7. Compton Effect.
8. Pair Production.
9. Photons and Gravity.

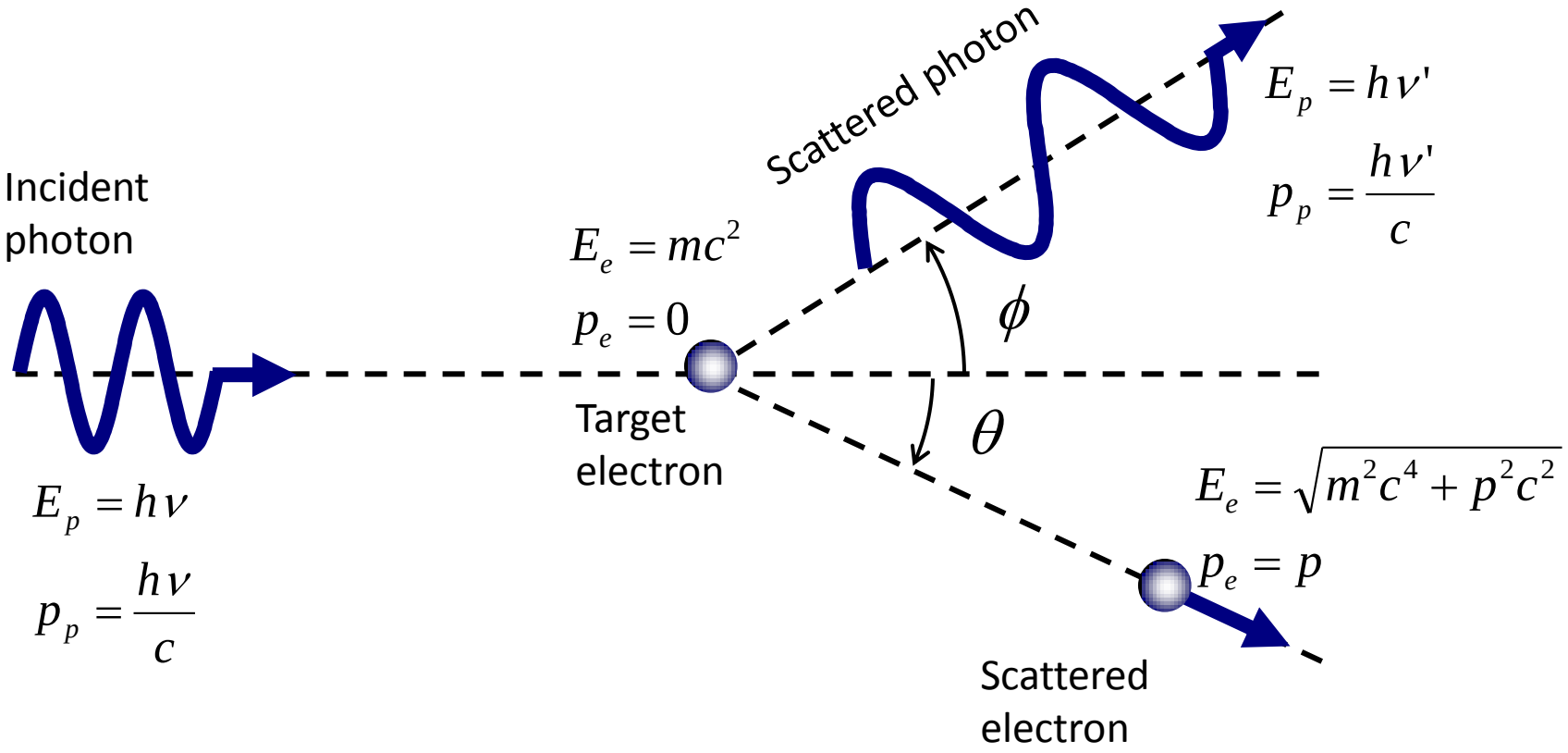
COMPTON EFFECT

What the quantum theory of light says…

Photons behave like particles except for their lack of rest mass.

Can we consider a collision between a photon and an electron as if both were billiard balls?

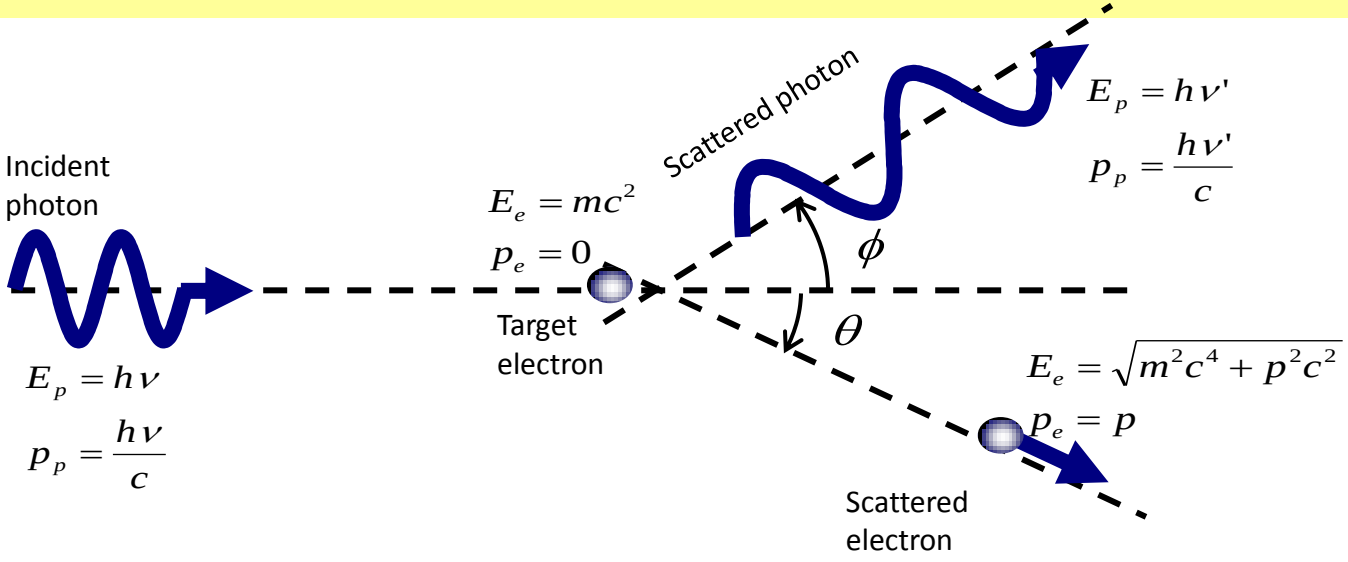
COMPTON EFFECT

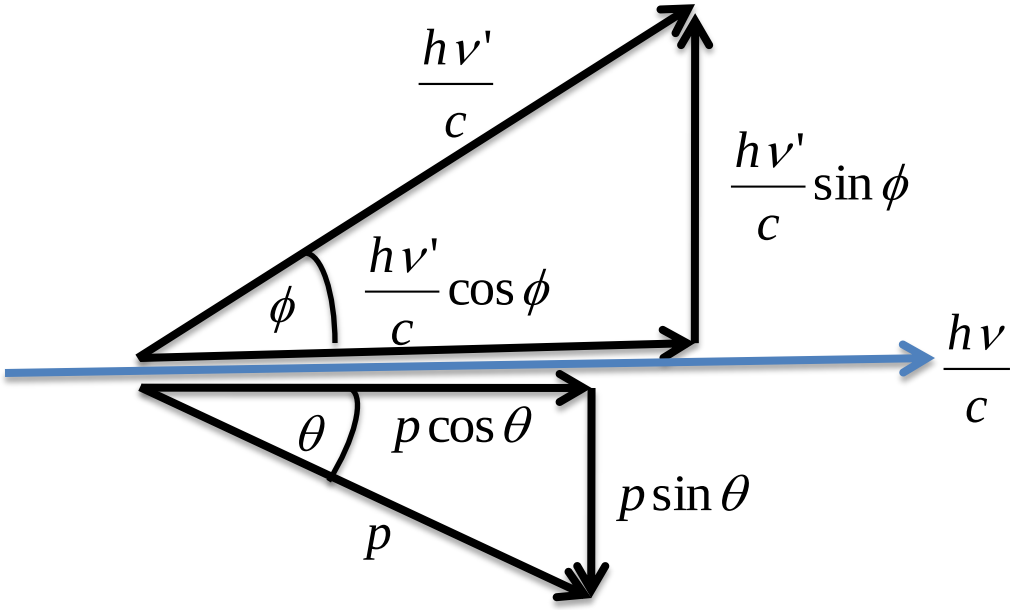


$$\text{loss in photon energy} = \text{gain in electron energy}$$

$$h\nu - h\nu' = KE$$

COMPTON EFFECT

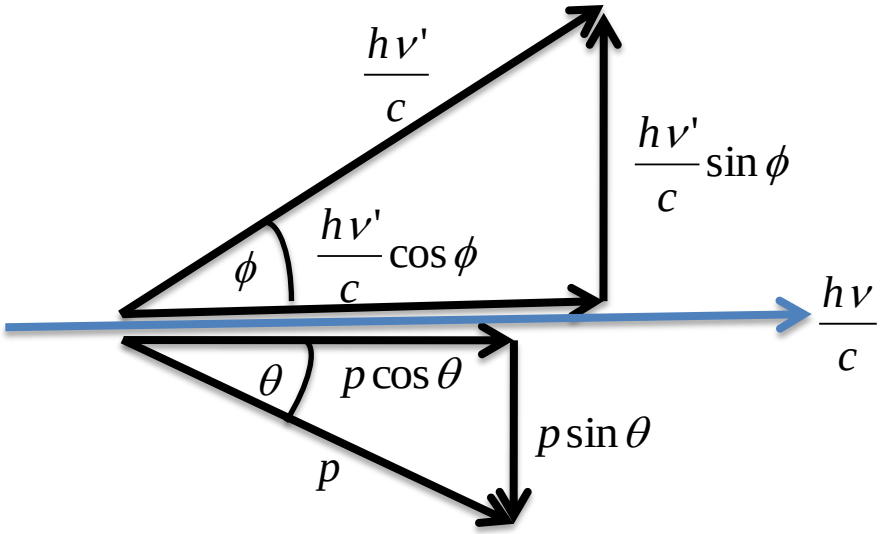




Energy & momentum are conserved!

COMPTON EFFECT

Conservation of momentum in x and y direction…



$$(p_x)_{\text{initial}} = (p_x)_{\text{final}}$$

$$\frac{h\nu}{c} + 0 = \frac{h\nu'}{c}\cos\phi + p\cos\theta$$

$$(p_y)_{\text{initial}} = (p_y)_{\text{final}}$$

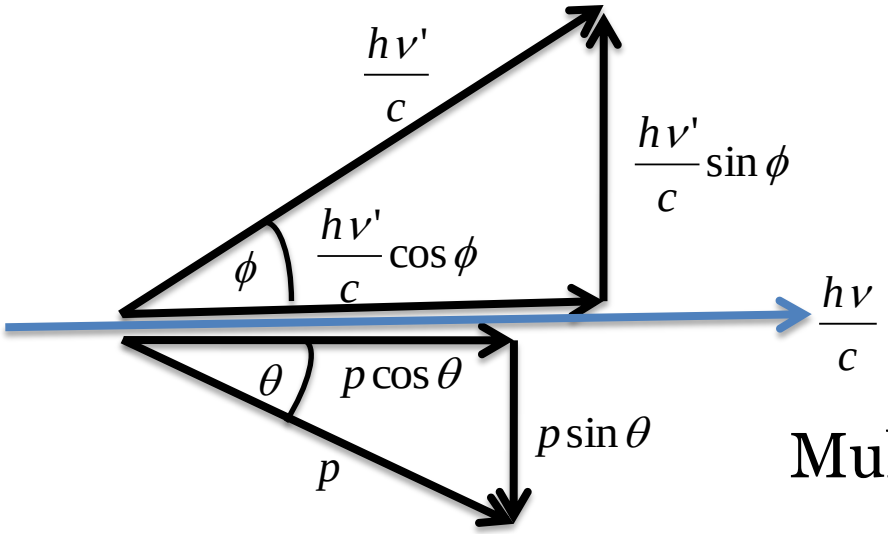
$$0 = \frac{h\nu'}{c}\sin\phi - p\sin\theta$$

Let us look what are the measurable quantities…

1. Wavelength difference.
2. ϕ

COMPTON EFFECT

Conservation of momentum in x and y direction…



$$\frac{h\nu}{c}+0=\frac{h\nu'}{c}\cos\ \phi+p\cos\ \theta$$

$$0=\frac{h\nu'}{c}\sin\phi-p\sin\theta$$

Multiply by c, square these equations and add them together…

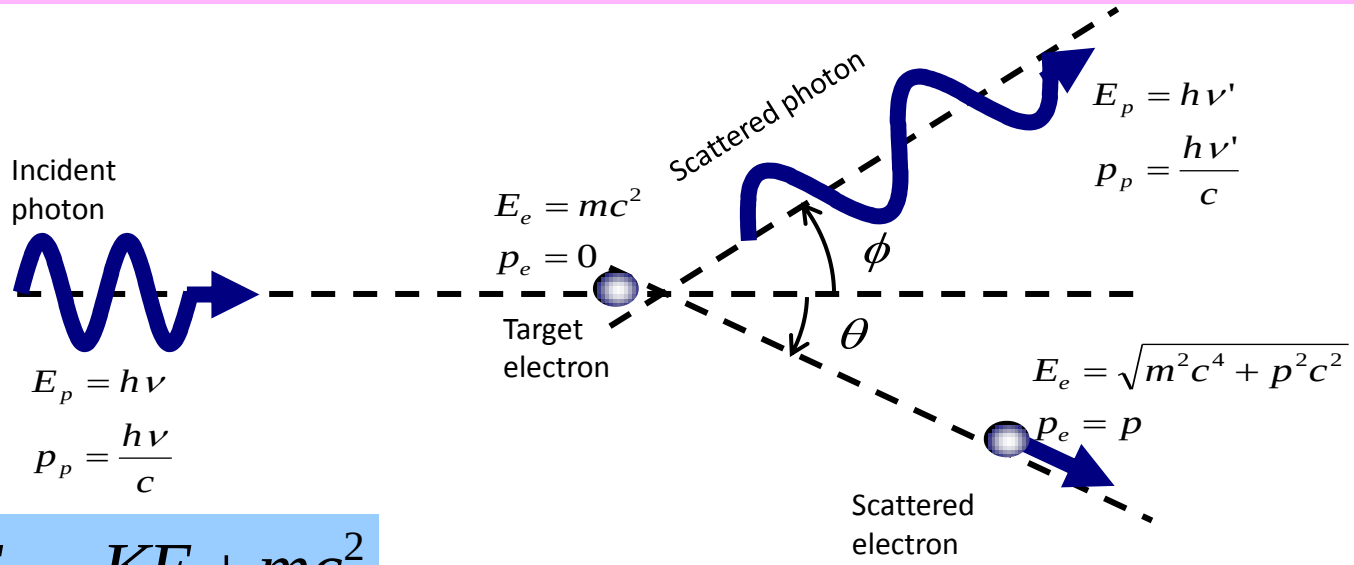
$$pc\cos\ \theta=h\nu-h\nu'\cos\ \phi$$

$$pc\sin\theta=h\nu'\sin\phi$$

$$p^2c^2=(h\nu)^2-2(h\nu)(h\nu')\cos\ \phi+(h\nu')^2$$

COMPTON EFFECT

Conservation of energy…



$$E_e = KE + mc^2$$

We know that the relativistic energy is…

$$E_e = \sqrt{p_e^2c^2 + m^2c^4}$$

Equate and square..

$$p^2c^2 = KE^2 + 2mc^2KE$$

$$KE = h\nu - h\nu'$$

$$p^2c^2 = (h\nu)^2 - 2(h\nu)(h\nu') + (h\nu')^2 + 2mc^2(h\nu - h\nu')$$

COMPTON EFFECT

Conservation of momentum…

$$p^2c^2 = (h\nu)^2 - 2(h\nu)(h\nu')\cos\ \phi + (h\nu')^2$$

Conservation of energy…

$$p^2c^2 = (h\nu)^2 - 2(h\nu)(h\nu') + (h\nu')^2 + 2mc^2(h\nu - h\nu')$$

By equating…

$$2mc^2(h\nu - h\nu') = 2(h\nu)(h\nu')(1-\cos\phi)$$

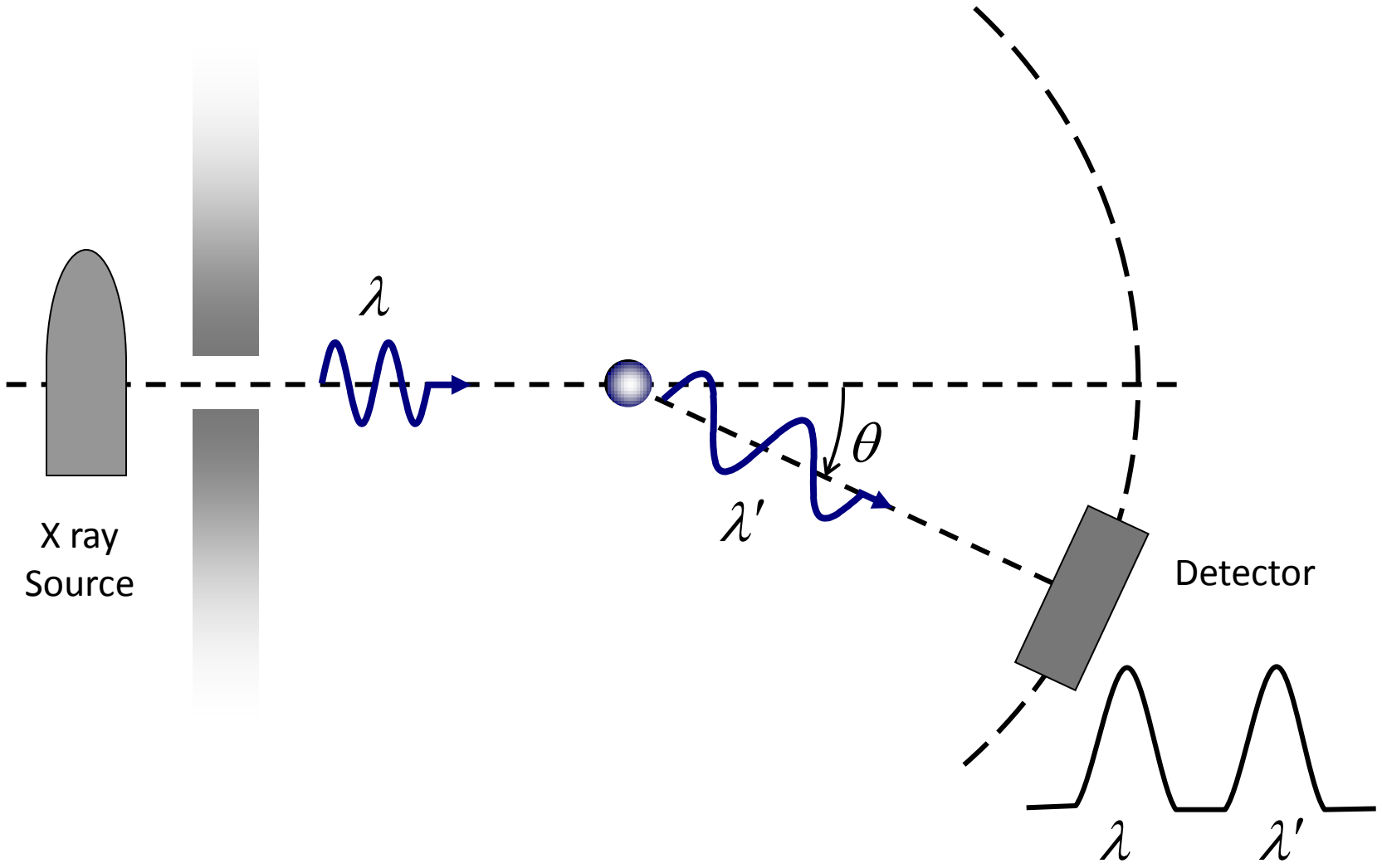
With ν/c=1/λ and ν'/c=1/λ'…

$$\Delta\lambda = \lambda' - \lambda = \frac{h}{mc}(1-\cos\phi)$$

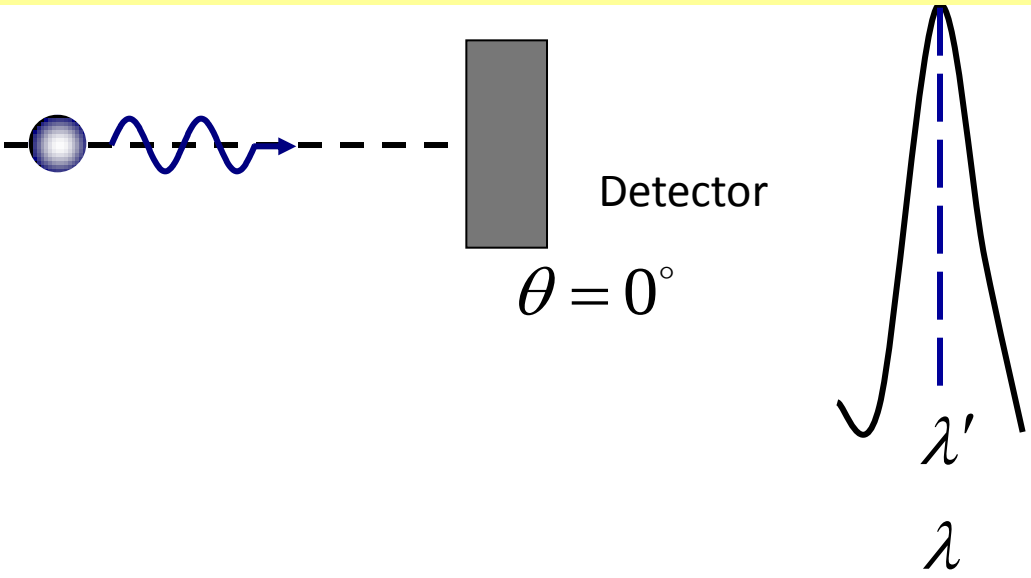
Compton wavelength of the electron

$$\lambda_C = \frac{h}{mc}$$

COMPTON EFFECT



COMPTON EFFECT



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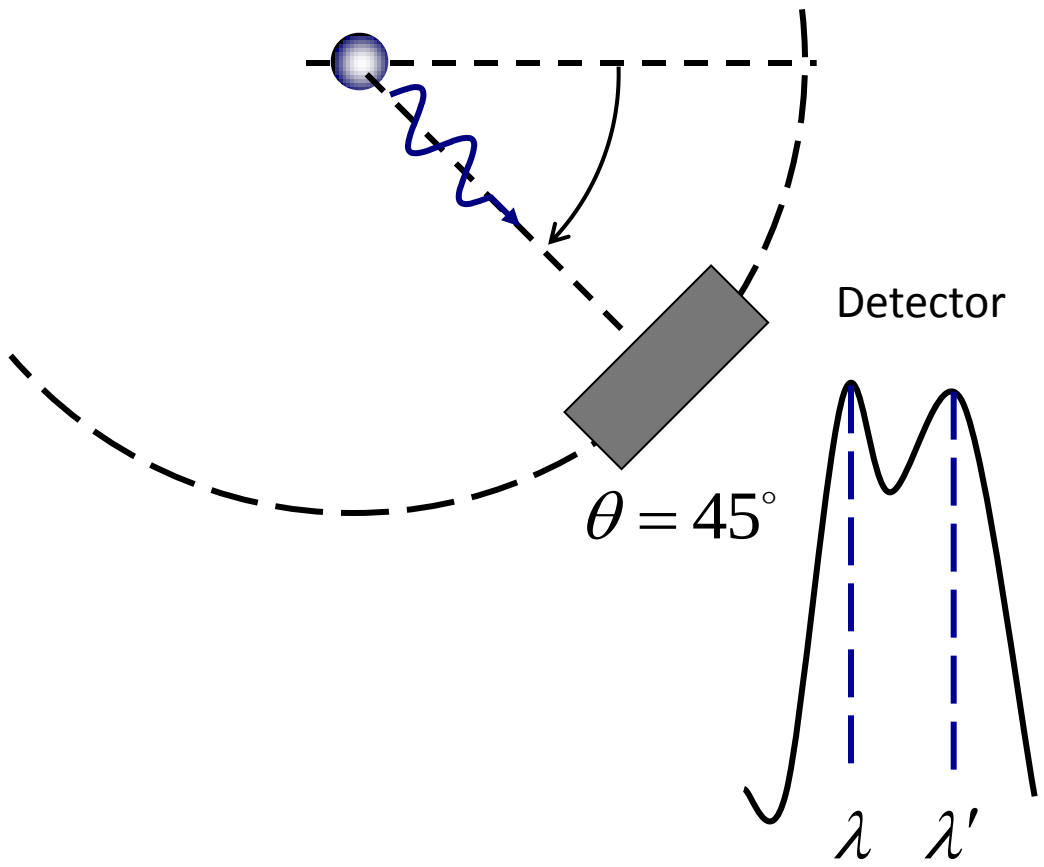

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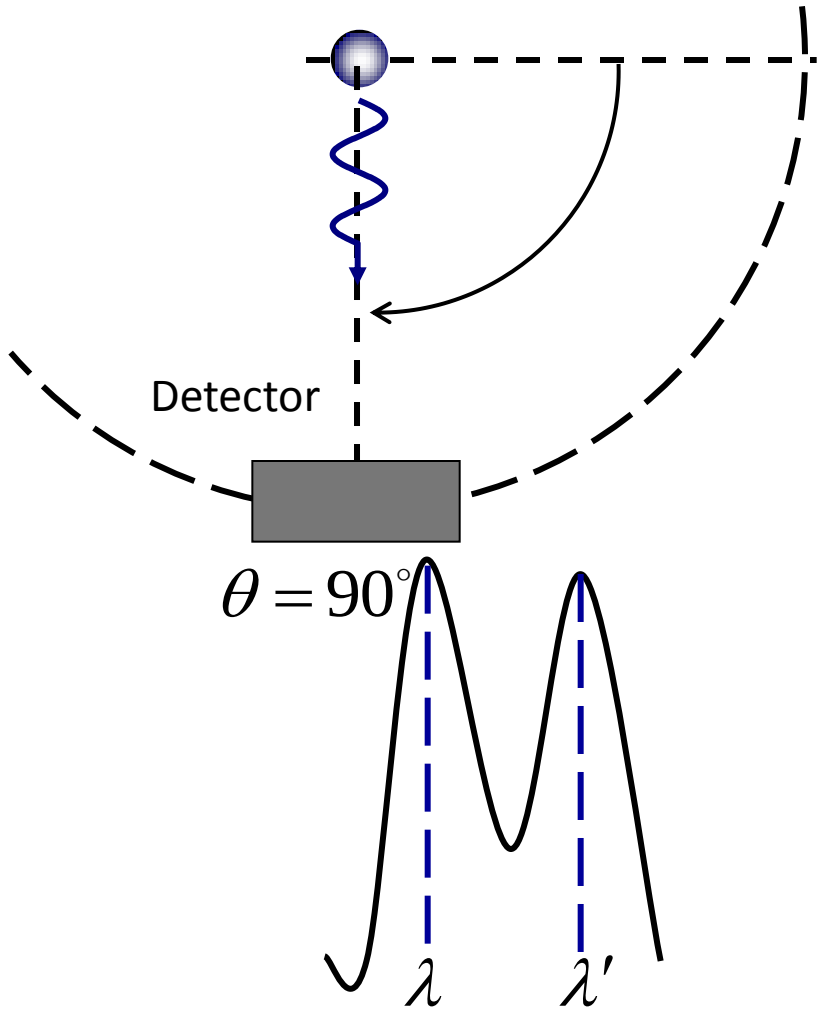

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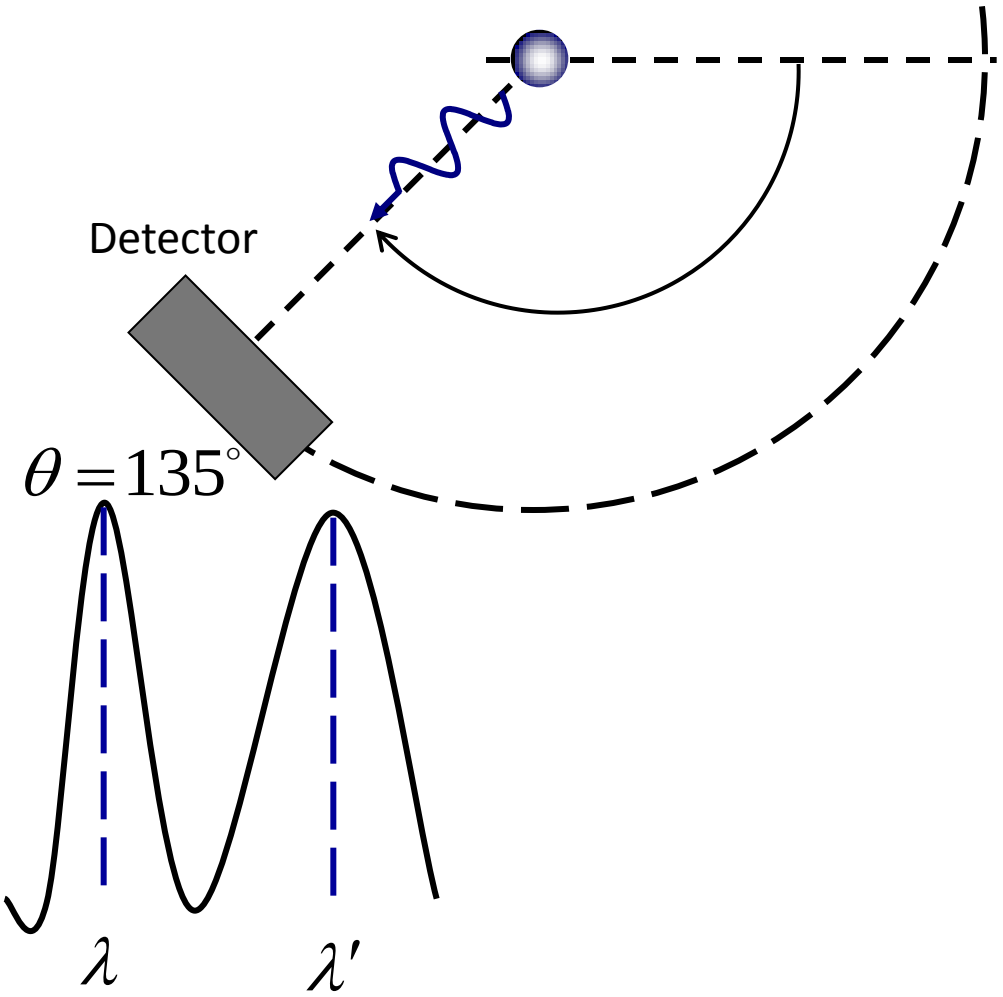
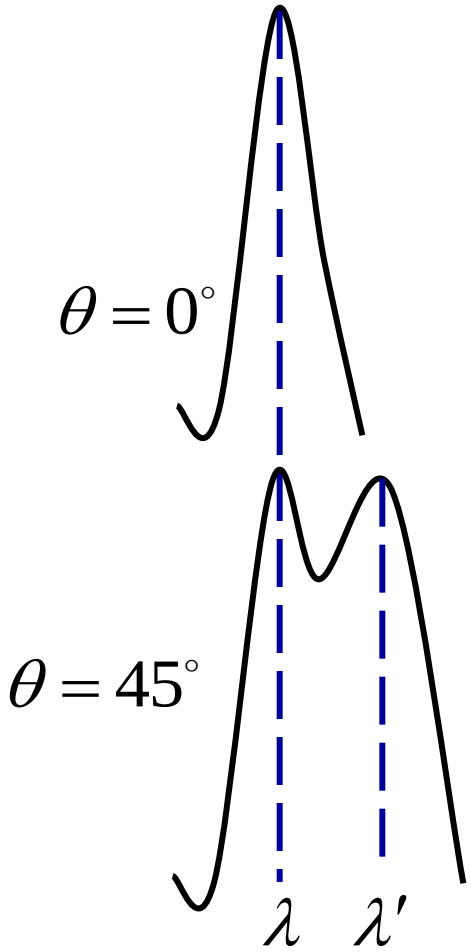
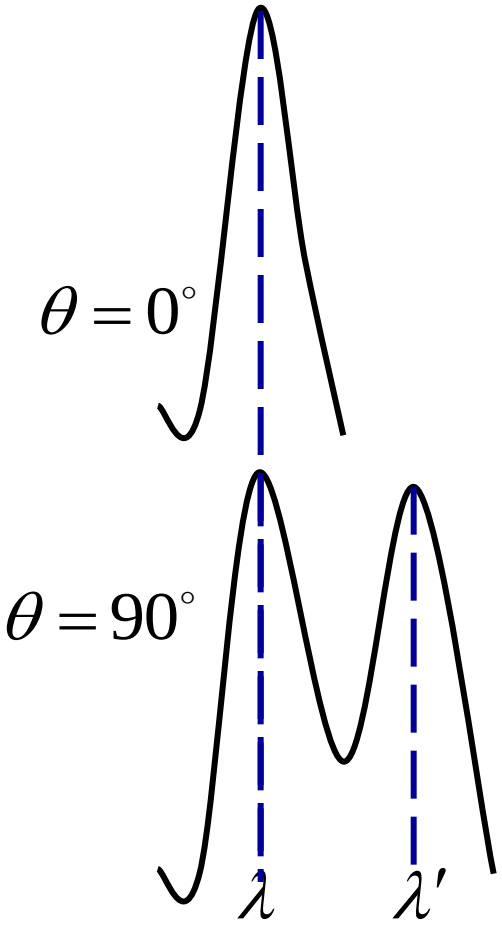


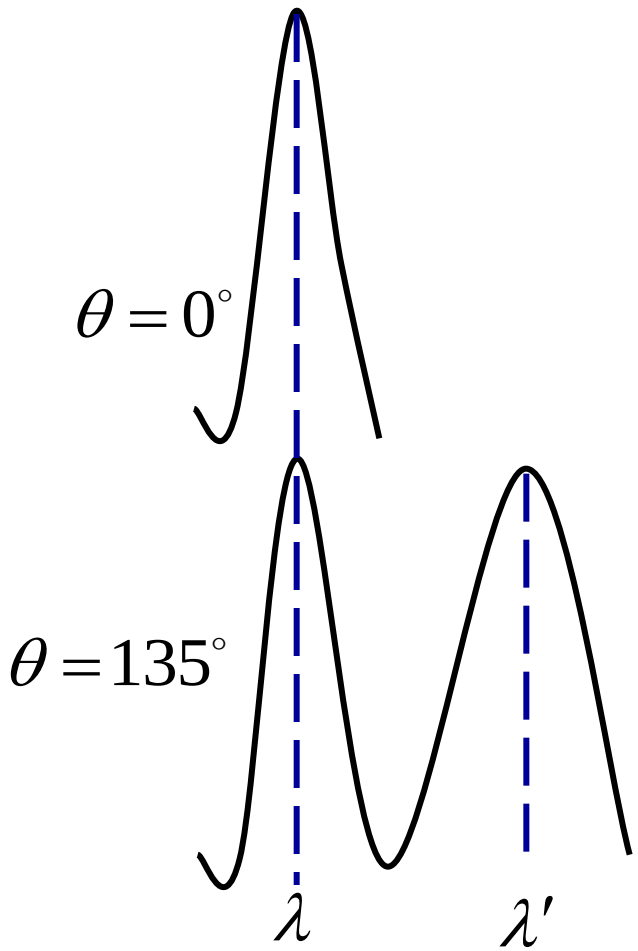
COMPTON EFFECT



COMPTON EFFECT

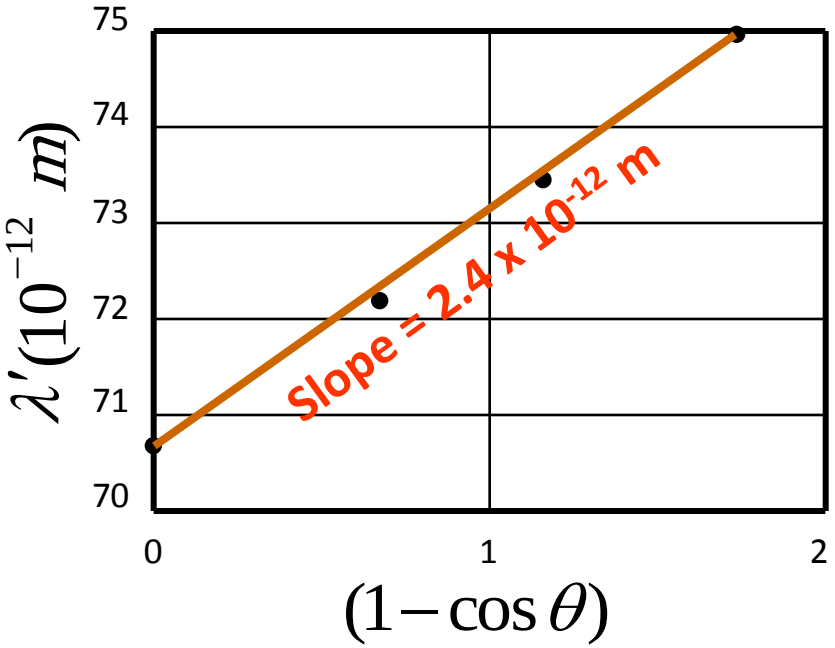


COMPTON EFFECT

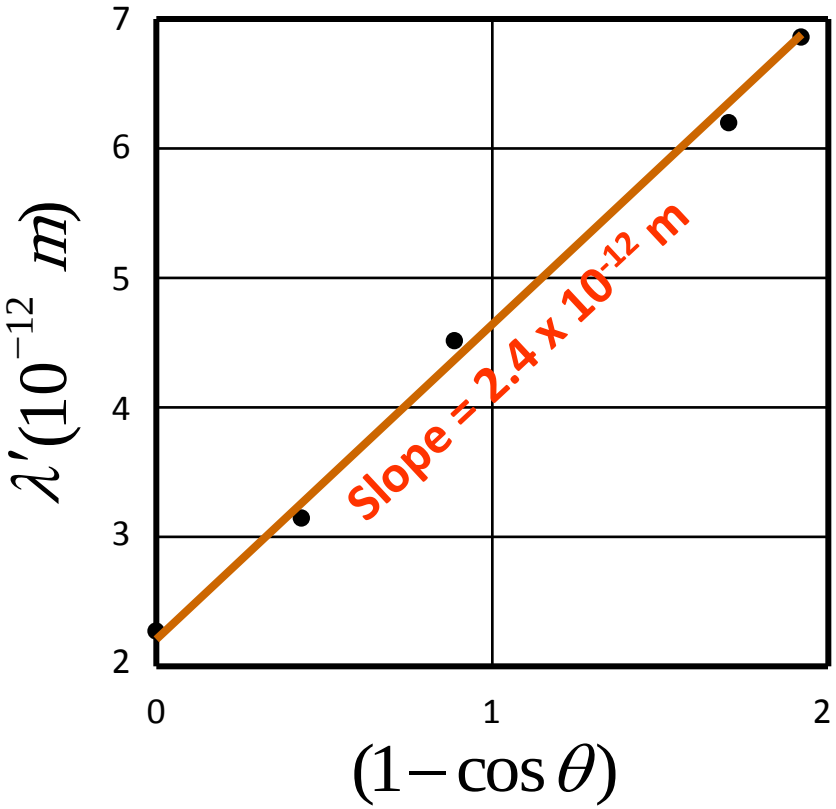


COMPTON EFFECT

X-Ray



γ-Ray



COMPTON EFFECT

Example 2.4:

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

(a) Find the wavelength of the x-rays scattered through 45^{0}.

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

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

COMPTON EFFECT

Remember….

Compton effect confirms the photon (particle) model…