Multiple choice questions:

Question	Exam A	Exam B
MC1	E	E
MC2	F	B
MC3	D	E
MC4	D	E

1. (20 marks) A doubly-charged helium atom, whose mass is 6.6×10^{-27} kg, is accelerated by a voltage of 3.4 kV.

6 a) What is its resultant velocity?
8 b) What will be its radius of curvature, if it moves in a plane perpendicular to a uniform 0.570-T field after exiting the electric field region?
6 c) What is its period of revolution?

a) $qV = \frac{1}{2} m v^2 \Rightarrow v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2(2e)V}{m}}$

$= \left[\frac{2 \times 2 \times 1.60 \times 10^{-19} C \times 3.4 \times 10^3 V}{6.6 \times 10^{-27} kg}\right]^{1/2}$

$\boxed{v = 5.7 \times 10^5 m/s}$

b) $Bqv = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{Bq} = \frac{mv}{B(2e)} = \frac{6.6 \times 10^{-27} kg \times 5.7 \times 10^5 m/s}{0.570 T \times 2 \times 1.60 \times 10^{-19} C}$

$r = 0.021 m \Rightarrow \boxed{2.1 cm}$

c) $T = \frac{2\pi r}{v} = \frac{2\pi \times 0.021 m}{5.7 \times 10^5 m/s} = \boxed{0.23 \mu s}$

B version a) $v = \left[\frac{2 \times 2 \times 1.60 \times 10^{-19} C \times 2.8 \times 10^3 V}{6.6 \times 10^{-27} kg}\right]^{1/2} = \boxed{5.2 \times 10^5 m/s}$

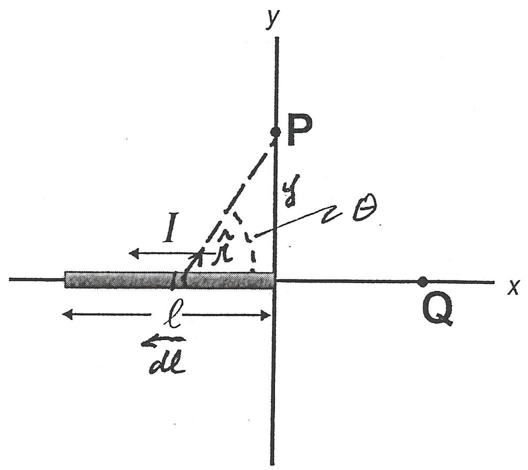
b) $r = \frac{6.6 \times 10^{-27} kg \times 5.2 \times 10^5 m/s}{0.370 T \times 2 \times 1.60 \times 10^{-19} C} = 0.029 m \Rightarrow \boxed{2.9 cm}$

c) $T = \frac{2\pi \times 0.029 m}{5.2 \times 10^5 m/s} = \boxed{0.35 \mu s}$

2. **(20 marks)** A segment of wire of length ℓ carries a current I as shown in the figure.

5 a) What is the expression (or value) for the magnetic field [magnitude and direction] at any point such as Q along the positive x axis (the axis of the wire)?

15 b) What is the expression (or value) for the magnetic field [magnitude and direction] at any point such as P along the positive y axis?



$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l}\times\hat{r}}{r^2}$$

a) For all points on the x axis

$d\vec{l}\times\hat{r} = 0$

$\therefore \boxed{\vec{B} = 0}$

b) On the y axis

$$d\vec{B} = \frac{-\mu_0 I}{4\pi}\frac{dx\sin\theta\,\hat{k}}{x^2+y^2}$$

but $\sin\theta = \frac{y}{\sqrt{x^2+y^2}}$

$$\therefore d\vec{B} = -\frac{\mu_0 I y}{4\pi}\frac{dx}{(x^2+y^2)^{3/2}}\hat{k}$$

$$\therefore \vec{B} = \int_0^\ell d\vec{B} = -\frac{\mu_0 I y}{4\pi}\int_0^\ell \frac{dx}{(x^2+y^2)^{3/2}}\hat{k}$$

$$= -\frac{\mu_0 I y}{4\pi}\left[\frac{x}{y^2\sqrt{x^2+y^2}}\right]_0^\ell \hat{k}$$

$$= -\frac{\mu_0 I y}{4\pi}\left[\frac{\ell}{y^2\sqrt{\ell^2+y^2}}\right]\hat{k}$$

$$\boxed{= \frac{-\mu_0 I \ell}{4\pi y\sqrt{\ell^2+y^2}}\hat{k} \quad \text{(ie into page)}}$$

B version:

a) On the x axis

$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{dy\sin\theta\,\hat{k}}{x^2+y^2}$$

$$= \frac{\mu_0 I x\,dy}{4\pi(x^2+y^2)^{3/2}}\hat{k}$$

$$\vec{B} = \int_0^\ell d\vec{B}$$

$$= \frac{\mu_0 I x}{4\pi}\int_0^\ell \frac{dy}{(x^2+y^2)^{3/2}}\hat{k}$$

$$= \frac{\mu_0 I x}{4\pi}\left[\frac{y}{x^2\sqrt{x^2+y^2}}\right]_0^\ell$$

$$\boxed{= \frac{\mu_0 I \ell}{4\pi x\sqrt{\ell^2+x^2}}\hat{k} \quad \text{(ie out of page)}}$$

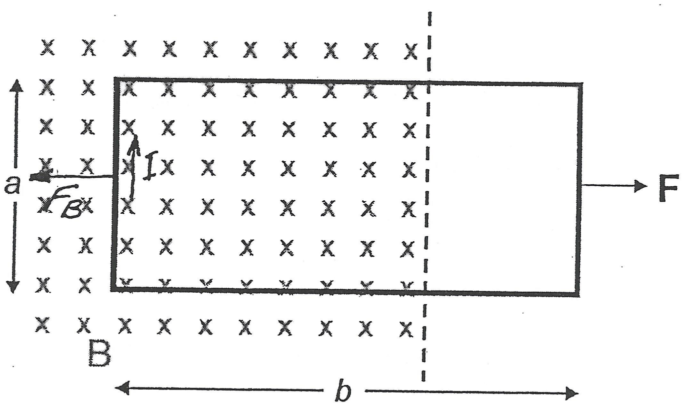
b) For all points on y axis $d\vec{l}\times\hat{r} = 0$

$\boxed{\vec{B} = 0}$

3. (20 marks) A single rectangular loop of wire of dimensions $a = 180$ cm and $b = 620$ cm is situated, as shown in the figure, with part inside a region with uniform magnetic field of 0.920 T, and part outside the field. The total resistance in the loop is 0.150 Ω. The loop is pulled to the right. (Neglect any effects of gravity.)

5 a) Give the direction of the current flow in the loop (clockwise or counterclockwise) and explain your reasoning.

15 b) What force is required to pull the loop at a constant velocity of 5.20 m/s?



a) $\boxed{\text{clockwise.}}$ As loop is pulled to the right, the magnetic flux through it decreases. By Lenz's law, the current must flow in a direction to increase the flux. It can do this by creating an additional magnetic field into the page. The right-hand rule demonstrat[es] that a clockwise current is required.

b) $|\mathcal{E}| = \frac{d\Phi_B}{dt} = B\frac{dA}{dt} = Bav$

$I = \frac{\mathcal{E}}{R} = \frac{Bav}{R}$

$F_B = IaB = \frac{Bav}{R}aB = \frac{B^2a^2v}{R}$

If velocity is constant $F = F_B$

$\therefore F = \frac{(0.920T)^2(1.80m)^2\,5.20m/s}{0.150\Omega}$

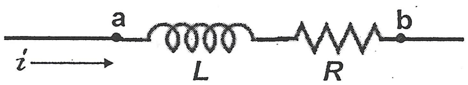
$\boxed{F = 95.1N}$

B version:

$F = \frac{(1.520T)^2(2.80m)^2\,5.20m/s}{0.250\Omega}$

$\boxed{F = 377N}$

4. **(20 marks)** An inductor and a resistor appear in series in a circuit (see figure). At one instant the potential difference, V_{ab} across the pair is 3.05 V while the current is 450 mA and is increasing at a rate of 200 mA/s. At a later instant, the potential difference is 2.15 V while the current is 400 mA and is decreasing at a rate of 260 mA/s. Determine the inductance, L, of the coil and the value, R, of the resistance.



$$V_{tot} = L\frac{di}{dt} + Ri$$

$$3.05 = L \times 200\times10^{-3} + R \times 450 \times 10^{-3} \qquad 1$$

$$2.15 = -L \times 260 \times 10^{-3} + R \times 400 \times 10^{-3} \qquad 2$$

$1.3 \times 1 + 2$

$$6.115 = R \times 985 \times 10^{-3}$$

$$\boxed{R = 6.21\,\Omega}$$

$$3.05 = L \times 200 \times 10^{-3} + 6.21 \times 450 \times 10^{-3}$$

$$\boxed{L = 1.28\,H}$$

B version:

$$5.15 = L \times 280 \times 10^{-3} + R \times 350 \times 10^{-3}$$

$$1.85 = -L \times 120 \times 10^{-3} + R \times 200 \times 10^{-3}$$

$\frac{12}{28} \times 1 + 2$

$$4.057 = 0.35R \Rightarrow \boxed{R = 11.6\,\Omega}$$

$$5.15 = L \times 280 \times 10^{-3} + 11.6 \times 350 \times 10^{-3}$$

$$\boxed{L = 3.90\,H}$$