

Physics & Astronomy - winter week 8 - Modern Physics

Zita

due 2 March
Tuesday

Giancoli Physics - Ch 36, -38

Team 1: Ch.36.4, Resolution. #20, 65 Mary + Zita

Team 2: Ch.37.11, E-mc². Q11 p.945, #36 p.946 Chelsea + Jared

Team 3: Ch.38.1-2: BB and PE effect. Q6 p.973, #15 p.974 Tristen + Matt

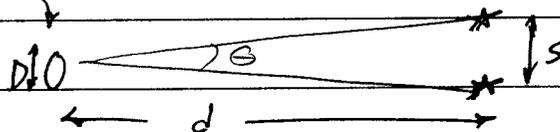
Team 4: Ch.38.3-4: Compton Effect. Q19 p.973, #25, 28 Joey + Brian

Team 5: Ch.38.5-6: waves/particles. #31, 37 Jenni + Erin

Zita: Bohr atom and Quantum mechanics (38 & 39)

#20
913 Two stars $d = 10$ ly away are barely resolved by a $D = 0.9$ m diameter telescope. How far apart (s) are the stars?

Assume $\lambda = 550$ nm



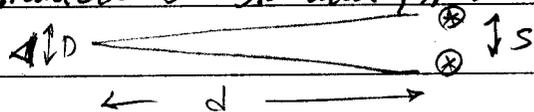
Rayleigh's criterion: aperture D can resolve angle $\theta = 1.22 \frac{\lambda}{D}$

$\theta =$

(radians)

Small angle formula: $s = d\theta =$

#65 (c) How far away can a human eye distinguish two car headlights that are $s = 2.0$ m apart? Eye diameter $D = 5.0$ mm, $\lambda = 500$ nm.



From (b), $\theta =$

Then $d = \frac{s}{\theta} =$

RESOLUTION + RELATIVITY

(36.65b) ⁹¹⁵ What is the minimum ^{angular} separation an eye could resolve when viewing two stars, considering only diffraction effects?

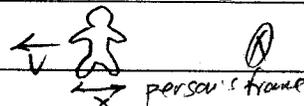
$$\theta = 1.22 \frac{\lambda}{D} = \frac{1.22 (500 \times 10^{-9} \text{ m}) (\text{rad}) \left| \frac{360^\circ}{2\pi \text{ rad}} \right| \left| \frac{60'}{1^\circ} \right|}{5 \times 10^{-3} \text{ m}} = \dots$$

In reality, it is about $\theta_{\text{actual}} = 1'$ of arc. Why the difference?

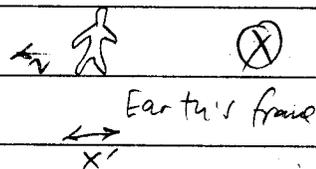
Ch 37- Relativity (945)

Q 11. If you were traveling away from Earth at speed $0.5c$, would you notice a change in your heartbeat? Would your mass, height, or waistline change? What would observers on Earth using telescopes say about you?

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = (1 - 0.5^2)^{-1/2} = \dots$$



$$x' = \frac{x}{\gamma} = \dots$$



36. (II) At what speed will an object's kinetic energy be 25 percent of its rest energy?

$$\text{rest energy} = mc^2$$

$$K = (\gamma - 1)mc^2$$

PHOTOELECTRIC EFFECT

Q38 Q6 If the threshold wavelength in the photoelectric (PE) effect increases when the emitting metal is changed, compare the work functions of the two metals

973

METAL I : λ_1

METAL II : $\lambda_2 > \lambda_1$

#15 In the PE, it is observed that no current flows unless the $\lambda_1 < 570 \text{ nm}$.
 (a) Find the metal's work func.
 (b) Find the stopping potential if light of $\lambda_2 = 400 \text{ nm}$ is used.

$$E_{\text{photon}} = KE_{\text{electron}} + \text{binding energy:}$$

$$hf = K_{\text{max}} + \Phi$$

$$hc = 1.24 \times 10^3 \text{ eV} \cdot \text{nm}$$

$$E_{\text{photon}} = \frac{hc}{\lambda} \geq \frac{hc}{\lambda_1} =$$

Current barely flows if $K_{\text{electron}} > 0$.

$$\text{Limiting case } \Phi = E_{\text{photon}} - K_{\text{max}} = \frac{hc}{\lambda_1} =$$

(b) Stopping potential is the voltage required to stop an electron with $K = eV$, where $K = \frac{hc}{\lambda} - \Phi$

$$V =$$

COMPTON EFFECT + emission (CE)

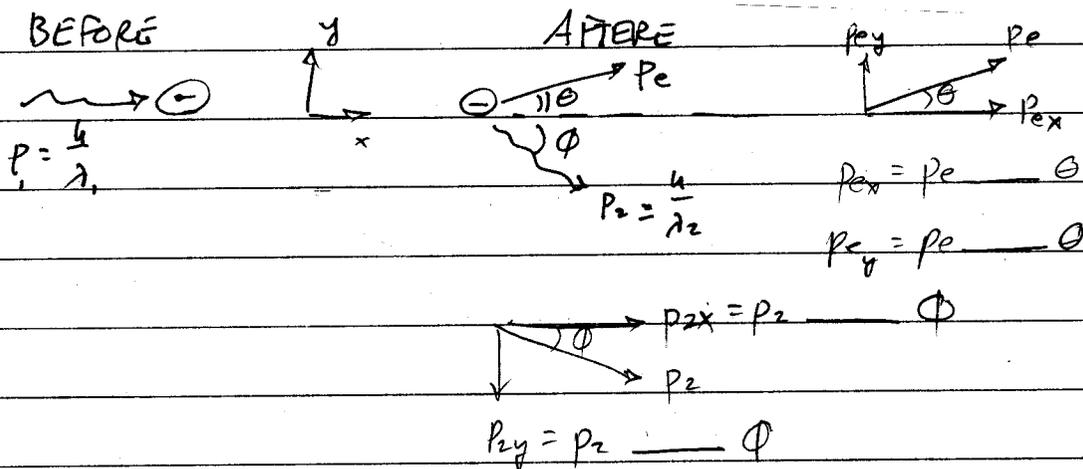
38. Q.19 Which can emit a line spectrum? continuous spectrum?

973

- (a) gases
- (b) liquids
- (c) solids

Q.18 In Rutherford's model, ^{of atom} what keeps e^- from flying off into space?

#25 CE: use the relativistic eqns of energy conservation and linear momentum to show that $\Delta\lambda = \frac{h}{m_e c} (1 - \cos\theta)$



Momentum conservation in x-direction:

$$p_1 = p_{ex} + p_{2x}$$

→

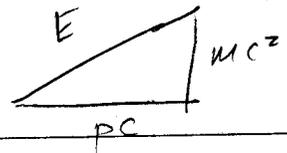
Momentum conservation in y-direction:

$$0 = p_{ey} - p_{2y}$$

→

(38.25)

Energy conservation



Relativistic electron energy

$$E_{\text{before}} = E_{\text{after}}$$

incident photon + electron's rest mass = outgoing photon + electron's total relativistic energy

$$\frac{hc}{\lambda_1} + mc^2 = \frac{hc}{\lambda_2} + (E = \sqrt{(pc)^2 + (mc^2)^2})$$

$$E: \quad \frac{hc}{\lambda_1} - \frac{hc}{\lambda_2} + mc^2 = \sqrt{(pc)^2 + (mc^2)^2}$$

Strategy: Square both sides and substitute in results from momentum conservation

$$\textcircled{1} p: \quad p \cos \theta = \frac{h}{\lambda_1} - \frac{h \cos \phi}{\lambda_2} \quad p \sin \theta = \frac{h \sin \phi}{\lambda_2}$$

$$p^2 \cos^2 \theta = \left(\frac{h}{\lambda_1} - \frac{h \cos \phi}{\lambda_2} \right)^2, \quad p^2 \sin^2 \theta = \frac{h^2 \sin^2 \phi}{\lambda_2^2}$$

Add and simplify momentum:

$$p: \quad p^2 = \left(\frac{h}{\lambda_1} \right)^2 + \left(\frac{h}{\lambda_2} \right)^2 - \left(\frac{2h^2}{\lambda_1 \lambda_2} \right) \cos \phi$$

$$\textcircled{2} E: \quad \text{Square energy: } \left(\frac{h}{\lambda_1} - \frac{h}{\lambda_2} + mc \right)^2 = p^2 + (mc)^2$$

$\textcircled{3}$ p into E and simplify

38.28 What is the longest wavelength that could produce a proton-anti-proton pair? $E = mc^2 = \frac{hc}{\lambda}$ where

$$m = 2 m_{\text{proton}} = \underline{\hspace{2cm}}$$

$$\lambda = \underline{\hspace{2cm}}$$

38.31 Calculate the wavelength of a $m = 0.21$ kg ball traveling at $v = 0.10 \frac{m}{s}$. Heisenberg uncertainty principle:

De Broglie wavelength: $\lambda = \frac{h}{mv}$ where $h =$ Planck's constant

37. Calculate the ratio of the kinetic energy of an electron to that of a proton if their wavelengths are equal.

Assume $v \ll c$.

$$\left(\lambda_e = \frac{h}{m_e v_e} \right) = \left(\lambda_p = \frac{h}{m_p v_p} \right) \rightarrow \frac{v_e}{v_p} = \underline{\hspace{2cm}}$$

$$\frac{K_e}{K_p} = \frac{\frac{1}{2} m_e v_e^2}{\frac{1}{2} m_p v_p^2} =$$