87/100

Examination Book

NAME Refath Bari #3

SUBJECT

INSTRUCTOR

EXAM SEAT NO. SECTION

DATE GRADE

1. 24

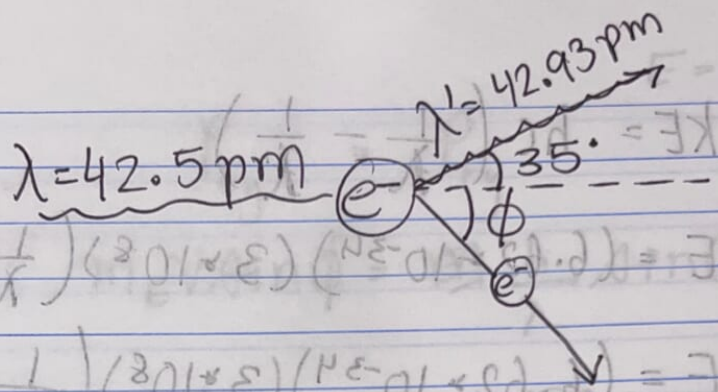
2. 47

3. 16

87

#2

C b)



$$\cancel{\vec{p}_i} = \cancel{\vec{p}_f}$$

$$|\cancel{\vec{p}_{F_i}}| = |\cancel{\vec{p}_{F_f}} + \vec{p}_{E_f}|$$

$\cancel{42.}$ $\cancel{hf}$

$$E_i = E_f$$

$$hf_i = hf_f + E_e$$

$$h(f_i - f_f) = E_e$$

$$hc\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = kE = (6.62 * 10^{-34})$$

$$KE = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right)$$

$$KE = (6.62 * 10^{-34})(3 * 10^{8})\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right)$$

$$KE = (6.62 * 10^{-34})(3 * 10^{8})\left(\frac{1}{42.5pm} - \frac{1}{49.3pm}\right)$$

$$KE = (1.986 * 10^{-25})\left(\frac{1}{42.5 * 10^{-12}} - \frac{1}{49.3 * 10^{-12}}\right)$$

$$KE = 1.986 * 10^{-25} * \frac{1}{10^{-12}}\left(\frac{1}{42.5} - \frac{1}{49.3}\right)$$

3

$$KE = 1.986 * 10^{-25} * 10^{12}\left(\frac{1}{42.5} - \frac{1}{49.3}\right)$$

$$KE = 1.986 * 10^{-13}(.00324)$$

$$KE = 6.44 * 10^{-16}\ J / (1.6 * 10^{-19}\ J/eV)$$

$$KE = 4028.39\ eV$$

$$KE = 4.028\ keV$$

$E = PC \rightarrow p = \frac{E}{c}$

$= \frac{hf}{c} = \frac{h}{\lambda}$

$P_{Ey} = P_{Fy}$

$m_E V \sin\phi = \frac{h}{\lambda} \sin(35^\circ)$ ✓

$\rightarrow 42.93$ pm

$\frac{1}{2} m_E v^2 = \cancel{4028.39}$

6.44×10^{-16} J

$v = \frac{2 \cdot 6.44 \times 10^{-16}}{9.1 \times 10^{-31}}$ = ?

$\cancel{v = 1.41 \times 10^{15}\ m}$

p_e direction ??

$\phi = ??$

Examination Book

NAME Refath Bari #2

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#2

B

metal	ϕ	Photoelectric effect?	V_{max}
lithium	2.3eV	YES (4.13 > 2.3)	$8.03 * 10^5$ m/s
berrylium	3.9eV	YES (4.13 > 3.9)	$2.8 * 10^5$ m/s
mercury	4.5eV	NO (4.13 < 4.5)	N/A

#2

C a) $\lambda = 42.5\ pm = 42.5 * 10^{-12}\ m$

$E = hf$ for photon

$E = \frac{hc}{\lambda} = \frac{(6.62 * 10^{-34})(3 * 10^8)}{(42.5 * 10^{-12})}$

$E = 4.67 * 10^{-15}\ J = 29205.8\ eV$
$= 29.2 \times 10^3\ eV$
$= 29.2\ keV$

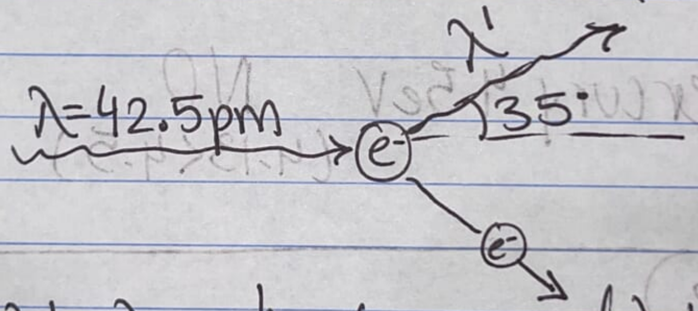
$E_{electron} = E_{photon}$

$$eV = \frac{hc}{\lambda} = 4.67 \cdot 10^{-15}\,J$$

$$V = \frac{4.67 \cdot 10^{-15}\,J}{1.6 \cdot 10^{-19}}$$

$$V = 29205.88 \text{ Volts}$$

b)



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

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

$$\lambda' = 42.5 \cdot 10^{-12}\,m + \frac{6.62 \cdot 10^{-34}}{(9.1 \cdot 10^{-31})(3 \cdot 10^{8})} \cdot (1-\cos(35°))$$

$$\lambda' = 42.5 \cdot 10^{-12}\,m + 2.42 \cdot 10^{-12}(1-\cos(35°))$$

$$\lambda' = 42.5 \cdot 10^{-12}\,m + 4.38 \cdot 10^{-13}\,m$$

4

$\lambda' = 42.5 * 10^{-12} m + 0.438 * 10^{-12} m$

$\lambda' = 42.93 * 10^{-12} m = 42.93 \text{ pm}$

Conservation of Momentum:

$$\vec{p}_i = \vec{p}_f$$

$$\vec{p}_f = \vec{p}_e' + \vec{p}_f'$$

$$hf_F = hf_F' + m_e v$$

$$\frac{h(f_F - f_F')}{m_e} = v_e \qquad \frac{1}{a \cdot 10^{-12}} - \frac{1}{b \cdot 10^{-12}}$$

$$\frac{hc\left(\frac{1}{\lambda_F} - \frac{1}{\lambda_F'}\right)}{m_e} = v_e \qquad \frac{1}{10^{-12}}($$

$$v_e = \frac{(6.62 * 10^{-34})(3 * 10^8)\left(\frac{1}{42.5\text{pm}} - \frac{1}{42.93\text{pm}}\right)}{(9.1 * 10^{-31})}$$

$$V_e = \frac{1.986 * 10^{-25}\left(\frac{1}{42.5pm} - \frac{1}{42.93pm}\right)}{9.1 * 10^{-31}}$$

?

$$V_e = 218241.75\left(\frac{1}{42.5pm} - \frac{1}{42.93pm}\right)$$

~~B~~ c) $2d\sin\theta = m\lambda$

$d = 0.2nm = .2 * 10^{-9} m$

$\lambda = 42.5pm = 42.5 * 10^{-12} m$

$2(.2 * 10^{-9})\sin\theta = 42.5 * 10^{-12} m$

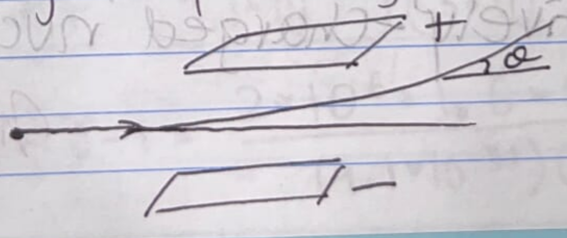
$$\sin\theta = \frac{42.5 * 10^{-12} m}{2(.2 * 10^{-9})} = 0.10625$$

5

$\theta = 6.099°$

d) In part C, we used the Bragg's law for diffraction in crystals. We see the wave-like properties of the x-ray, because diffraction is a wave phenomenon. In the other hand, we see a particle nature of the x-rays in part C, because momentum and energy is conserved, just like two particles or balls hitting each other. We thus see a wave-particle duality.

#3 J. J. Thomson predicted that an atom may be divisible because of his cathode ray tube experiment, which suggested there was a negatively-charged particle in the atom.



Using his experiment, Thomson was able to calculate e/m by balancing the electric and magnetic fields. After Thomson discovered the electron, ~~Re~~ Rutherford did an alpha particle scattering experiment in which +2 α alpha particles emitted from a source such as radium passed through, or bounced back from a thin gold foil. It had to be thin so there was not multiple scattering. Most α were transmitted, suggesting the atom was mostly empty space. But some bounced back, suggesting a small, dense, also large amount positively-charged nucleus. ??

2

plum-pudding

Model

2

4

Mass?

#3

B

$\cancel{E^{e^-}_{rest} = 0.511\text{ MeV} = m_e c^2}$

$\cancel{E^{p+}_{rest} = 988\text{ M}}$

$m^{p+}_{rest} = 938\text{ MeV}/c^2 \quad m^{e^-}_{rest} = 0.511\text{ MeV}/c^2$

$KE = 2\text{ MeV}$

a) de Broglie $\lambda = \frac{h}{p}$

2 MeV > 0.511 MeV so use relativistic p & KE

$KE = mc^2(\gamma - 1) = 2\text{ MeV}$

$p = mv\gamma$

$KE = (9.1\times10^{-31})(3\times10^8)^2(\gamma-1) = 2\times10^6\,\text{eV} \times 1.6\times10^{-19}\,\text{J/eV}$

$\cancel{KE} = \gamma - 1 = \frac{2\times10^6\times1.6\times10^{-19}\text{ J}}{(9.1\times10^{-31})(3\times10^8)^2}$

b) proton: $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mk}}$

$p = mv = \sqrt{2mk} = \sqrt{2m(\frac{1}{2}mv^2)}$

$k = \frac{1}{2}mv^2$ $= \sqrt{m^2v^2} = mv$

2 MeV << 938 MeV

So NO relativity needed.

$\lambda = \frac{h}{\sqrt{2mk}} = \frac{\cancel{6.62 \times 10^{-34}}}{}$

$\lambda = \frac{hc}{\sqrt{2mc^2k}} = \frac{1240\,eV}{\sqrt{2(938\,MeV/c^2)c^2k}}$

$\lambda = \frac{1240\ eV \cdot nm}{\sqrt{2 \cdot 938 \times 10^6 \cdot 2 \times 10^6 eV^2}}$

λ photon $= \frac{1240\ eV \cdot nm}{61253571\ eV} = 2.02 \times 10^{-5}\ nm$

$\lambda_{photon} = 2.02 \times 10^{-14} m$

a) $\gamma - 1 = \frac{3.2 * 10^{-13}}{8.19 * 10^{-14}} = 3.907$

$\gamma = 4.907$

$\frac{1}{\sqrt{1-\beta^2}} = 4.907 \Rightarrow \frac{1}{4.907} = \sqrt{1-\beta^2}$

$\left(\frac{1}{4.907}\right)^2 = 1-\beta^2$

$1 - \left(\frac{1}{4.907}\right)^2 = \beta^2$

$\beta = \sqrt{1-\left(\frac{1}{4.907}\right)^2} = .979$

$\beta = v/c = .979 \Rightarrow v = .98c$

$p = mv\gamma$

$= (9.1 * 10^{-31} kg)(.98c)(4.907)$

$\lambda = \frac{h}{p} = \frac{6.62 * 10^{-34}}{(9.1 * 10^{-31})(.98c)(4.907)}$

$\lambda_{electron} = \frac{6.62 * 10^{-34}}{1.31 * 10^{-21}} = \boxed{5.04 * 10^{-13} m}$

5

Examination Book

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d) $\Delta t = 3ns = 3\times10^{-9}s$

$\lambda = 500\,nm = 500\times10^{-9}\,m$

$f = f_0\left(\frac{1+\beta}{1-\beta}\right)^{1/2}$ for approaching

$f_0\lambda_0 = c \Rightarrow f_0 = \frac{c}{\lambda_0} = \frac{c}{500\times10^{-9}m}$

$f_0 = \frac{3*10^8\,m/s}{500*10^{-9}m} = 6\times10^{14}\,Hz$

$f = (6*10^{14}\,Hz)\left(\frac{1+\beta}{1-\beta}\right)^{1/2}$

where $\beta = v/c = .38c/c = .38$

$f = (6*10^{14}\,Hz)\left(\frac{1+.38}{1-.38}\right)^{1/2}$

$f = (6*10^{14}\,Hz)\left(\frac{1.38}{.62}\right)^{1/2}$

$f = 8.95*10^{14}\,Hz$

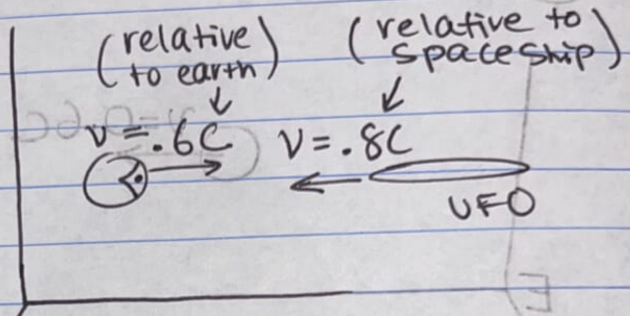
$\lambda = \frac{c}{f} = \frac{c}{8.95*10^{14}Hz} = 3.35*10^{-7}\,m$

4

in "nm"

??

c)



$$u_x' = \frac{u_x + v}{1 + \frac{v u_x}{c^2}}$$

$$.8c = \frac{.6c + vc}{1 + \frac{.6c \cdot vc}{\cancel{c^2}}}$$

$$.8\cancel{c} = \frac{\cancel{c}(.6+v)}{1 + .6v}$$

$$(1+.6v)(.8) = .6 + v$$

$$.8 + .48v = .6 + v$$

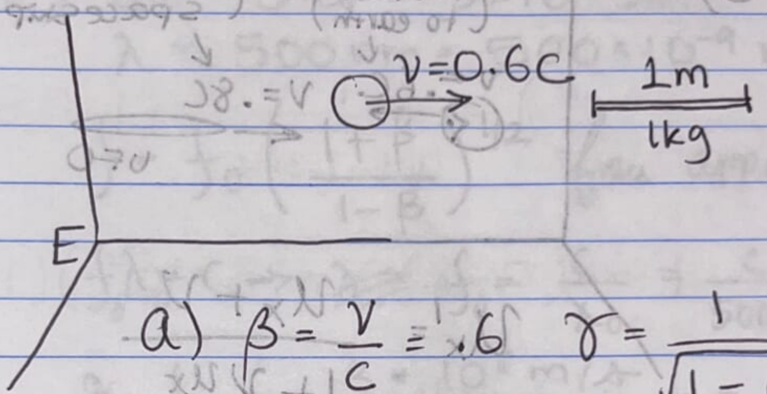
$$.2 = .52v \Rightarrow v = .38c$$

4

?

Direction??

#1

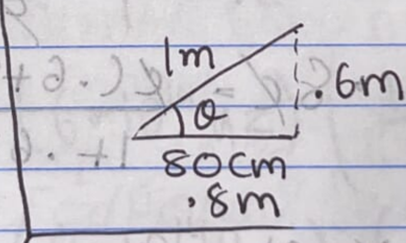


a) $\beta = \frac{v}{c} = .6 \quad \gamma = \frac{1}{\sqrt{1-\beta^2}} = 1.25$ 3

$L = \frac{1m}{1.25} = .8m$

$m = 1kg * 1.25 = 1.25kg$ 2

b)



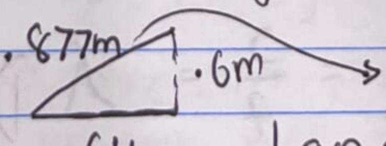
$\sqrt{1^2 - .8^2} = .6m$

$\theta = \tan^{-1}(.6/.8)$

$\theta = 36.86°$ 4

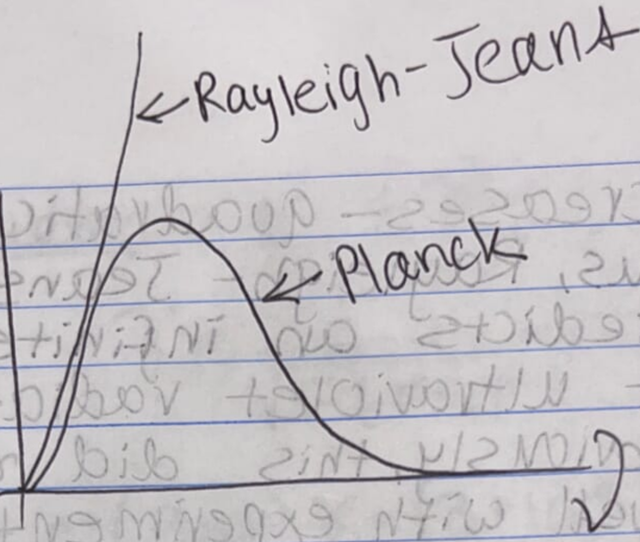
$x' = .8/\gamma = .64m$

$y' = y$ since $\perp$ to direction of motion 3



$\sqrt{.6^2 + (.64)^2} \approx .877m$

$\tan\theta = .6/.64 \Rightarrow \theta = 43.15°$

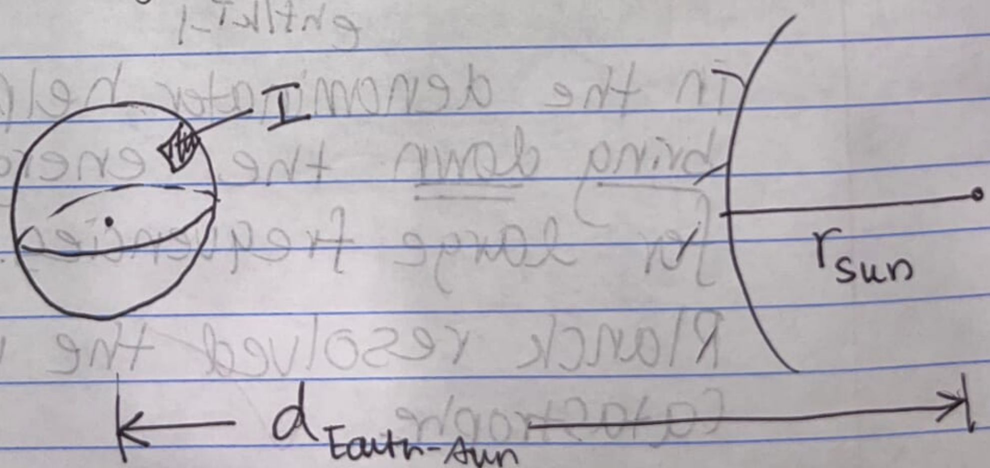


$$I = \frac{P}{A} = 1400 \, W/m^2$$

$$r_{sun} = 7 * 10^8 \, m$$

$$d_{Earth-sun} = 1.5 * 10^{11} \, m$$

Surface temperature of sun = ?



increases — quadratically!
Thus, Rayleigh-Jeans predicts an infinite amount of ultraviolet radiation. Obviously, this did not fit well with experimental data, so a resolution was needed.

Planck helped resolve the problem. By considering the energy of oscillators to be quantized as $E = hf$, planck obtained an average energy of $\langle E \rangle = \dfrac{hf}{e^{hf/kT} - 1}$. The exponential in the denominator helped to bring down the energy density for large frequencies. Thus, Planck resolved the ultraviolet catastrophe.

duration: $t = t_0 \gamma$

$$\gamma = \frac{1}{\sqrt{1-(.384c/c)^2}} = 1.081$$

$$t = (3ns)\gamma = (3*10^{-9})(1.081)$$

$$t = 3.24 ns$$

4

A=12
B=10

#2 The Rayleigh-Jeans formula
A explained the experimentally measured blackbody spectrum only for large wavelengths and short freqauvencies.
Why? Rayleigh-Jeans predicted the energy density to be

$$\rho(\nu) = \frac{8\pi\nu^2}{c^3} kT$$

Clearly, as the frequency $\nu\uparrow$ increases, the energy density lithium: $KE_{max} = 1.8375\ eV$

beryllium: $KE_{max} = 4.1375eV - 3.9eV = .23eV$

mercury: $KE_{max} =$ N/A (no photoelectric effect!)

$KE_{max} = 1.8375eV << 0.511\ MeV$

so not relativistic

$\frac{1}{2}mv^2 = 1.8375\cancel{eV} * 1.6 * 10^{-19}\ J/\cancel{eV}$

$\frac{1}{2}mv^2 = 2.94 * 10^{-19}\ J$

$\frac{1}{2}(9.1 * 10^{-31})\ v^2 = 2.94 * 10^{-19}\ J$

$$v^2 = \frac{2 * 2.94 * 10^{-19}\ J}{9.1 * 10^{-31}\ kg} = 6.46 * 10^{11}\ \frac{m^2}{s^2}$$

6

$v_{lithium} = 803836.95 = \underline{\underline{8.03 \times 10^5\ m/s}}$

$\frac{1}{2}(9.1 * 10^{-31})\ v^2 = \underline{0.23\ eV} * 1.6 * 10^{-19}\ J/eV$ → $KE << 0.511\ MeV$

$\frac{1}{2}(9.1 * 10^{-31})\ v^2 = 3.68 * 10^{-20}\ J$ (no relativity!)

$2.8 \times 10^5\ m/s$

$$v^2 = \frac{2 * 3.68 * 10^{-20}\ J}{9.1 * 10^{-31}\ kg} = 8.08 * 10^{10}\ m^2/s^2$$

↳ $v = 284392.5\ m/s$

$E = hf = (6.62 * 10^{-34})(1 * 10^{15}\ Hz)$

$E = \dfrac{6.62 * 10^{-19}\ J\ \cancel{* 1.6 * 10^{-19}}}{1.6 * 10^{-19}\ J/eV} = 4.1375 eV$ ✓

metal	ϕ	Photoelectric effect?
lithium	2.3eV ✓	YES (4.13 > 2.3) ✓
berylium	3.9eV ✓	YES (4.13 > 3.9) ✓
mercury	4.5eV	NO (4.13 < 4.5) ✓

<u>Velocities</u>: $hf = \phi + KE_{max}$

lithium $4.1375 = 2.3 + KE_{max}$

$1.8375 = KE_{max}$

$\cancel{1.87}\ KE\ \cancel{= 1.8375 \geq 0.}$

You need P at sun surface!!

3 total power: $P = \sigma A T^4 \Rightarrow \frac{P}{A} = \sigma T^4$

$\cancel{\left(\frac{1400}{\sigma}\right)^{1/4} = T_{sun} = \left(\frac{1400 \ W/m^2}{5.67 * 10^{-8} \ W/m^2k^4}\right)^{1/4}}$

$T = 396.4 \ K$ Wein's law

peak wavelength: $\lambda_{max} = \frac{W}{T}$ ✗

3 $\lambda_{max} = \frac{2.9 * 10^{-3} \ mk}{396.4 K} = 7.31 * 10^{-6} m$ ✗

#2 (B)

metal	ϕ
lithium	2.3eV
beryllium	3.9eV
mercury	4.5eV

$hf = \phi + KE$

$\lambda = 300 nm = 300 * 10^{-9} m$

$f = c/\lambda = c/(300 * 10^{-9}) = 1 * 10^{15}$