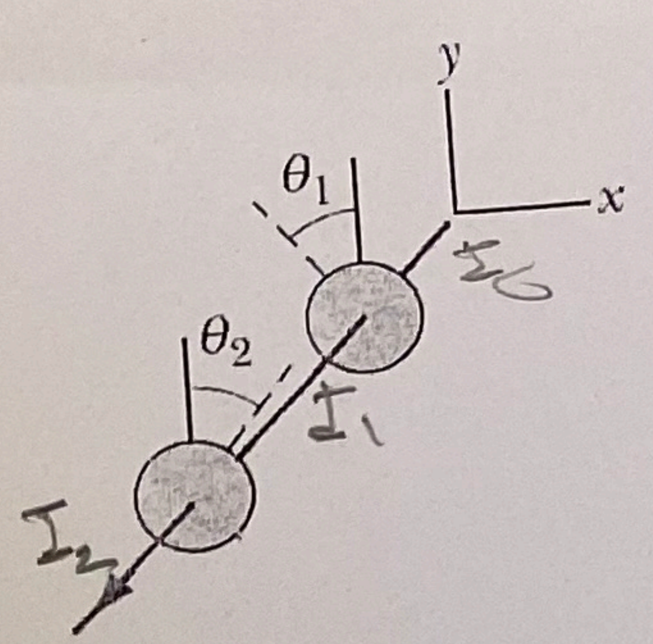
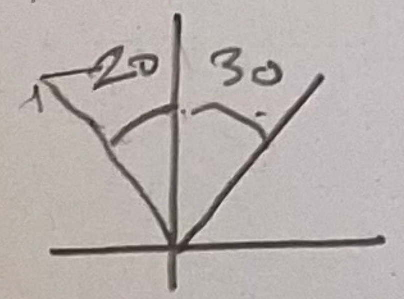
Q5: (10 pts) 10

a) A beam of unpolarized light, is sent into a system of two polarizing sheets with polarizing directions at angles θ_1 = -20° and θ_2 = +30° to the y axis, as shown in Fig. What is the intensity of the unpolarized light if the intensity of the transmitted light by the system is 40 W/m²? **(5 pts)**



b) At what rate must the potential difference between the plates of a parallel-plate capacitor with a 2.0 mF capacitance be changed to produce a displacement current of 2.5 A? **(5 pts)**



a) $I_0 = ?$ $\quad I_2 = 40\ W/m^2$ $\quad \theta_{between} = 50°$

$I_1 = \frac{I_0}{2}$

$I_2 = I_1 \cos^2(50)$ 5

$I_2 = \frac{I_0}{2}\cos^2(50)$

$I_0 = \frac{2 I_2}{\cos^2(50)} = \boxed{193.62\ W/m^2}$

(b) $\frac{dV}{dt} = ?$ $\quad i_d = 2.5\ A$

$\cancel{E = \frac{\epsilon_0 A}{d}}$ $\quad \cancel{q = CV}$

$E = \frac{\sigma}{\epsilon_0} = \frac{q}{A\epsilon_0} = \frac{CV}{A\epsilon_0}$

$i_d = \epsilon_0 \frac{d\Phi_E}{dt}$

$i_d = \epsilon_0 \cdot A \frac{dE}{dt}$

$i_d = \epsilon_0 A \cdot \frac{d}{dt}\left(\frac{CV}{A\epsilon_0}\right)$

$i_d = \frac{\epsilon_0 A}{A\epsilon_0} \cdot C \cdot \frac{dV}{dt}$ 5

$i_d = C\frac{dV}{dt}$

$\frac{dV}{dt} = \frac{i_d}{C} = \frac{2.5}{2\times10^{-3}} = \boxed{1250\ V/s}$

d-Term

Q6: (10 pts) 10 Draw a diagram

A converging lens with a focal distance f = 10 cm is used to get an image of a given object at a distance p from its center. Find the size (compared to the object) and nature (real/virtual) of the image when,

a) Object distance p = 15 cm **(5 pts)**

b) Object distance p = 7.0 cm **(5 pts)**

a) $\frac{1}{f} = \frac{1}{p} + \frac{1}{i}$

$\frac{1}{i} = \frac{1}{f} - \frac{1}{p}$

$= \frac{1}{10} - \frac{1}{15}$

$= \frac{1}{30}$

$\boxed{i = 30\,cm}$

Since the sign is (+) Postive the image is $\boxed{\text{Real}}$

5

$m_1 = -\frac{i}{p} = -2$

b) $\frac{1}{i} = \frac{1}{f} - \frac{1}{p}$

$= \frac{1}{10} - \frac{1}{7}$

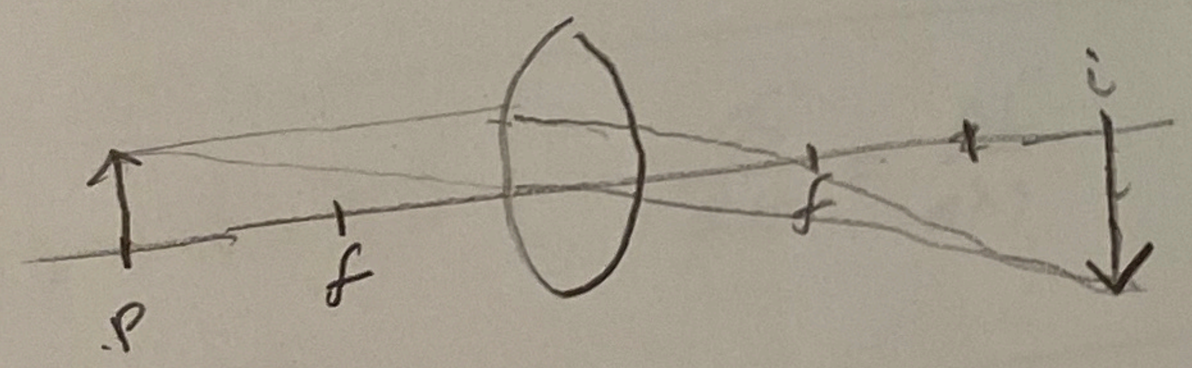
$= -\frac{3}{70}$

$\boxed{i = -23.3\,cm}$

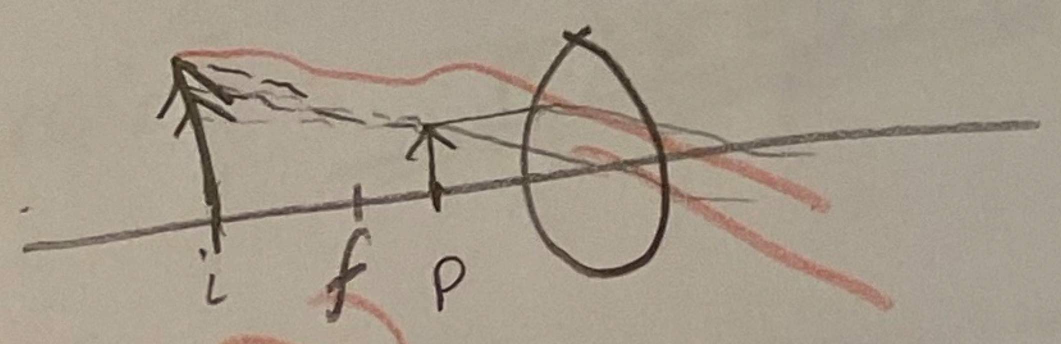
$\boxed{\text{Virtual}}$

$m_2 = -\frac{i}{p} = 3.33$

(a)



(b)

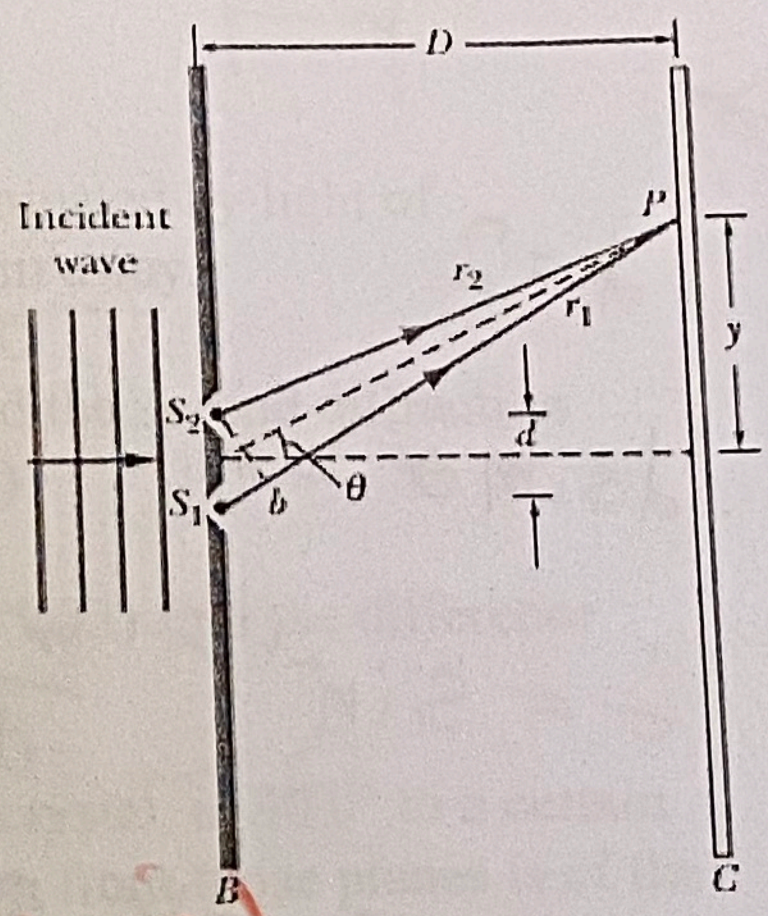


5

Q7: (20 pts) $\omega = 2\pi f$ $K = \frac{2\pi}{\lambda}$ 5 15

In the double-slit interference experiment (shown in figure), the electric fields of the waves arriving at point P are given by

$$E_1 = (2.00\ \mu V/m)\ \sin[(1.26 \times 10^{15})t + 1.3 \times 10^7 x]$$
$$E_2 = (2.00\ \mu V/m)\ \sin[(1.26 \times 10^{15})t + 1.3 \times 10^7 x + 39.6\ rad],$$



where time t is in seconds and x is in meters

(a) What is the intensity of light at point P? **(5 pts)**

(b) How many minima are there between P and the central of the axis. **(5 pts)**

(c) What is the angle θ if the slit separation is 2.00 mm? **(5 pts)**

$I = 4 I_0 \cos^2(\beta)$

explain!

$E_h = 2 + 2\cos(39.6) = 1.35\ uV/m$

$E_v = 0 + 2\sin(39.6) = 1.89\ uV/m$

$E_R = \sqrt{E_h^2 + E_v^2} = 2.32\ uV/m$

$\beta = \frac{1}{2}\phi = 19.7\ rad$

$I_0 = \frac{1}{c\mu_0}\left(\frac{E_0}{\sqrt{2}}\right)^2 = 7.14 \times 10^{-9}\ W/m^2$

$I = \cancel{4} I_0 \cdot \cos^2(19.7)$

$= \cancel{4}(7.14 \times 10^{-9}) \cos^2(19.7)$ 5

(a) $\boxed{= 3.107 \times 10^{-9}\ W/m^2}$

~~$I = 4 I_0 \cos^2(\theta)$~~

~~$= 1.24 \times 10^{-8}\ W/m^2$~~

$m\lambda = d\sin\theta$ $\frac{\phi}{2\pi} = \frac{\Delta L}{m\lambda}$

$\lambda = \cancel{2\pi K} =$

$\lambda = \frac{2\pi}{k} = 483\ nm$

$\Delta L = m\lambda$

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

$\frac{\phi}{2\pi} = \frac{\Delta L}{\lambda}$ 5

$\Delta L = \cancel{m\lambda}\ x = \frac{\phi}{2\pi} \cdot \lambda$

$(\frac{1}{2} + m) = \frac{\phi}{2\pi} = 6.27$

(b) $\boxed{\text{there are } \underline{6} \text{ minima}}$

$(m + \frac{1}{2}) = 6.27$

$\boxed{m = 5.77}$

~~$m = 5.5$~~

c →

Mid-Term Exam
204

Q8: (15 pts) 14

In a single slit diffraction experiment, a slit 1.00 mm wide is illuminated by light of wavelength 600 nm. We see a diffraction pattern on a screen 3.00 m away.

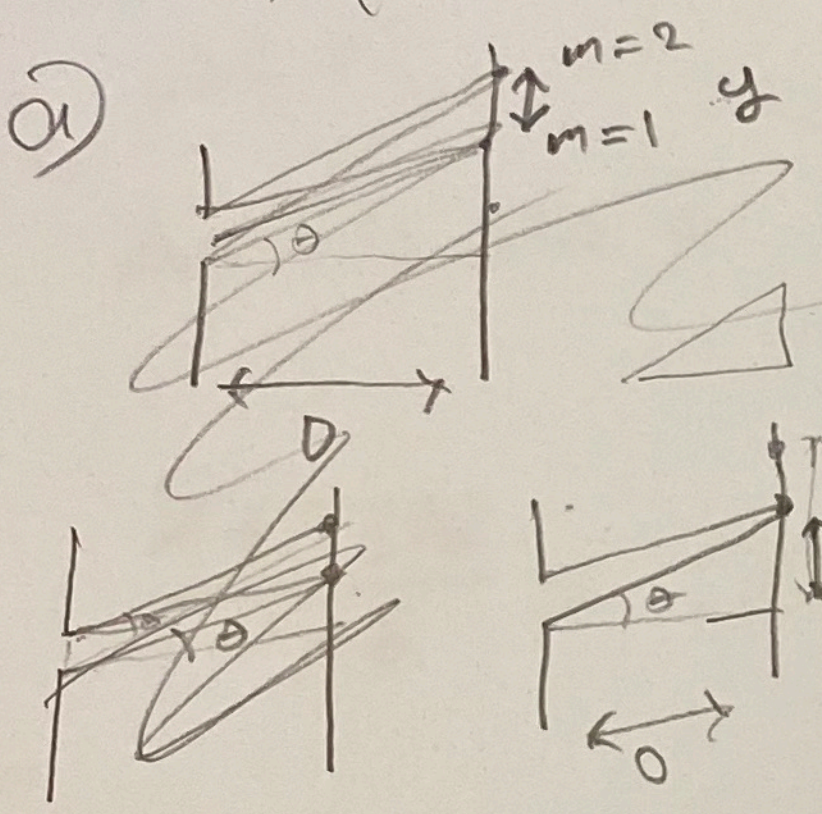
a) What is the distance between the first diffraction minimum and the second diffraction minimum? (Assume the diffraction angle is very small) **(7 pts)**

b) If the whole experimental set up is emerged into a water (n = 1.33) find the difference between the central maximum and the first minimum **(5 pts)**

c) An x-ray beam of a certain wavelength is incident on a NaCl crystal, at 30.0° to a certain family of reflecting planes of spacing 39.8 pm. If the reflection from those planes is of the first order, what is the wavelength of the x rays? **(3 pts)**

$m = 1$

a)



$\cancel{a\sin\theta = m\lambda \quad \theta = \frac{y}{D}}$

$\theta = \frac{m\lambda}{a}$

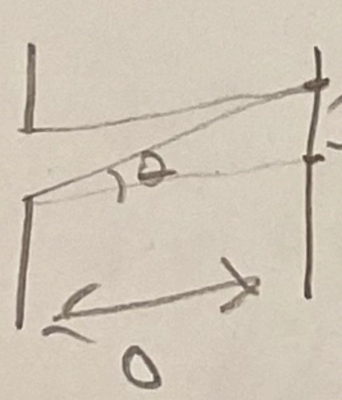
$\theta = \frac{\lambda}{a} = \frac{y_1}{D} \Rightarrow y_1 = \frac{\lambda}{a} D$ ($m=1$)

$\theta_2 = \frac{2\lambda}{a} = \frac{y_2}{D} \Rightarrow y_2 = D\frac{2\lambda}{a}$ 6

$y_2 - y_1 = \frac{\lambda D}{a}(2-1) = 2\frac{\lambda D}{a} = \boxed{3.6 \times 10^{-3}\ m}$

b)

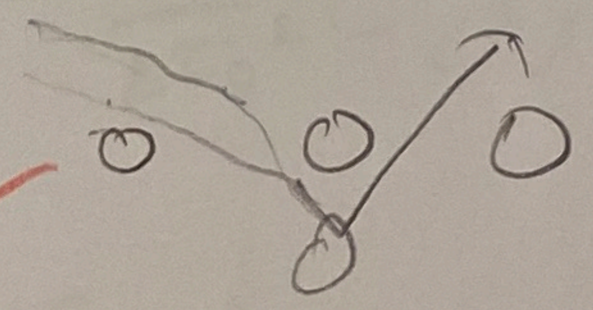
$\lambda_n = \frac{\lambda}{n} = \frac{600 \times 10^{-9}}{1.33} = 4.5 \times 10^{-7}\ m = 450\ nm$ 5



$\theta = \frac{m\lambda}{d} = \frac{\lambda_n}{d} = \frac{y}{D}$

$y = D\frac{\lambda_n}{a} = \boxed{1.35 \times 10^{-3}\ m}$

c)



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

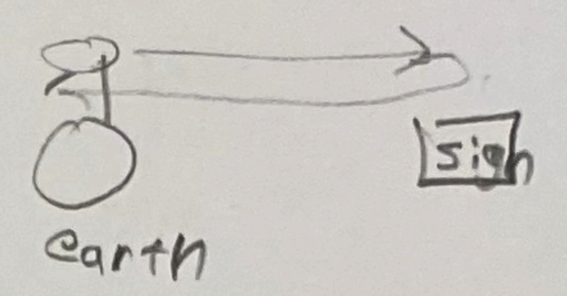
$\lambda = 2(39.8 \times 10^{-12}) \sin 30°$

$\boxed{= 3.98 \times 10^{-11}\ m}$ 3

Q 9: (~~10 pts~~) 15 14

a) Your starship passes Earth with a relative speed of 0.9990c. After traveling 10.0 y (your time), you stop at lookout post LP13, turn, and then travel back to Earth with the same relative speed. The trip back takes another 10.0 y (your time). If 25 years is the average generation time, which generation of your family will you meet? **(5 pts)**

b) Sally noticed that Sam's spaceship (of proper length $L_0 = 250$ m) pass each other with constant relative speed v. If Sally measures a time interval of 4.00 *ms* for the ship to pass her, find the value of v. **(5 pts)**



a) $\Delta t_0 = 20$ years

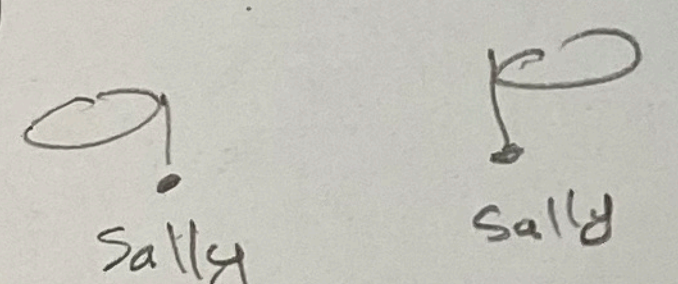
$\Delta t = ?$

$$\Delta t = \gamma \Delta t_0 = \frac{\Delta t_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{20}{\sqrt{1-0.999^2}} = 447.325\,y$$

7

$$\frac{447.325}{25} = 17.89 \text{ generations} \approx 18 \text{ generations}$$

b)



for sally

$$V = \frac{\text{distance}}{\text{time}} = \frac{L}{\Delta t_0} = \frac{L}{\Delta t}$$

Its not a proper time

~~$\Delta t = 4ms$~~ $\Delta t_0 = 4\,ms$

$L_0 = 250\,m$

$L = \frac{L_0}{\gamma}$

$$V = \frac{L_0}{\gamma \Delta t_0}$$

$$V = \frac{L_0}{\Delta t_0} \cdot \sqrt{1-\frac{V^2}{C^2}}$$

$$V^2 = \frac{L_0^2}{\Delta t_0^2}\left(1-\frac{V^2}{C^2}\right)$$

$$V^2 = \frac{L_0^2}{\Delta t_0^2} - \frac{L_0^2}{\Delta t_0^2}\left(\frac{V^2}{C^2}\right)$$

Not concluded

4 7

$$V^2\left(1 + \frac{L_0^2}{\Delta t_0^2 \cdot C^2}\right) = \frac{L_0^2}{\Delta t_0^2}$$

$$V = \sqrt{\frac{L_0^2}{\Delta t_0^2} \cdot \frac{1}{1+\frac{L_0^2}{\Delta t_0^2 C^2}}}$$

$V = 62.5 \times 10^3$ m/s

$\boxed{V = 62 \times 10^3 \text{ m/s}}$

8.5

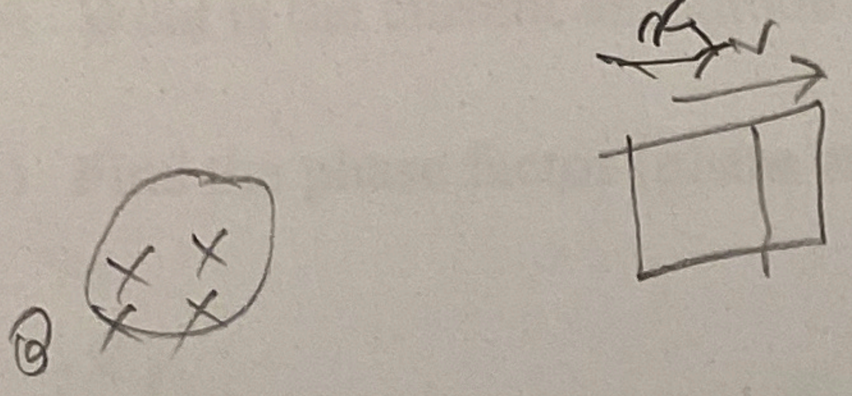
$2\,cm^2 \times \left(\frac{1\,m}{100\,cm}\right)^2$

Q2. (10 pts)

a) A loop antenna of area 2.00 cm² and resistance 5.00 mΩ is perpendicular to a uniform magnetic field of magnitude 15.0 mT. The field magnitude drops to zero in 3.00 ms. How much thermal energy is produced in the loop by the change in field? **(5 pts)**

b) At time $t = 0$, a 60 V potential difference is suddenly applied to the leads of a coil with inductance $L = 50$ mH and resistance $R = 200\ \Omega$. At what rate is the current through the coil increasing at $t = 2.0$ ms? **(5 pts)**

a)



$$\mathcal{E} = -\frac{d\phi_B}{dt} = -\frac{d(B\cdot A)}{dt} = -A\frac{dB}{dt} = -A\frac{\Delta B}{\Delta t} = -(2\times10^{-4})\left(\frac{0-15\times10^{-3}}{3\times10^{-3}}\right) = 1\times10^{-3}\ V$$

$$E_{thermal} = i^2R = \frac{\mathcal{E}^2}{R^2}\cdot R = \frac{\mathcal{E}^2}{R} = \frac{(1\times10^{-3})^2}{5\times10^{-3}}$$

$$\boxed{= 0.2\ J}$$

×

3.5

$Q = P \times t$

(b) $\left.\frac{di}{dt}\right|_{t=2ms} = ?$

$$i = \frac{\mathcal{E}}{R}(1-e^{-t/\tau_L})$$

$$\frac{di}{dt} = \frac{\mathcal{E}}{R}\left(e^{-t/\tau_L}\cdot\frac{1}{\tau_L}\right) = \frac{\mathcal{E}}{\cancel{R}}\cdot\frac{\cancel{R}}{L}(e^{-t/\tau_L}) = \frac{\mathcal{E}}{L}(e^{-t/\tau_L})$$

$$\tau_L = \frac{L}{R} = \frac{50\times10^{-3}}{200} = 2.5\times10^{-4}\ s$$

$$\left.\frac{di}{dt}\right|_{t=2ms} = \frac{60}{50\times10^{-3}}\left(e^{-\frac{2\times10^{-3}}{2.5\times10^{-4}}}\right)$$

$$\boxed{= 0.403\ A/s}$$

5

Q4: (15 pts)

12.5

The magnitude of the dipole moment associated with an atom of iron in an iron bar is 2.1 x 10^{-23} J/T . Assume that all the atoms in the bar, which is 5.0 cm long and has a cross-sectional area of 1.0 cm^2, have their dipole moments aligned. (The density of iron is 7.9 g/cm^3, Molar mass of the iron is 56g)

A

$\frac{7.9 g}{cm^2} \cdot \frac{1 kg}{1000 g} \cdot \left(\frac{100 cm}{m}\right)^2 = 79 kg/m$

(a) What is the dipole moment of the bar? **(7 pts)**

(b) How much work is required to flip the magnetic moment of the magnet from parallel to antiparallel orientation in the presence of the external field of 1.5 T. **(5 pts)**

(c) What torque must be exerted to hold this magnet perpendicular to an external field of magnitude 1.5 T? **(3 pts)**

$V = LA = 5\times10^{-2}(1\times10^{-4})$
$= 5\times10^{-6} m^3 =$

2

$M = \frac{n\mu}{V}$

$\rho = \frac{m}{V}$ X $\rho = \frac{V}{m}$, $m = \frac{V}{\rho} = \frac{5\times10^{-6}}{79} = 6.33\times10^{-8}$ kg

a) $n\mu = ?$

$M = \frac{m}{N}$, $N = \frac{m}{M} = \frac{6.33\times10^{-8}}{56\times10^{-3}}$

$= (6.81\times10^{17})(2.1\times10^{-23})$

$\boxed{= 1.43\times10^{-5} J/T}$

X

5.5

$N = 1.13\times10^{-6}$ moles

$N = N N_A = 6.81\times10^{17}$ atoms

X

b)

$W = \Delta U_B = U_{antip.} - U_{parllel}$

$= -\mu B_{ext} \cos(180) - (-\mu B_{ext} \cos(0))$

$= 2\mu B$

4.5

$= 2(1.43\times10^{-5})(1.5)$

$= 4.29\times10^{-5}$ J X

c)

$\tau = \mu \times B$

$= (1.43\times10^{-5})(1.5)$

2.5

$= 2.145\times10^{-5}$ J

X