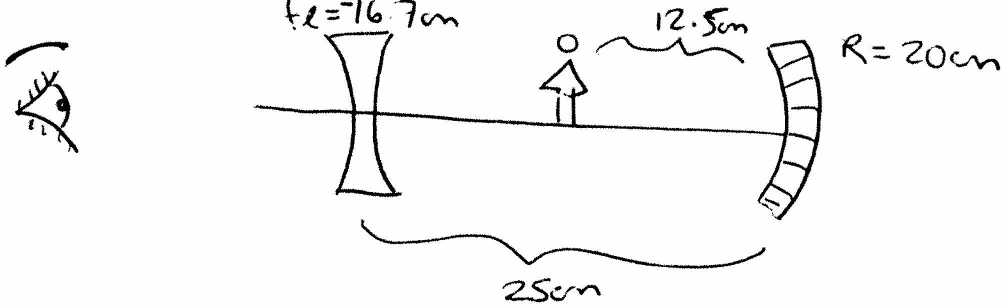
Physics Final Review

Frances Delaney

1) Lens + Mirror ~ Optics

→ Question From Midterm 1:



2) Mirror: R = 20cm → f = 10cm & f = R/2

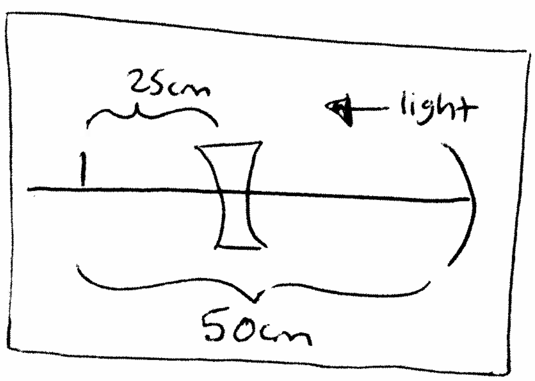
$$\frac{1}{p_m} + \frac{1}{q_m} = \frac{1}{f_m} \rightarrow \frac{1}{p_m} + \frac{1}{12.5\text{cm}} = \frac{1}{10\text{cm}}$$

real → (+)

$$\frac{1}{p} = \frac{1}{10} - \frac{1}{125}$$

$$\frac{1}{p} = \frac{12.5 - 10}{125}$$

$$\frac{1}{p} = \frac{2.5}{125}$$



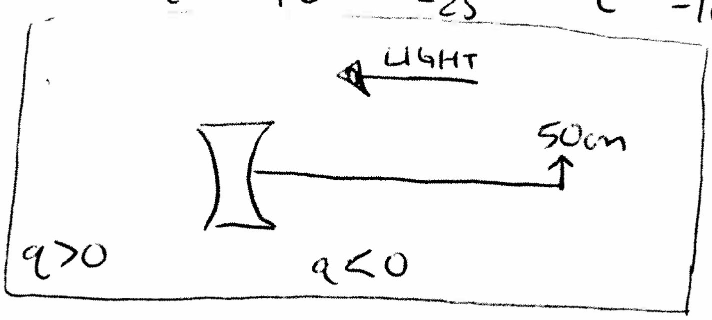
$p_m = 50$ cm

$p_L = -25$cm (virtual object)

$$\frac{1}{p_L} + \frac{1}{q_L} = \frac{1}{f_L} \rightarrow \frac{1}{-25} + \frac{1}{q} = \frac{1}{-16.7} \rightarrow \frac{1}{q} = \frac{1}{-16.7} + \frac{1}{25}$$

$$\frac{1}{q} = \frac{-25 + 16.7}{(16.7)25}$$

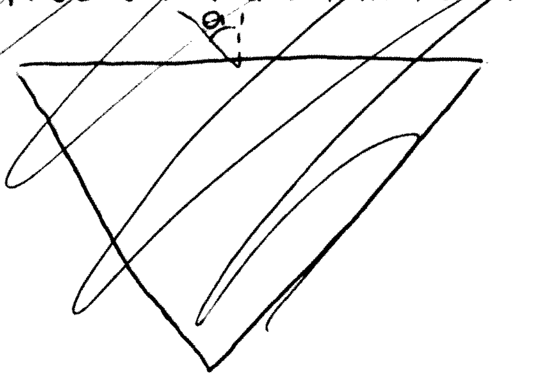
$$\frac{1}{q} = \frac{-8.3}{(16.7)25}$$



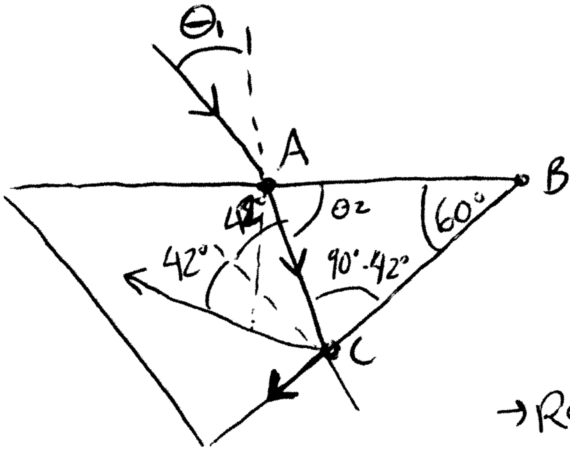
$q_L = -50$ cm

$$M = M_L \cdot M_m = \left(-\frac{-50}{-25}\right)\left(-\frac{50}{12.5}\right) = +8$$

~~Prism Problem from midterm~~



2) Prism Problem from Midterm 1:



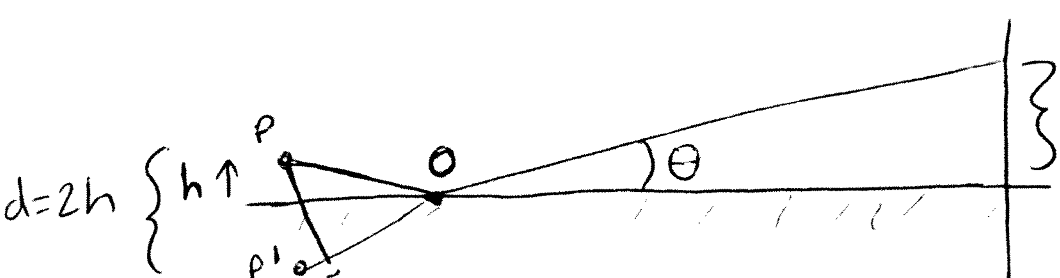
42° = critical angle
$\theta_1 = ?$

→ From △ABC:
$180° = \theta_2 + 48 + 60°$
$\theta_2 = 72°$

<u>Critical Angle = 42°:</u>
$n \sin 42 = \sin 90$
$n = \frac{1}{\sin 42}$ ⟶

→ Refraction at point A:
$\sin\theta_1 = n \sin (90 - \theta_2)$
$\sin\theta_1 = n \sin (18°)$
$\sin\theta_1 = \frac{\sin 18}{\sin 42}$

3) Lloyd's Mirror (Question from Midterm 2):

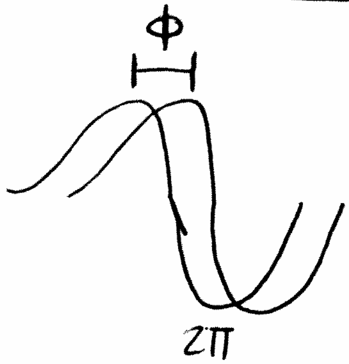


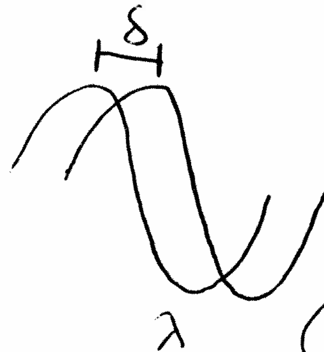
h = 1cm
L = 100m
λ = 500nm

<u>Condition for interference at point P:</u>

$\frac{\delta}{d} = \sin\theta \approx \frac{y_n}{L}$ (*Note: $\sin\theta = \tan\theta$ for small θ.)

Generally true for interference:





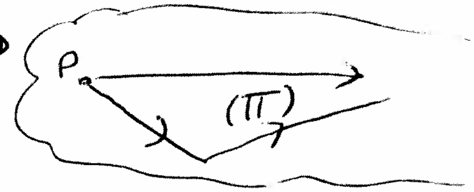
$$\frac{\delta}{\lambda} = \frac{\Phi}{2\pi}$$

$\Phi = (2\pi)m + \pi$ } for m
$\Phi = (2\pi)m$ } or m.

$$\frac{2\pi m + \pi}{2\pi} = m + 1/2$$

$$\frac{2\pi m}{2\pi} = m$$

For dark condition: $\boxed{\frac{\delta}{\lambda} = m}$ because →



$$\delta = m\lambda$$

$$\frac{y_m}{L} = \frac{\delta}{d} = \frac{m\lambda}{d} = \frac{m\lambda}{2h}$$

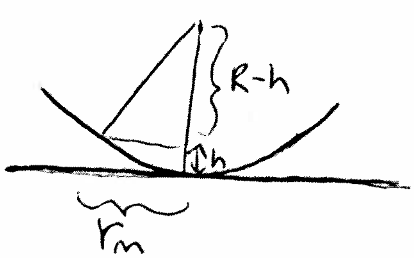
$$y_1 = \frac{\lambda}{2h} L = \frac{500 \times 10^{-9}}{2 \times 10^{-2}} 100m$$

$$= 5/2 \times 10^{-3} m$$

$$= \boxed{2.5 mm}$$

*because of the mirror, the fringes will be dark fringes (π shift)

4) Newton's Rings:



→Dark Fringe radii

$$R^2 = (R-t)^2 + r_m^2$$

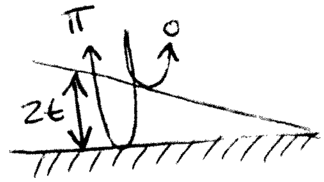
$$\cancel{R^2} = \cancel{R^2} - 2Rt + t^2 + r_m^2$$

$$2Rt - t^2 = r_m^2$$

↳ negligable t is small, t^2 = tiny.

Pythagorean Theorem

Interference:



Dark fringe condition: $\boxed{\dfrac{2t}{\lambda/n} = m}$

$$\boxed{2t = m\frac{\lambda}{n}}$$

$$r_m = \sqrt{2R\,\tfrac{1}{2}\,m\frac{\lambda}{n}}$$

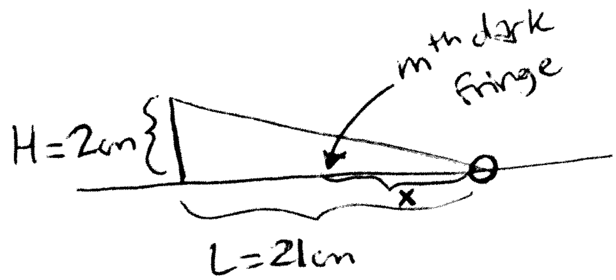
$$r_m = \sqrt{R\,m\frac{\lambda}{n}}$$

$n_{air} = 1$

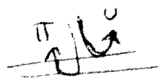
$$\boxed{r_m = \sqrt{R \cdot 1 m}}$$

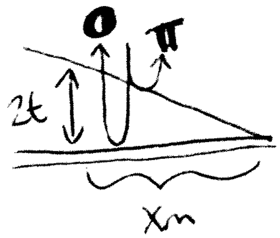
5) Wedge Question (DGD 6)

- glass on glass
- $\tan\theta = 2/21$
- $n = 1.55$



Dark because





$$\frac{t}{X_m} = \tan\theta$$

$$\frac{2t}{\lambda/n} = m$$

$$2t = m\left(\frac{\lambda}{n}\right)$$

$$t = \frac{1}{2}m\left(\frac{\lambda}{n}\right)$$

sub in

When $X_m = L$
$m = m_{max}$

$$\frac{\frac{1}{2}m\left(\frac{\lambda}{n}\right)}{X_m} = \frac{H}{L}$$

$$\boxed{X_m = \left(\frac{1}{2}\right)\left(\frac{\lambda}{n}\right)\left(\frac{L}{H}\right)m}$$

$$\frac{2t}{\lambda/n} = m$$

$$2t = m\frac{\lambda}{n} \rightarrow t = \frac{1}{2} m \frac{\lambda}{n}$$

$$L = \left(\frac{1}{2}\right)\left(\frac{\lambda}{n}\right)\left(\frac{L}{H}\right) m_{max} \rightarrow m_{max} = \frac{2nH}{\lambda} = \frac{(2)(1.55)(0.02m)}{500 \times 10^{-9} m}$$

$$\boxed{m_{max} = \frac{6.2}{5} \times 10^{+5}}$$

ANS: # of dark Fringes = $\frac{6.2}{5} \times 10^{+5} + 1$

6) Nuclear + Quantum Physics

$$N(t) = N_0 e^{-\lambda t}$$

Memorize!

$$N(t) = N_0 \left(\frac{1}{2}\right)^{\frac{t}{\tau_{1/2}}}$$

$$R = \frac{dN}{dt} = -\lambda N e^{-\lambda t}$$

$$= \lambda N(t)$$

$$\frac{\ln 2}{\lambda} = \tau_{1/2}$$

$$R = 100 \text{ decays / minute} = \frac{100}{60}\frac{d}{s} = \frac{10}{6}\frac{1}{s}$$

$$m = 44g \rightarrow 44g \times 6.5 \times 10^{10} \frac{\text{atoms}}{1g \text{ wood}} = N(0) \rightarrow N(0) = 2.86 \times 10^{12}$$

$$\boxed{6.5 \times 10^{10} \frac{\text{atoms}}{1 \text{ gram of wood}}}$$

$$N(t) = \frac{10}{6}\frac{1}{\lambda} \rightarrow \lambda N(t) = \frac{10}{6}$$

$$= \frac{10}{6}\left(\frac{\ln 2}{\lambda}\right)\left(\frac{1}{\ln 2}\right)$$

$$= \frac{10}{6}\frac{1}{\tau_{1/2}}\left(\frac{1}{\ln 2}\right)$$

$$5730y = 5730 \times 365 \times 24 \times 3600 = 1.8 \times 10^{11}$$

$$N(t) = N(0)\left(\frac{1}{2}\right)^{\frac{t}{\tau_{1/2}}}$$

$$\frac{N(1)}{N(0)} = \left(\frac{1}{2}\right)^{\frac{t}{\tau_{1/2}}}$$

$$\ln \frac{N(t)}{N(0)} = -(\ln 2)\frac{t}{\tau_{1/2}}$$

$$t = (\tau_{1/2})\frac{1}{\ln 2} \ln \frac{N(t)}{N(0)}$$

$$= (5730y)\frac{1}{\ln 2} \ln \frac{1.8\times 10^{11}}{2.86\times 10^{12}}$$

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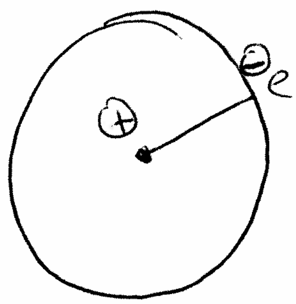
* Know basic rules for Bohr's atom (nothing on formula sheet → know how to derive it).

7) <u>Bohr's Atom</u>

$$U = k_e \frac{Qq}{r}$$

$$U = k_e \frac{(-e)(+e)}{r}$$



$$F = k_e \frac{e^2}{r^2} = m_e \frac{v^2}{r}$$

(Coulomb's) (centripetal)

$$E_{tot} = \underbrace{\frac{mv^2}{2}}_{K} - \underbrace{k_e \frac{e^2}{r}}_{U}$$

$$mv^2 = k_e \frac{e^2}{r}$$

$$E_{tot} = \frac{1}{2}k\frac{e^2}{r} - k\frac{e^2}{r} = -\frac{1}{2}k\frac{e^2}{r}$$

$$n\hbar = mvr$$

$$(mv)^2 = \left(\frac{n\hbar}{r}\right)^2$$

$$m\, mv^2 = k\frac{e^2}{r} m$$

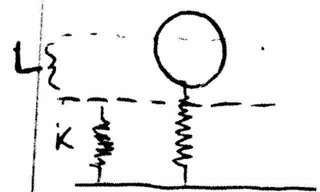
$$m^2v^2 = kme\frac{e^2}{r}$$

$$\frac{n^2\hbar^2}{r^2} = km\frac{e^2}{r} \rightarrow \boxed{\frac{n^2\hbar^2}{kme^2} = r}$$

Then sub into (E)

8) Vibrations (Midterm 1)

Balloon + spring Question:

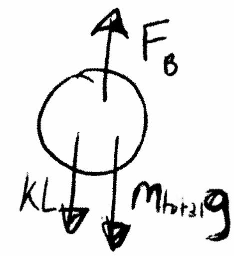


$K = 70\ N/m$

$M_{balloon} = 2g$

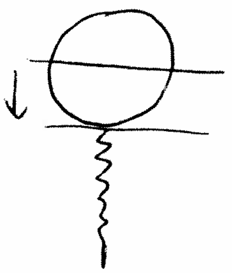
$V_{He} = 4\ m^3$

$\rho_{He} = 0.180\ Kg/m^3$



$F_B = g(V_{balloon} \cdot \rho_{air}) = KL + (m_{balloon} + \rho_{He} V_{bal})g$

↳ solve for L



$F_{elastic} = Kx = M_{total} \frac{d^2x}{dt^2}$

9) Speaker Questions:

Doppler

Max f → max V →

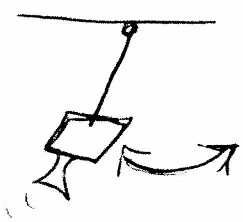
min f → max V ←

K given, mass given

$x = x_0 \cos \omega t$

$V = \frac{dx}{dt} = x_0 \omega \sin t$

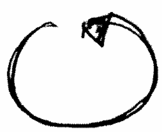
$V_{max} = x_0 \omega = x_0 \sqrt{\frac{K}{m}}$

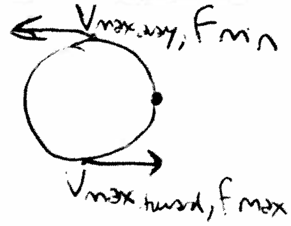


max f → max V

min f   min

$x_0 \omega = x_0 \sqrt{\frac{g}{l}}$



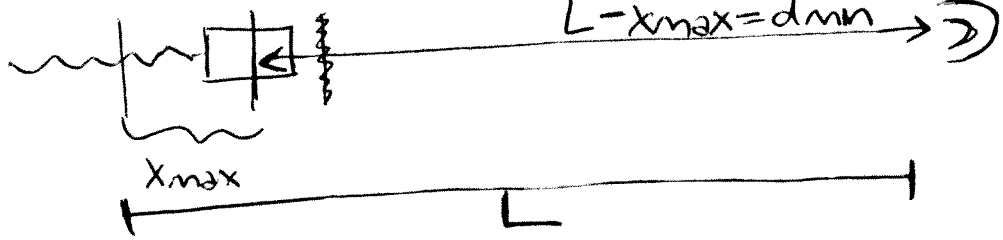


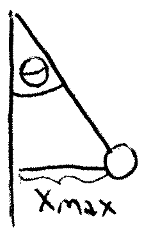
ω = known, r = known

$V_{max} = r \cdot \omega$

For Intensity, I_{max} happens when d_{min} →

For Intensity, $I_{max} \leftrightarrow d_{min}$





$$I_{max} = \frac{P}{4\pi d^2_{min}}$$

SHO: Always leads to solution of: $\frac{d^2x}{dt^2} = -\omega^2 x$

$x(t) = A\cos\omega t$

Calculation + Analysis

$$\frac{d^2\theta}{dt^2} = \square^2 \theta$$

$\square = \omega$

Speaker Question:

$k = 40 N/m$

$A = 0.6m$

a) $f = 480Hz$

$f_{max} = ?$

$f_{min} = ?$

$V_{max} = A\sqrt{\frac{k}{m}}$

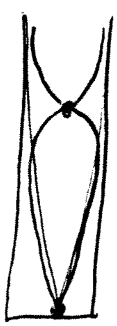
$= \_\_\_\_$

$\omega = \sqrt{\frac{k}{m}}$

$f_{max} = \frac{V_0}{V - V_s} f$

b) $f'''_{tube} = f_{max}$

$f_{max} = \frac{343}{343 - V_{max}}(480)$



$\boxed{\frac{3}{4}\lambda = L}$

$f_{min} = \frac{V}{V + V_s} f = \_\_\_\_$

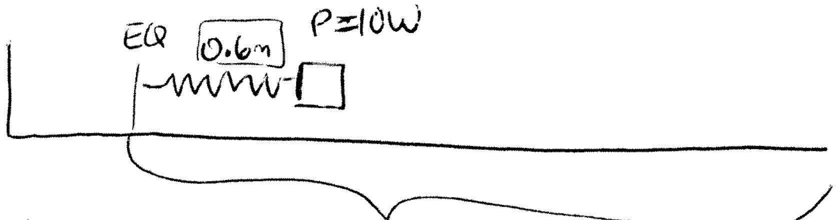
$\lambda = \frac{4}{3} L$

$\lambda f = V_s$

$f_{tube} = \frac{V_s}{\lambda} = \frac{V_s}{\frac{4}{3}L} = \boxed{\frac{3}{4}\frac{V_s}{L}}$ → $f_{max} = \frac{3}{4}\frac{V_s}{L}$

find L

c) I_{max}



$d_{min} = 11m - 0.6m = 10.4m$

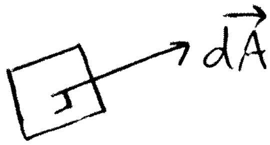
$I_{max} = \frac{10W}{4\pi(10.4m)^2}$

$I_{min} = \frac{10W}{4\pi(11 + 0.6)^2}$

$\beta = 10 \log \frac{I_{max}}{I_0} = \_\_\_\_$

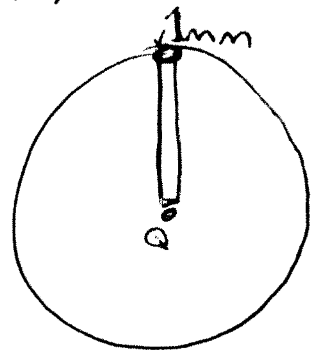
$\beta = 10 \log \frac{I_{min}}{I_0} = \_\_\_\_$

10) Gauss' Law: $\Phi_{net} = \frac{q}{\varepsilon_0}$; $\Phi_{net} = \oint \vec{E} \cdot d\vec{A}$



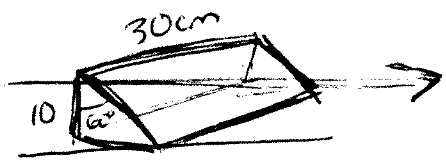
largest flux = perpendicular, tilt it, you get less + less flux.

#7 (pg 740) Question: $R = 10cm$
$Q = 10\mu C$
non-conducting

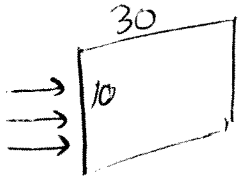


$\frac{q}{\varepsilon_0} \quad \frac{A_{hole}}{A_{sphere}}$

#4 pg 740



$|E| = 7.80 \times 10^4 \ N/C$



$\Phi = EA$

$E \cap w = 7.8 \times 10^4 \cdot 0.1 \cdot 0.3$

$\frac{N}{C} m \rightarrow 7.8 \times 0.03 \times 10^4$

Φ through ↑ = Φ through ↘

- what comes in goes out, flux is the same within an object

c) Net flux = 0

YALNAZ M.

Exam Review Session

1) Lens + mirror - optics
2) Lloyds mirror
3) newtons rings

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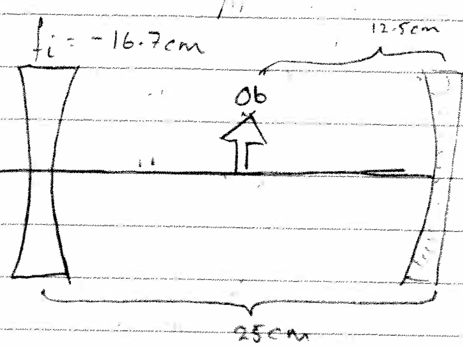
5)

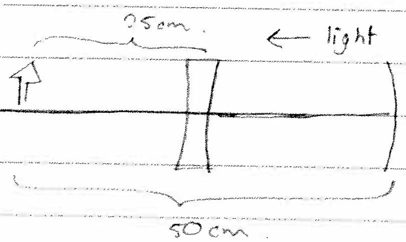


1) mirror $R = 20$ cm

$f = \frac{R}{2} = \frac{20}{2}$

$f = 10$ cm

$$\frac{1}{P_m} + \frac{1}{q_m} = \frac{1}{f_m} = \frac{1}{P_m} + \frac{1}{12.5} = \frac{1}{10}$$



$$\frac{1}{P_m} = \frac{1}{10} - \frac{1}{12.5}$$

$$\frac{1}{P_m} = \frac{1}{50}$$

$$P_m = 50$$

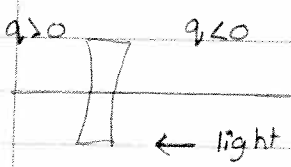
$P_L = -25$ cm

$$\frac{1}{P_L} + \frac{1}{q_L} = \frac{1}{f_L} = \frac{1}{-25} + \frac{1}{q_L} = \frac{1}{-16.7}$$

$$\frac{1}{q_L} = -\frac{1}{16.7} - \frac{1}{-25}$$

$$q_L = -50.30 \text{ cm}$$

$M = \frac{-q}{p}$

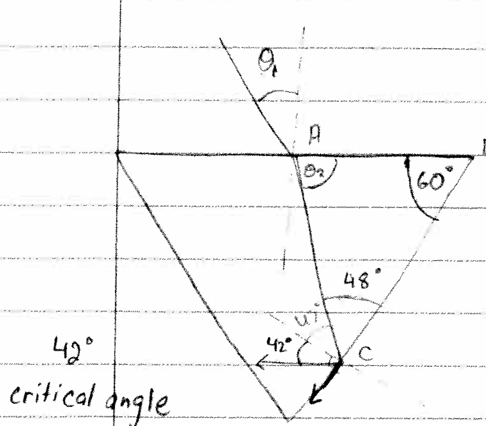


Magnification

$$M = M_L M_m = \left(-\frac{-50}{-25}\right)\left(-\frac{50}{12.5}\right)$$

$$= +8$$

Prism Problem - Dispersion (MIDTERM I)



From $\triangle ABC$

$180 = \theta_2 + 48 + 60$

$\theta_2 = 72°$

$90 - \theta_2 = 18°$

refraction at point A

$\sin\theta_1 = n \sin 18$.

n of prism

$n \sin 42 = \sin 90$

$n = \frac{\sin 90}{\sin 42}$

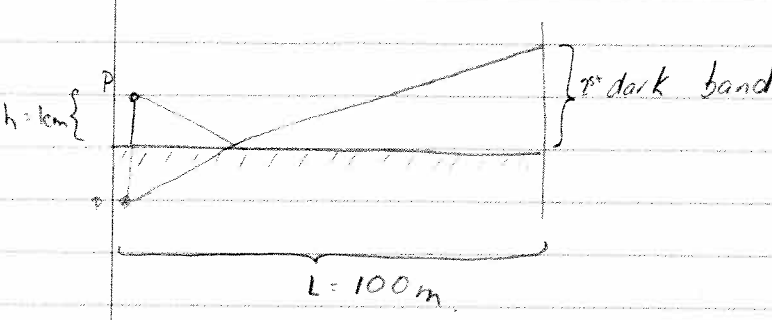
$n = 1.49$.

$\theta_1 = \sin^{-1}(1.49 \sin 18)$

$\theta_1 = 27.5°$.

4) (multiple choice on midterm II)

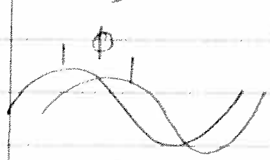
$\lambda = 500\,nm$.



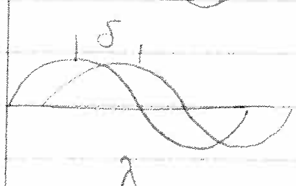
(Note: $\sin\theta \simeq \tan\theta$ for small θ)

$\frac{\delta}{d} = \sin\theta = \frac{y_m}{L}$

general interference



$\frac{\delta}{\lambda} = \frac{\phi}{2\pi}$.



$\phi = (2\pi)m + \pi$

$= \frac{(2\pi)m + \pi}{2\pi}$

$= m + \frac{1}{2}$

dark band (waves cancel)

$\frac{\delta}{\lambda} = m$.

$\delta = m\lambda$

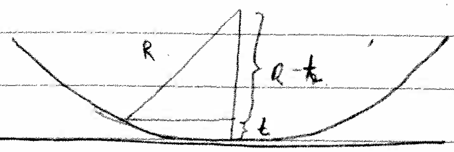
$\frac{y}{L} = \frac{m\lambda}{d}$

$y = \frac{\lambda}{2h} L$

$y = \left(\frac{500\times10^{-9}\,m}{2\times10^{-2}\,m}\right)(100\,m)$

$y = 2.5\,mm$

Newtons rings



radii

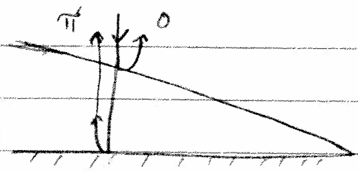
$$PT \longrightarrow R^2 = (R-t)^2 + r_m^2$$

$$R^2 = R^2 - 2Rt + t^2 + r_m^2$$

$$2Rt - \underbrace{t^2}_{\text{negligable}} = r_m^2$$

negligable . t (t is small)

Interference



dark fringe condition

$$\frac{2t}{\lambda/n} = m$$

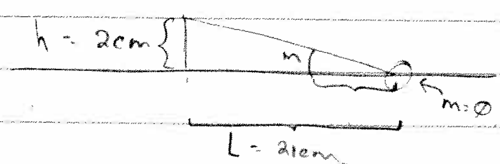
$$2t = m\frac{\lambda}{n}$$

$$r_m = \sqrt{2R\,\frac{1}{2}\,m\,\frac{\lambda}{n}}$$

$$r_m = \sqrt{R\,m\,\frac{\lambda}{n}} \qquad n_{air} = 1$$

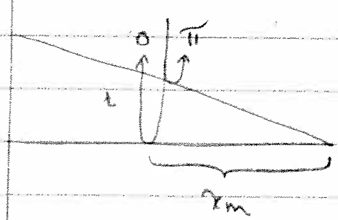
$$r_m = \sqrt{Rm\lambda}$$

Wedge



glass on glass

(DGD 6 #7?)



$$\frac{t}{x_m} = \tan\theta$$

$$\frac{2t}{\lambda/n} = m.$$

$$2t = m\frac{\lambda}{n}$$

$$t = \frac{1}{2}m\frac{\lambda}{n}$$

dark fringe $\tan\theta = \frac{2}{21}$

$$\frac{\frac{1}{2}m\frac{\lambda}{n}}{x_m} = \frac{H}{L}$$

$$x_m = \frac{1}{2}\,\frac{\lambda}{n}\,\frac{L}{H}\,m$$

When $x_m = L$

$m = m_{max}$

$$L = \frac{1}{2}\,\frac{\lambda}{n}\,\frac{L}{H} \Rightarrow m_{max}$$

$$m_{max} = \frac{2nH}{\lambda} = \frac{(2)(1.53)(0.02m)}{500\times10^{-9}m} = 1.24\times10^{5}$$

Nuclear and Quantum Physics

$N(t) = N_0 e^{-\lambda t}$ | $N(t) = N_0 \left(\frac{1}{2}\right)^{t/T_{1/2}}$ $\quad \frac{\ln 2}{\lambda} = T_{1/2}$

$R = \frac{dN}{dt} = \left| -\lambda N_0 e^{-\lambda t} \right| = \lambda N(t)$

Question on practice final

$R = 100 \frac{decays}{min} = \frac{100}{60} \cdot \frac{d}{s} = \frac{10}{6} \frac{1}{s}$

$m = 44g$ $\quad N(0) = (44)(6.5 \times 10^{10} \text{ atoms})$

6.5×10^{10} atoms/g wood $\quad N(0) = 2.86 \times 10^{12}$

$R = \lambda N(t) = \frac{10}{6}$ $\quad N(t) = N(0)\left(\frac{1}{2}\right)^{t/t_{1/2}}$

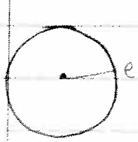
$N(t) = \frac{10}{6}\left(\frac{1}{\lambda}\right)$ $\quad \frac{N(t)}{N(0)} = \left(\frac{1}{2}\right)^{T/t_{1/2}}$

$= \frac{10}{6}\left(\frac{\ln 2}{\lambda}\right)\left(\frac{1}{\ln 2}\right)$ $\quad \frac{N(t)}{N(0)} = (\ln 2)\frac{T}{t_{1/2}}$

$= \frac{10}{6}(T_{1/2})\left(\frac{1}{\ln 2}\right)$ $\quad t = (T_{1/2})\frac{1}{\ln 2}\frac{N(t)}{N(0)} =$

5730 years $= 1.8 \times 10^{11}$ s

Bohr's atom



$F = k_e \frac{e^2}{r^2} = m_e \frac{v^2}{r}$ $\quad E_{TOT} = \underbrace{\frac{mv^2}{2}}_{k} - \underbrace{k_e \frac{e^2}{r}}_{U}$

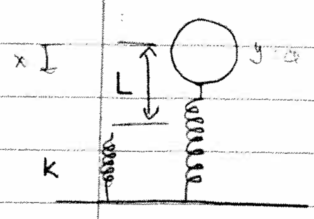
$mv^2 = k_e \frac{e^2}{r}$ $\quad n\hbar = mvr \rightarrow (mv)^2 = \left(\frac{n\hbar}{r}\right)^2$

$E_{TOT} = \frac{1}{2}k\frac{e^2}{r} - k\frac{e^2}{r} = -\frac{1}{2}k\frac{e^2}{r}$ $\quad m^2v^2 = km\frac{e^2}{r}$

$U = k_e \frac{Q_a}{r} = k_e \frac{(-e)(+e)}{r}$ $\quad \frac{n^2\hbar^2}{kme^2} = r \leftarrow (mv)^2 = \frac{n^2\hbar^2}{r^2}$

↳ sub into E_{TOT}

1 (spring balloon) midterm I



$k = 70\,N/m$

$M_{balloon} = 2g$

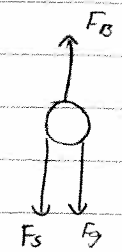
$V_{He} = 4\,m^3$

$\rho_{He} = 0.180\ kg/m^3$

F_B

$F_s = -km$

$F_g = mg$



$M_{He} = \rho_{He} V_{He}$

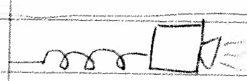
$$g(V_b\,\rho_{air}) = kL + (M_b + \rho_{He} V_{He})g$$

↑ solve for L.

$$\Uparrow F_{elastic} = kx = -M_{tot}\frac{d^2x}{dt^2}.$$

Speakers

doppler



max f → max v→

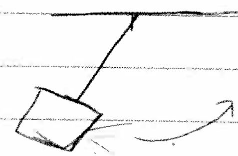
min f → max v←

k given.

m given

$x = x_0 \cos \omega t$

$\frac{dx}{dt} = x_0\,\omega \sin \omega t$

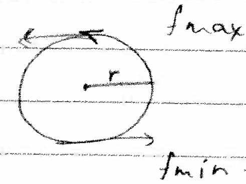


max f → max v

min v → min v

$x_0\omega = x_0\sqrt{\frac{g}{L}}$

$v_{max} = x_0\omega = x_0\sqrt{\frac{k}{m}}$

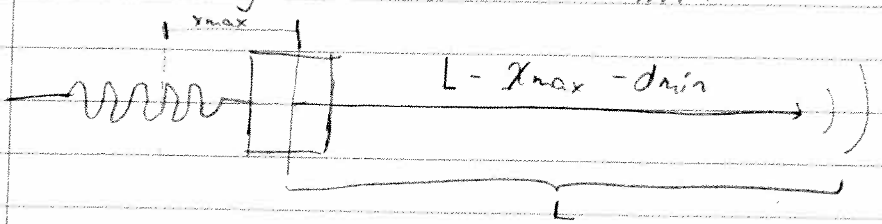


ω is given

r is given

$\}\ V_{max} = r\omega$

For intensity $I_{max} \longleftrightarrow X_{min}$



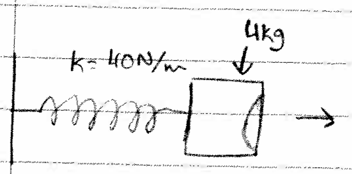
$$I_{max} = \frac{P}{4\pi d_{min}^2}$$

3) Question on midterm I (Bolt and speaker)

Simple Harmonic Oscillators

↳ always negative

Second derivative → $\frac{d^2x}{dt^2} = -\omega^2 x$ $x(t) = A\cos\omega t$



$V_{max} = A\sqrt{\frac{k}{m}} = 1.897\ m/s$

$A = 0.6\,m$

$f_{max} = ?$

$f_{min} = ?$

$f = 480\,Hz$

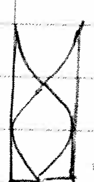
$f_{max} = \left(\frac{V_s}{V_s - V_o}\right) f$

$f_{min} = \left(\frac{V_s}{V_s + V_o}\right) f$

(b) 3rd Harmonic

$f'''_{tube} = f_{max}$

$\lambda f = V_s$



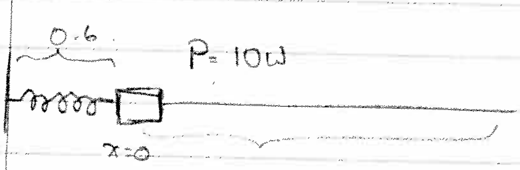
$\frac{3}{4}\lambda = L$

$\lambda = \frac{4L}{3}$

$f = \frac{V_s}{\lambda} = \frac{V_s}{\frac{4}{3}L} = \frac{3}{4}\frac{V_s}{L}$

$f_{max} = \frac{3}{4}\frac{V_s}{L}$

(c) I_{max}



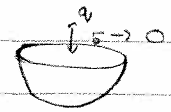
$I_{max} = \frac{10W}{4\pi(10.4)^2}$

$\beta = 10\log\left(\frac{I_{max}}{I_o}\right)$

$d_{min} = 11m - 0.6 = 10.4m$

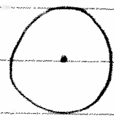
$d_{max} = 11m + 0.$

Gauss' Law



$\Phi_{net} = 0$

$\Phi_{net} = \Phi_{half\ sphere} + \Phi_{flat} = \emptyset$

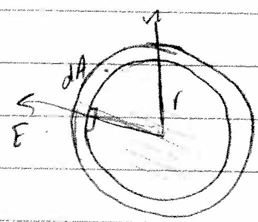


$\frac{1}{2} \frac{q}{\varepsilon_0}$

$\Phi_{flat} = \Phi_{net} - \frac{1}{2}\frac{q}{\varepsilon_0}$

$= -\frac{1}{2} \frac{q}{\varepsilon_0}$

$\Phi_{net} = \frac{q_{inside}}{\varepsilon_0}$ $\quad \Phi_{net} = \oint \vec{E} \cdot \vec{dA}$



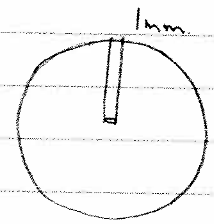
- a very small area of a sphere which is pretty much flat.

question 7 (section 24.2) - Pg 740 (textbook)

non-conduting

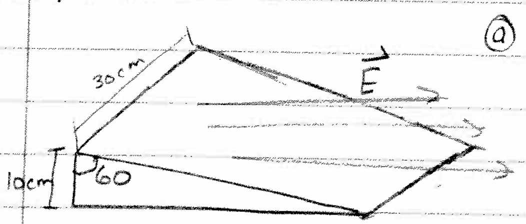
$R = 10cm$

$Q = 10\mu C$



$\frac{q}{\varepsilon_0} = \frac{A_{hole}}{A_{sphere}}$

questio 4



ⓐ $\vec{E} = 7.80 \times 10^4\ N/c$

$\Phi = E A$

$= (7.80 \times 10^4)(0.1)(0.3)$

$= 2340$

ⓑ total flux in closed surface is $\emptyset$, therefore

$\Phi_{slanted} = -\Phi_{vertical}$

ⓒ $\emptyset$