Phys 222 Exam 3 April 20, 2018

Name: JED'S COPY

ANOTHER AMAZING TEST

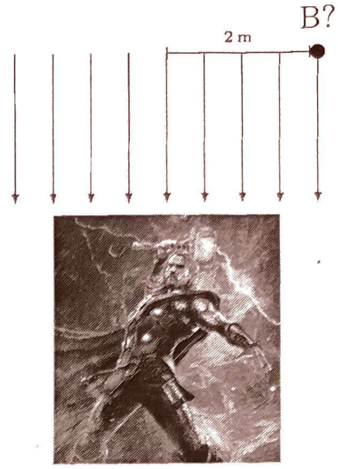
Please answer the following questions in the space provided. Show *and explain* your work for full credit and any chance at partial credit! Show me your MARVELous physics knowledge!

Useful Constants
$g = 9.8\,\mathrm{m/s^2}$
$\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/Nm^2}$
$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9\,\mathrm{Nm^2/C^2}$
$\frac{\mu_0}{4\pi} = 1 \times 10^{-7}\,\mathrm{T\,s/C}$
$c = 3 \times 10^8\,\mathrm{m/s}$

Old Useful Equations		
$F_c = \frac{mv^2}{r}$	$\Delta V = IR$	$A_{circle} = \pi r^2$

p	n	µ	m	c	k	M	G
10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{3}	10^{6}	10^{9}

(2) 1. As Thor begins to call down a lightning bolt, the electric field near him increases significantly. The field is initially 0 V/m. Half a second later, the field is 1×10^8 V/m pointing downward. What is the magnetic field a distance of 2 m from Thor? You can assume the electric field exists throughout the entire region.



A. 2.23 nT

B. 1.11 μT

C. 6.6 mT

D. 0.667 T

Take a circle of radius of 2 meters.

$$\oint \vec{B}\cdot d\vec{\ell} = \mu_0\left(I_{enc} + \varepsilon_0 \frac{d\Phi_E}{dt}\right)$$

$$B\cdot 2\cancel{\pi}\cancel{r} = \mu_0\left(0 + \varepsilon_0 \frac{\Delta\Phi_E}{\Delta t}\right)$$

$$= \mu_0\varepsilon_0 \cancel{\pi} r^{\cancel{2}} \frac{\Delta E}{\Delta t}$$

$$B = \frac{\mu_0\varepsilon_0 r}{2}\frac{\Delta E}{\Delta t} = \frac{(4\pi\times10^{-7})(8.85\times10^{-12})(2)}{2}\frac{(1\times10^{8})}{0.5} = 2.22\times10^{-9}\ \text{T}$$

2. Quicksilver didn't lift up his feet very well when moving across some carpet, and thus picked up a net charge of 30 nC. Suppose he takes off running near the North pole at 10% the speed of light. So that we don't have to envision things on a sphere, take the magnetic field near the North pole to be a constant 2×10^{-5} T pointing into the page ($-\hat{\mathbf{z}}$). Quicksilver starts running due East (in the positive $\hat{\mathbf{x}}$ direction).

(1) (a) What magnetic force does Quicksilver experience?

A. 1.8×10^{-5} N

B. 1.8×10^{-4} N

C. 600 N

D. 18 000 N

$B \otimes \xrightarrow{\quad} v$

$$F = qv\times B = (30\times10^{-9})(0.1\times3\times10^{8})(2\times10^{-5})$$
$$= 1.8\times10^{-5}$$

(1) (b) From Quicksilver's perspective, in what direction does he feel the force?

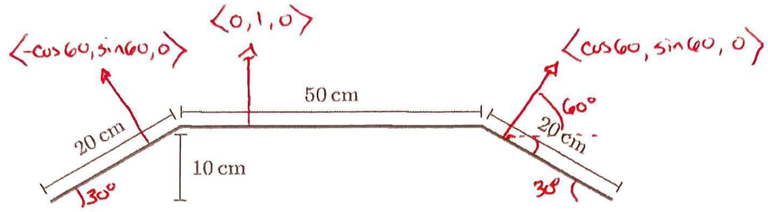
A. Pushing him forward

B. Pushing him to the right

C. Pushing him backwards

D. Pushing him to the left

(4) 3. Captain America's iconic shield is rounded, but to make our life a little easier we'll just consider it to be 3 piece trapezoid. Pictured from the side, it looks like:



and has a length of 1 m into the page. An electric field of $\langle 5, -2, 3\rangle$ V/m is present in the area surrounding the shield. What is the net electric flux through the shield surface?

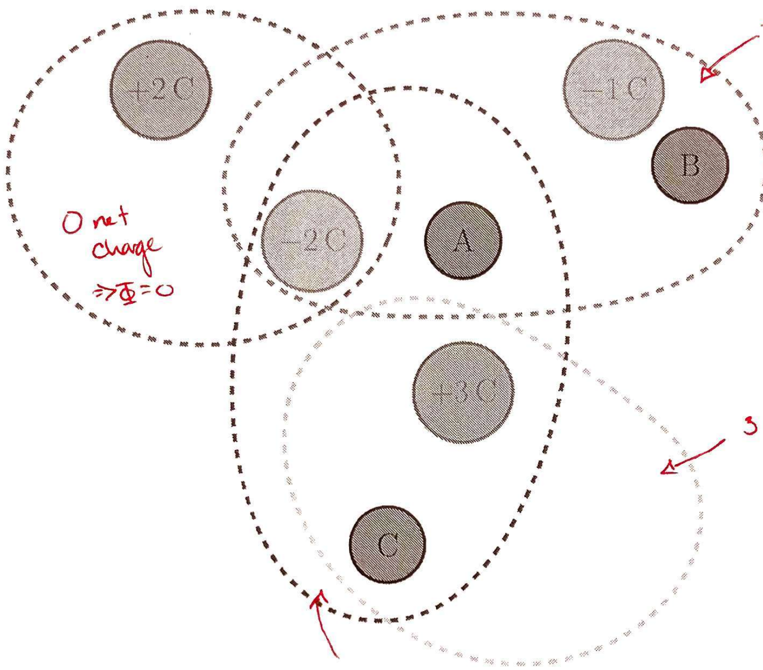
$$\Phi_{left} = E \cdot \hat{n}_{left} A_{left} = \langle 5,-2,3\rangle \cdot \langle -\cos 60, \sin 60, 0\rangle (0.2 \times 1) = -0.846$$

$$\Phi_{top} = E \cdot \hat{n}_{top} A_{top} = \langle 5,-2,3\rangle \cdot \langle 0,1,0\rangle (.5 \times 1) = -1$$

$$\Phi_{right} = E \cdot \hat{n}_r A_r = \langle 5,-2,3\rangle \cdot \langle \cos 60, \sin 60, 0\rangle (0.2 \times 1) = 0.153$$

$$\Phi_{tot} = -0.846 - 1 + 0.153 = -1.693 \text{ Vm}$$

(3) 4. Scarlet Witch has conjured up three energy balls of unknown charge along with four balls of known charge. She has also helpfully conjured up four Gaussian surfaces which have identical net electric flux. Determine the three unknown charges.



$-2 + A + B - 1 = 0$

$-2 + 2 + B - 1 = 0$

$B = 1$

0 net charge $\Rightarrow \Phi = 0$

We know

$\Phi = \frac{q_{enc}}{\varepsilon_0}$

$3 + C = 0$

$\Rightarrow C = -3$

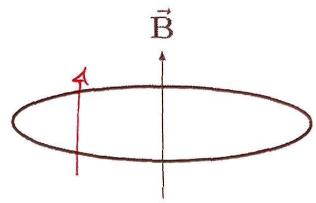
$-2 + A + 3 + C = 0$

$-2 + A + 3 - 3 = 0$

$A = 2$

5. Ironman is testing out a new electromagnetic projectile weapon which launches a small metal ring. It does so by rapidly changing the magnetic field running through the center of the ring. Suppose the ring has a radius of 1 cm, an internal resistance of 10 mΩ and lays flat. The magnetic field points upwards and increases at a rate of 10 T/ms.

(2) (a) In what direction (as viewed from above) will current flow through the ring? Explain yourself for full credit.



Mag field points upward & is increasing, resulting in an increasing amount of flux upwards. The induced current resists this, and thus will flow clockwise (viewed from above) by right hand rule.

(4) (b) What is the magnitude of the current flowing through the ring?

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = \frac{d}{dt}\left[B\cdot A\right] = A\frac{dB}{dt} = \pi r^2 \frac{dB}{dt}$$

$$I = \frac{\mathcal{E}}{R} = \frac{\pi r^2 \frac{dB}{dt}}{R} = \frac{\pi(1\times10^{-2})^2(10\,000)}{10\times10^{-3}} = 314.159\text{ A}$$

6. Vision blasts out a laser beam traveling in the positive x direction from the Infinity Stone in his forehead. The radiation has a electric field which can be written as

$$\vec{\mathbf{E}} = \langle 0, 100\cos(\omega t), 0\rangle \text{ V/m}$$

where ω is 3.3×10^{15} rad/s.

(2) (a) What is the wavelength of the radiation?

$T = \frac{2\pi}{\omega} = 1.904 \times 10^{-15}$

$cT = \lambda = (3 \times 10^{8})(1.904 \times 10^{-15}) = 5.71 \times 10^{-7}\,m$

$= 571\,nm$

(3) (b) Write out an expression describing the magnetic field vector of the radiation.

magnitude: $|B| = \frac{|E|}{c} = \frac{100}{c}\cos(\omega t)$

by rhr need B to point in positive z-direction

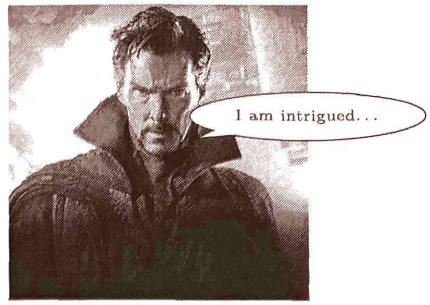
$\Rightarrow \vec{B} = \left\langle 0, 0, \frac{100}{c}\cos(\omega t)\right\rangle\ T$

(2) (c) Assuming that the laser has a radius of 3 mm, what is the peak energy output every second? (*You can just work with the amplitudes here, and let the cosines or sines go to 1*)

$\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B} = \frac{1}{\mu_0}\cdot 100 \cdot \frac{100}{c} = 26.53\ W/m^2$

$26.53\ \frac{W}{m^2} \cdot \pi(3 \times 10^{-3} m)^2 = 7.5 \times 10^{-4} W = 7500\ \mu W$

: (bonus)) 7. Dr. Strange is intrigued by the so called Hall Effect and seeks an explanation. Describe what the Hall Effect is and a few of the special electric properties it can let us measure.



The Hall effect comes from an external magnetic field causing current to deviate and hit the sides of the circuit. This causes charge to build up on the sides of the circuit until the generated electric field force exactly counters the magnetic force. This results in an emf across the circuit, ⊥ to the direction of current, which can be measured.

Such measurements can give us excellent knowledge about the charge density in the conductor and if the majority charge carriers are electrons or holes (positives).

** Inserting Ending Credits Scene Here **