Physics 1c Fall 2009

Final Exam form A.

1) Fusion Energy

$$^3T + {}^3T \rightarrow {}^4He + 2n$$

The change in mass δm

$$\Delta m = 2m_T - m_{He} - 2m_n$$

$$= 2(3.016249) - 4.002603 - 2(1.008665)\,u$$

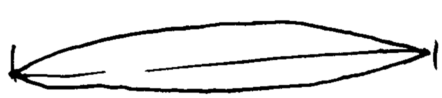
$$= 1.26 \times 10^{-2}\,u$$

$$E = \Delta m c^2 = \frac{1.26 \times 10^{-2}\,u\,(1.66 \times 10^{-27}\,kg/u)(3 \times 10^8\,m/s)^2}{1.6 \times 10^{-19}\,J/eV}$$

$$= 11.8 \times 10^6\,eV$$

$$= \boxed{11.8\,MeV}$$

2) Violin String - $f = 660\,Hz$ fundamental $\begin{cases} \rho = 7.8 \times 10^3\,kg/m^3 \\ L = 0.325\,m \\ D = 0.25\,mm \end{cases}$



L

$$\lambda = 2L$$

$$f = \frac{V}{\lambda} = \frac{V}{2L}$$

Speed of wave on a string -

$$V = \sqrt{\frac{F}{m/L}} \qquad m = \rho A L = \frac{\rho \pi D^2}{4} L$$

$$V = \sqrt{\frac{F L 4}{\rho \pi D^2 L}} = \sqrt{\frac{4F}{\rho \pi D^2}}$$

$$f = \frac{1}{2L}\sqrt{\frac{4F}{\rho \pi D^2}} = \sqrt{\frac{4F}{4L^2 \rho \pi D^2}}$$

$$f^2 = \frac{F}{L^2 \rho \pi D^2}$$

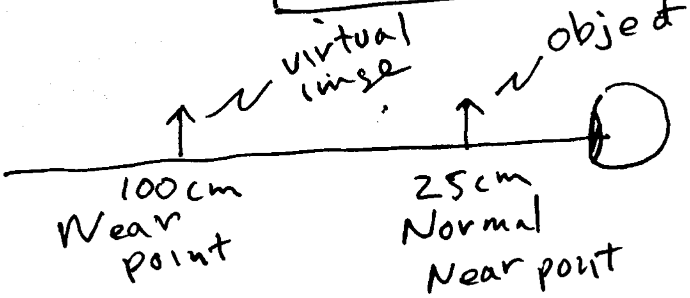
2)

$$F = f^2 L^2 \rho \pi D^2$$

$$= (660\ s^{-1})^2 (0.325\ m)^2 (7.8\times10^3\ \tfrac{kg}{m^3})\ \pi\ (0.25\times10^{-3})^2$$

$$F = \boxed{70.5\ N}$$

3)



A lens should produce an image of an object at the normal near point (25 cm) at the students near point (100 cm)

$$p = 25\ cm$$

$$q = -100\ cm$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$f = \frac{pq}{p+q} = \frac{(25)(-100)}{25-100} = 33.3\ cm$$

$$= 0.33\ m$$

$$P = \frac{1}{f} = \boxed{3.0\ \text{diopters}}$$

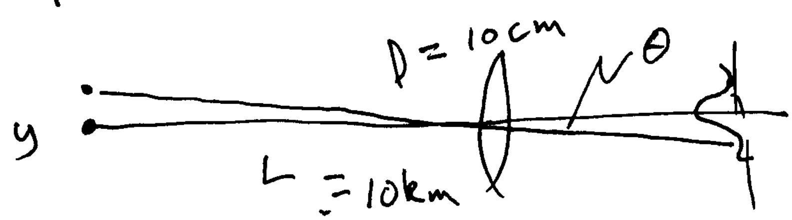
4) The earth with $T \approx 300K$ emits blackbody radiation with a peak in the infrared region – (where CO_2 and other greenhouse gasses absorb).

5) Compound microscope

$$m = \frac{L}{f_{ob}} \frac{25\text{ cm}}{f_{eyepiece}} = \frac{(22\text{ cm})}{(1.2\text{ cm})}\frac{(25\text{ cm})}{(4\text{ cm})}$$

$$m = \boxed{115}$$

6) Diffraction Limit – Camera



$\lambda = 500\text{ nm}$

$$\theta = 1.22\frac{\lambda}{D} = \frac{y}{L}$$

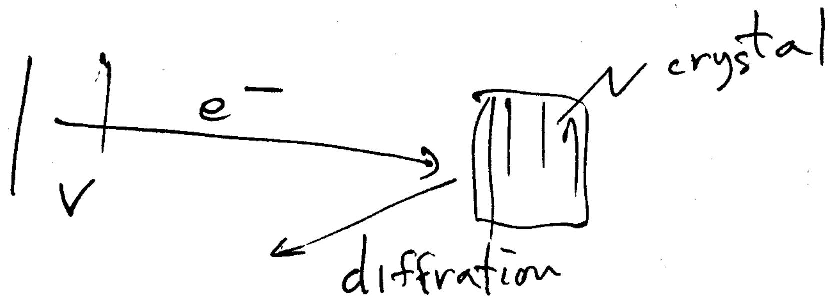
$$y = 1.22\frac{\lambda}{D}L = 1.22\frac{(500\times10^{-9}\text{ m})}{10\times10^{-2}\text{ m}}(10\times10^{3}\text{ m})$$

$$y = 6\times10^{-2}\text{ m} = \boxed{6\text{ cm}}$$

7) microwave radiation – ($f \sim 10$ GHz) has a wavelength near $\boxed{1\text{ cm}}$ and photon energy near $\boxed{10^{-4}\text{ eV}}$

8) The penetration depth for radiation increases in the order

$$\alpha < \beta < \gamma$$

9) 

The wavelength of the electrons decreases as the voltage increases due to the higher speed

$$\lambda = \frac{h}{mv} \quad \text{decreases}$$

The Bragg angle is given by

$$2d \sin\theta = m\lambda$$

∴ **θ will decrease**

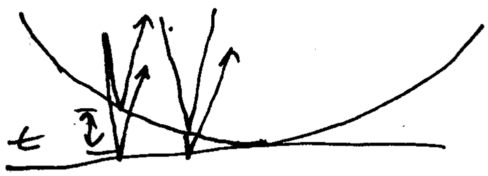
10) For ^{235}U fission, reaction is faster with slow neutrons (this is why a moderator is used in a nuclear reactor).

For fusion, reaction requires fast particles. This is why this reaction requires high temperatures

11) The liquid crystal display (LCD) is based on the rotation of the plane of polarized light

KZ

12) Newtons Rings



There is a phase shift of 180° between light reflected from the 2 surfaces ∴

∴ for constructive interference (Bright fringe) the requirement is

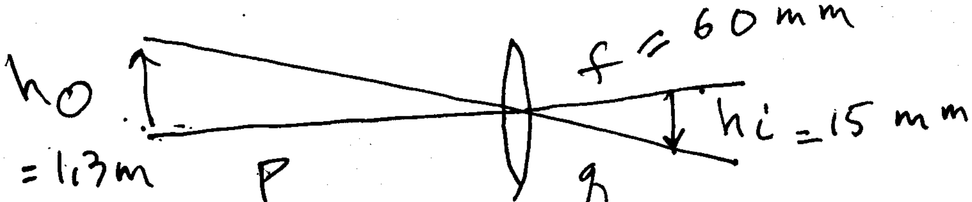
$$2t = \lambda(m+\tfrac{1}{2}) \quad (m=0,1,2\cdots)$$

the second fringe has $m=1$

$$2t = \lambda(1+\tfrac{1}{2}) = \lambda(\tfrac{3}{2})$$

$$t = \frac{3}{4}\lambda = \frac{3}{4}(500) = \boxed{375\,nm}$$

13) Digital Camera

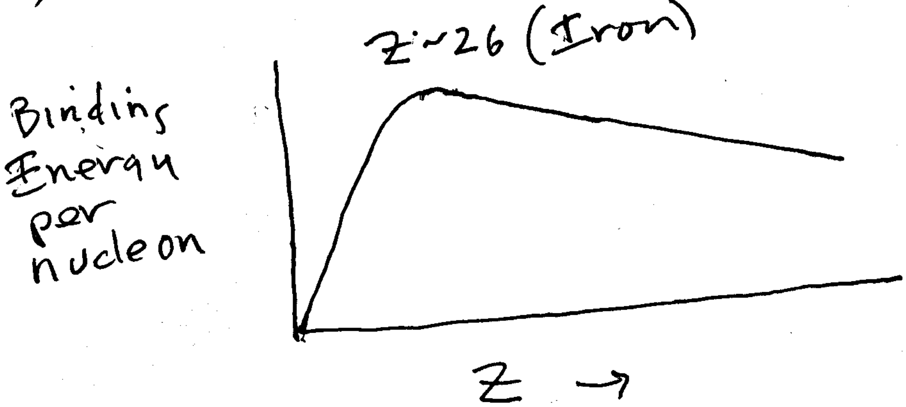


For the camera the object is much farther from the lens than the focal length $p \gg f$ so to a good approximation the image is close to the focal point $q \sim f$.

Then
$$\frac{h_o}{h_i} = \frac{p}{q} = \frac{p}{f}$$

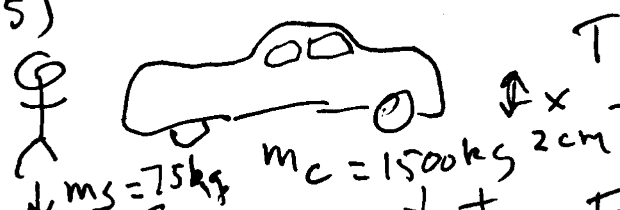
$$p = \frac{h_o}{h_i} f = \frac{1.3\,m}{15\times10^{-3}\,m}(60\times10^{-3}\,m) = \boxed{5.2\,m}$$

14) Curve of the Binding Energy



At high Z the energy per nucleon due to the short range nuclear force is almost contant since the average no. of near neighbors is almost not changing. However, the energy due to the long-range electrical force continues to increase. This reduces the binding energy as Z increases.

(5)



The oscillations are due to the springs in the suspension

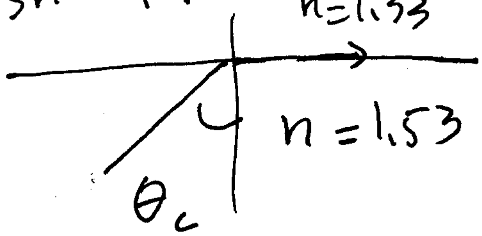
Force constant $F = kx$

$$k = \frac{F}{x} = \frac{m_s g}{x}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m_s + m_c}} = \frac{1}{2\pi}\sqrt{\frac{m_s g}{x(m_s + m_c)}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{75\,\text{kg}\,(9.8\,\text{m/s}^2)}{2\times10^{-2}\,\text{m}\,(75 + 1500)\,\text{kg}}} = \boxed{0.77\,\text{Hz}}$$

16) Light Pipe

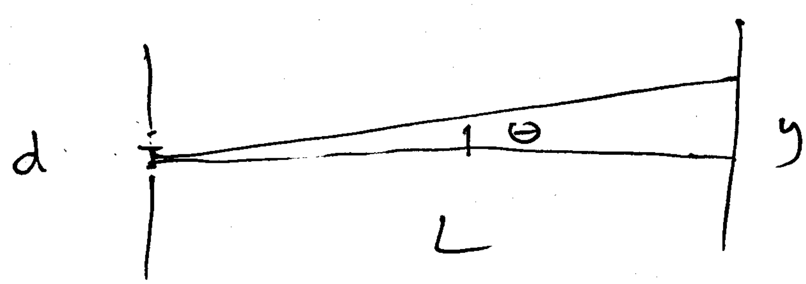


$$n_p \sin\theta_c = n_w \sin 90$$

$$\sin\theta_c = \frac{n_w}{n_p} = \frac{1.33}{1.53} = 0.869$$

$$\boxed{\theta_c = 60^\circ}$$

17) Two-slit interference



$d \sin\theta = m\lambda$ $\quad m = 1$

$\sin\theta = \frac{y}{L}$ for small angles

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

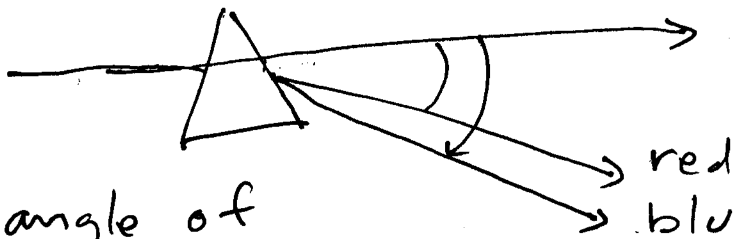
$$d = \frac{m\lambda L}{y} = \frac{(650\times10^{-9}\,m)(10\,m)}{(2\times10^{-2}\,m)}$$

$$d = 3.2\times10^{-4}\,m$$

$$\boxed{0.32\,mm}$$

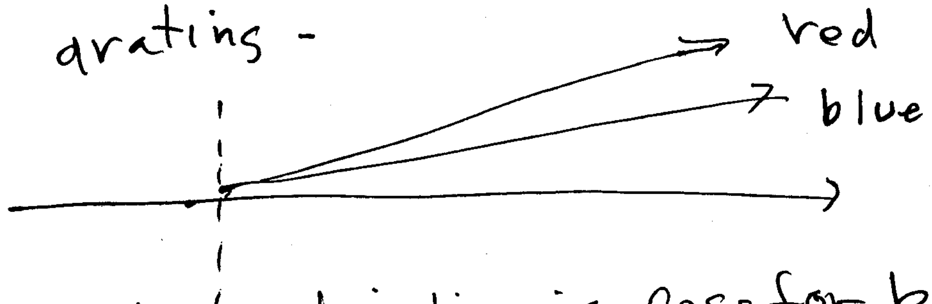
18) Dispersion of Light

prism



The angle of deviation for blue is greater than red since $n_{blue} > n_{red}$ - and the deviation increases with increasing n.

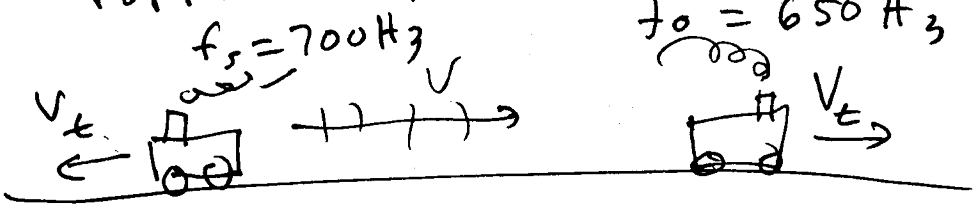
grating -



The angle of deviation is less for blue than red due to the relation -

$$d \sin \theta = m \lambda$$

19). Doppler effect



The two trains are moving away from each other since the frequency is lower

$$f_o = f_s \frac{(V - V_o)}{(V + V_s)} = f_s \frac{(V - V_t)}{(V + V_t)}$$

$$f_o V_t + f_o V = f_s V - f_s V_t$$

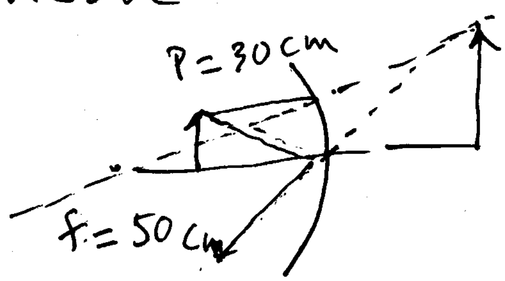
19) $f_o V_t + f_s V_t = f_s V - f_o V$

$$V_t = \frac{V(f_s - f_o)}{f_o + f_s} = \frac{340\,m/s\,(700 - 650)\,Hz}{(700 + 650)\,Hz}$$

$$V_t = \boxed{12.6\ m/s}$$

20) The incandescent light bulb is inefficient because it has a spectrum like a black body at ~4000K which has an appeciable fraction of light in the infrared region which is not useful for illumination.

21) Concave Mirror



$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$q = \frac{pf}{p-f} = \frac{(30)(50)}{30-50} = -75\,cm$$

$$m = -\frac{q}{p} = -\frac{(-75)}{30} = 2.5$$

22) ^{14}C dating –

$T_{\frac{1}{2}} = 5700$ yr

The ^{14}C in the wood decays so the no of nuclei is reduce by a factor of 10.

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

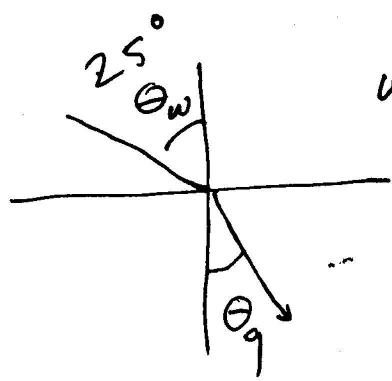
$$\frac{N}{N_0} = \frac{1}{10} = \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

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

$$t = T_{\frac{1}{2}} \frac{\log N/N_0}{\log 1/2} = 5700 \frac{\log(0.1)}{\log(0.5)}$$

$$\boxed{t = 1.9 \times 10^4 \text{ yrs}}$$

23) Refraction



water $n_w = 1.33$

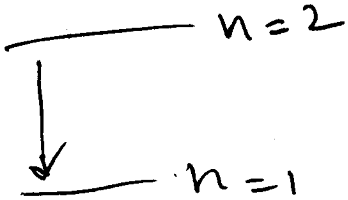
glass $n_g = 1.50$

$$n_w \sin\theta_w = n_g \sin\theta_g$$

$$\sin\theta_g = \frac{n_w \sin\theta_w}{n_g} = \frac{1.33 \sin 25}{1.50}$$

$$\boxed{\theta_g = 22^\circ}$$

24) K_α ~~x~~rays Tungsten $Z = 74$



for an electron interacting with the nucleacharge

$$E_n = -Z_{eff}^2 E_0 \left(\frac{1}{n^2}\right)$$

where $E_0 = 13.6$ eV

We take $Z_{eff} = Z$

Then

$$\Delta E = E_{n=2} - E_{n=1} = Z^2 E_0 \left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$\Delta E = Z^2 E_0 (3/4) = (74)^2 (13.6 eV)(3/4)(1.6\times10^{-19} J/eV) = 8.9\times10^{-15} J$$

The wavelength of the x ray is -

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

$$\lambda = \frac{hc}{\Delta E} = \frac{6.6\times10^{-34} J\cdot s\ (3\times10^{8}\ m/s)}{8.9\times10^{-15} J}$$

$$\lambda = 2.2\times10^{-11} m$$

0.022 nm

25) The uncertainty principle states that

$$\Delta x\, \Delta P_x \geq \frac{h}{4\pi}$$

In the quantum limit when Δx decreases ΔP_x must increase -