Physics 2020
Summer Semester 2008
Richard Ingebretsen

EXAM 4

1

Name: ______________________ unid: u _ _ _ _ _ _ _ _

Discussion TA (circle): Adam Bill Doug Eric

A. *[6 pts.]* An electron is moving through a magnetic field whose magnitude is 7.80×10^{-4} T. The electron experiences only a magnetic force and has an acceleration of magnitude 3.60×10^{14} m/s^2. At a certain instant, it has a speed of 6.50×10^6 m/s. Determine the angle θ (less than 90°) between the electron's velocity and the magnetic field.

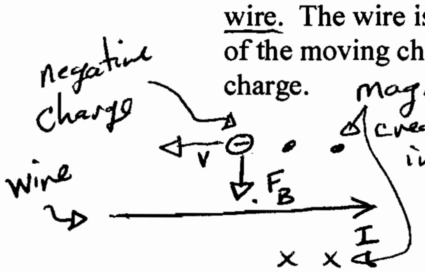
$\Sigma F = ma$ $\quad F_B = qvB\sin\theta$

$F_B = ma \rightarrow ma = qvB\sin\theta$

$\sin\theta = \frac{ma}{qvB} \Rightarrow \theta = \sin^{-1}\left[\frac{(9.11E-31\,kg)(3.6E14\,\frac{m}{s^2})}{(1.6E-19\,C)(6.5E6\,\frac{m}{s})\,7.8E-4\,T}\right]$

$\boxed{\theta = 23.846^\circ}$

B. *[6 pts.]* A -6.00 μC charge is moving with a speed of 6.60×10^4 m/s parallel to a very long, straight wire. The wire is 5.00 cm from the charge and carries a current of 76.5 A in a direction opposite to that of the moving charge. Find the magnitude and direction (clearly specify direction) of the force on the charge.



$B = \frac{\mu_0 I}{2\pi r} \rightarrow |F_B| = |q|v\left(\frac{\mu_0 I}{2\pi r}\right)\sin 90^\circ$

$|F_B| = |q|vB\sin\theta \qquad \theta = 90^\circ$

$= \frac{(6E-6\,C)(6.6E4\,\frac{m}{s})(\mu_0)(76.5\,A)}{(2)(\pi)(.05\,m)}$

$\boxed{|F_B| = 1.21\,E-4\,N}$

Force is Toward wire by the Right Hand Rule

C. *[6 pts.]* Two astronauts are 10.0 m apart in their spaceship. One speaks to the other. The conversation is transmitted to earth via electromagnetic waves. The time it takes for sound waves to travel at 343 m/s through the air between the astronauts equals the time it takes for the electromagnetic waves to travel to the earth. How far away from the earth is the spaceship?

$= D \qquad = V \qquad = L$

$V = \frac{D}{t} \qquad t = \frac{D}{V}$

Time for Sound = Time for electromagnetic waves

$\frac{D}{V} = \frac{L}{C}$

$C\left(\frac{D}{V}\right) = L \rightarrow \frac{(3E8\,\frac{m}{s})(10\,m)}{(343\,\frac{m}{s})} = 8746355\,m$

$\boxed{\approx 8.7\,E6\,m}$

D. *[7 pts.]* A beam of polarized light has an average intensity of 16 W/m^2 and is sent through a polarizer. The transmission axis makes an angle of 33° with respect to the direction of polarization. Determine the rms value of the electric field of the transmitted beam.

$\bar{S} = \bar{S}_0\cos^2\theta$

$= 16\,\frac{W}{m^2}\cos^2 33^\circ$

$\bar{S} = 11.25\,\frac{W}{m^2}$

$S = c\epsilon_0 E^2$ so $\bar{S} = c\epsilon_0 E_{rms}^2$

$E_{rms} = \sqrt{\frac{\bar{S}}{c\epsilon_0}} \rightarrow E_{rms} = \sqrt{\frac{11.25\,\frac{W}{m^2}}{(3E8\,\frac{m}{s})(8.85E-12\,\frac{C^2}{Nm^2})}}$

$\boxed{E_{rms} = 65.1\,\frac{N}{C}}$

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EXAM 4

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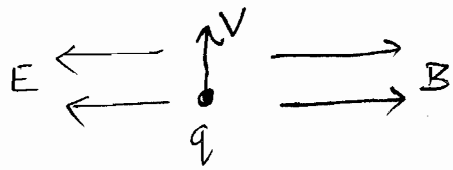
Name: Bill

unid: u _ _ _ _ _ _ _ _

Discussion TA (circle): Adam (Bill) Doug Eric

A. *[8 pts.]* A magnetic field has a magnitude of 1.20×10^{-3} T, and an electric field has a magnitude of 4.00×10^{3} N/C. The fields point in opposite directions. A positive 1.8 μC charge moves at a speed of 3.20×10^{6} m/s in a direction that is perpendicular to both fields. Determine the magnitude of the net force that acts on the charge.



$F_E = qE$

$F_B = Bqv$

$F = \sqrt{F_E^2 + F_B^2} = \sqrt{(qE)^2 + (Bqv)^2} = q\sqrt{(E)^2 + (Bv)^2}$

$= 1.8\times10^{-6}\,C\sqrt{(4.0\times10^{3}\,N/C)^2 + (1.20\times10^{-3}\,T \times 3.20\times10^{6}\,m/s)^2} = \boxed{0.00998\,N}$

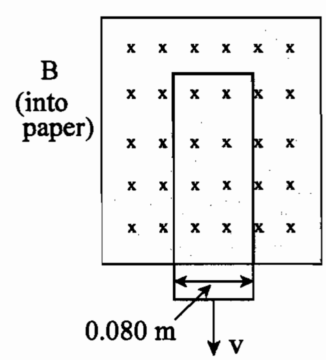
B. *[9 pts.]* A beam of protons moves in a circle of radius 0.1 m. The protons move perpendicular to a 0.30 T magnetic field. Determine the magnitude of the centripetal force that acts on each proton.

$F = Bqv = \frac{mv^2}{r} \Rightarrow v = \frac{Bqr}{m}$

$F = \frac{mv^2}{r} = \left(\frac{m}{r}\right)\left(\frac{Bqr}{m}\right)^2 = \frac{B^2q^2r}{m}$

$= \frac{(0.30T)^2(1.6\times10^{-19}C)^2(0.1m)}{(1.67\times10^{-27}kg)} = \boxed{1.38\times10^{-13}\,N}$

C. *[8 pts.]* A rectangular loop of wire is moving toward the bottom of the page with a constant speed of 0.021 m/s (see the drawing). The loop is leaving a region in which a 2.1 T magnetic field exists; the magnetic field outside this region is zero. During a time of 2.0 s, what is the magnitude of the change in the magnetic flux?



$\Delta\Phi = B(\Delta A)\cos\theta = B(Lvt)\cos\theta$

$= (2.1T)(0.080m)(0.021\,m/s)(2s)(1)$

$= 0.0070056\,Tm^2$

$= \boxed{0.00706\,Wb}$

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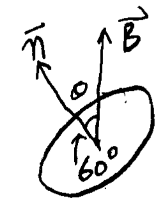
EXAM 4

3

Name: Famin   unid: u _ _ _ _ _ _ _ _

Discussion TA (circle): Adam   Bill   Doug   Eric

A. *[12 pts.]* A circular coil (800 turns, radius = 0.045 m) is rotating in a uniform magnetic field. At t = 0 s, the normal to the coil is perpendicular to the magnetic field. At t = 0.010 s, the normal makes an angle of θ = 60° with the field because the coil has made one-twelfth of a revolution. An average emf of magnitude 0.075 V is induced in the coil. What is the magnitude of the uniform magnetic field at the location of the coil?



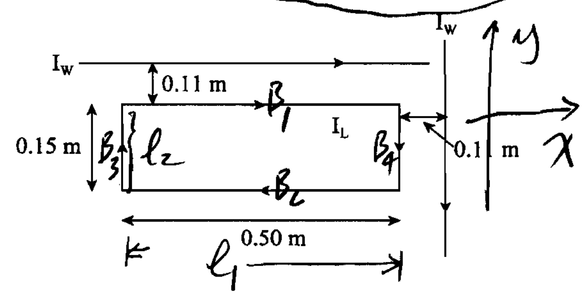
$$\mathcal{E} = -\frac{\Delta\Phi}{\Delta t}$$

$$\Delta\Phi = N\pi r^2(\cos\theta - \cos 90^\circ)B$$

$$\mathcal{E} = -\frac{N\pi r^2(\cos\theta)B}{\Delta t} \Rightarrow |B| = \frac{\Delta t\,\mathcal{E}}{N\pi r^2\cos\theta}$$

$$= \frac{0.01 \times 0.075}{800 \times \pi(0.045)^2\cos 60^\circ} = 2.947\times10^{-4}\,T = 0.2947\,mT$$

B. *[13 pts.]* A rectangular current loop is located near two long, straight wires that carry a current of I_W = 10 A (see the drawing). The current in the loop is I_L = 26 A. Determine the magnitude of the net magnetic force that acts on the loop.



$$F_y = I_L l_1(B_1 - B_2)$$
$$= I_L l_1\left(\frac{\mu_0 I_W}{2\pi(0.11)} - \frac{\mu_0 I_W}{2\pi(0.26)}\right)$$
$$= \frac{l_1 \mu_0 I_W I_L}{2\pi}\left(\frac{1}{0.11} - \frac{1}{0.26}\right)$$
$$= \frac{0.5\times4\pi\times10^{-7}\times10\times26}{2\pi}\,\frac{0.15}{0.11\times0.26}$$
$$= 1.364\times10^{-4}\,N$$

$$F_x = I_L l_2(B_4 - B_3)$$
$$= I_L l_2\frac{\mu_0 I_W}{2\pi}\left(\frac{1}{0.11} - \frac{1}{0.11+0.5}\right)$$
$$= \frac{26\times0.15\times4\pi\times10^{-7}\times10}{2\pi}\,\frac{0.5}{0.11\times0.61}$$
$$= 5.812\times10^{-5}\,N$$

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(1.364\times10^{-4})^2 + (5.812\times10^{-5})^2}$$
$$= 1.483\times10^{-4}\,N$$

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Discussion TA (circle): Adam Bill Doug Eric

A. A 300 turn solenoid with a length of 20.0 cm and a radius of 2.50 cm carries a current of 5.0 Amps. A square with sides 1.00 cm and made of 4 turns is placed inside the solenoid so that the flux is maximal. The square has a resistance of 2.00 Ω.

2. *[12 pts.]* Find the magnitude of the average induced current in the square when the current in the solenoid decreases to 2.00 Amps in a period of 0.0900 seconds.

$$\mathcal{E} = -\frac{\Delta\Phi}{\Delta t}, \quad I = \mathcal{E}/R$$

$$I = -\frac{\Delta B A_T}{\Delta t}\frac{1}{R} = -\frac{\mu_0 N \Delta I}{l\,\Delta t}(n d^2)\frac{1}{R}, \quad \leftarrow \begin{cases} B = \frac{N\mu_0 I}{l} \\ A_T = n d^2 \leftarrow \text{total area} \end{cases}$$

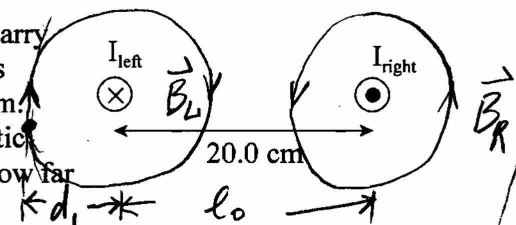
$$= -\frac{N\mu_0}{l}\left(\frac{I_f - I_i}{\Delta t}\right)(n d^2)\frac{1}{R}$$

$$= -\frac{300 \times 4\pi \times 10^{-7}}{0.2}\left(\frac{2.0-5.0}{0.09}\right)4 \times (0.01)^2 \frac{1}{2.0} = 1.257 \times 10^{-5} A = 12.57\,\mu A$$

2. *[3 pts.]* Does the current in the square flow the same direction or opposite direction as the current in the solenoid?

The same direction.

B. *[10 pts.]* Two long straight wires, oriented perpendicular to the page, carry currents of I_{left} = 10.0 A and I_{right} = 25.0 A. I_{left} is into the page and I_{right} is coming out of the page. The wires are separated by a distance of 20.0 cm. Somewhere along an extended line though the two wires the net magnetic field is zero. Is it to the **right** or the **left** of the left wire (circle one)? How far away is this point from the left wire?



The left of the left wire.

$$0 = B_L - B_R$$

$$= \frac{\mu_0 I_L}{2\pi d_1} - \frac{\mu_0 I_R}{2\pi(d_1 + l_0)}$$

$$d_1 I_R = (d_1 + l_0) I_L$$

$$d_1 = \frac{l_0 I_L}{I_R - I_L} = 20\frac{10}{25-10} = 13.33\,cm$$