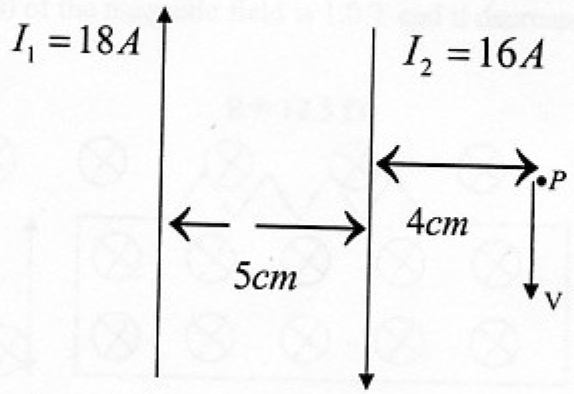
**Problem #1. (35 points)**

Wire (1) carries a current $I_1 = 18A$ pointing up (or North). Wire (2) carries a current $I_2 = 16A$ pointing down (or South). The wires are 5 cm apart and point P is 4 cm to the right (East) of wire (2) as shown.




**(7 pts)** (a) Find the **magnitude and direction** of the magnetic field at point P due to wire 1.

Direction ⊗ (into plane)

$$B_1 = \frac{\mu_0 I_1}{2\pi r_1} = \frac{(4\pi \times 10^{-7}\ \frac{Tm}{A})(18\ A)}{2\pi\ (0.09\ m)} = 4 \times 10^{-5}\ T$$

**(7 pts)** (b) Find the **magnitude and direction** of the magnetic field at point P due to wire 2.

Direction ⊙ (out of plane)

$$B_2 = \frac{\mu_0 I_2}{2\pi r_2} = \frac{(4\pi \times 10^{-7}\ Tm/A)(16A)}{2\pi\ (0.04\ m)} = 0.8 \times 10^{-5}\ T$$

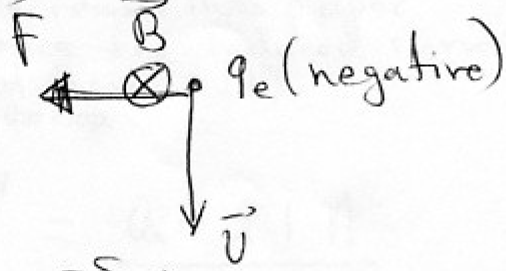
**(9 pts)** (c) Find the **magnitude and direction** of the total or net magnetic field at point P.

The net magnetic field (Choose + direction out of plane)

$$B_{net} = -|\vec{B}_1| + |\vec{B}_2| = -4 \times 10^{-5}\ T + 0.8 \times 10^{-5}\ T$$
$$= -3.2 \times 10^{-5}\ T \text{ (into the plane)}$$

**(12 pts)** (d) Assume that at point P there is particle of charge $q = -3.0\mu C$ which is moving down (South) with a velocity of $2.5 \times 10^5\ m/s$ as shown. Find the **magnitude and direction** of the magnetic force on this particle.

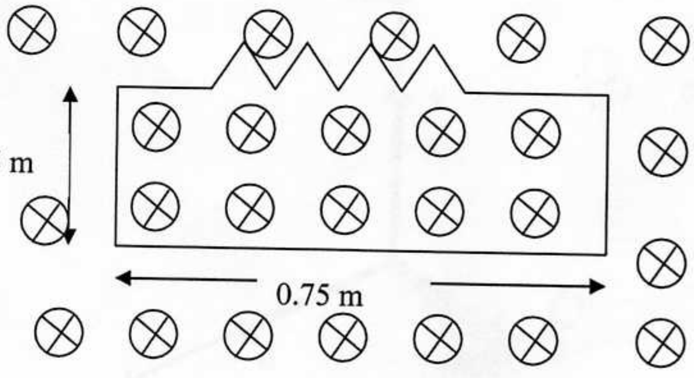
$\theta = 90°$




$$|\vec{F}| = |q|\, v\, B \sin\theta$$
$$= (3 \times 10^{-6}\ C)(2.5 \times 10^{5}\ m/s)(3.2 \times 10^{-5}\ T) = 2.4 \times 10^{-5}\ N$$

**Problem #2. (35 points)**

A rectangular wire containing a 12.5 Ω resistor is placed in a region of uniform magnetic field **B** which is pointing into the plane of the circuit, as shown below. The rectangular wire has a width of 0.35 m and length of 0.75 m. The magnetic field **decreases** in magnitude with time at a constant rate. The initial value (at t = 0s) of the magnetic field is 1.0 T and it decreases to 0.5 T in 0.5s.




I choose (normal into plane)

**(7 pts)** (a) Calculate the **initial** magnetic flux through the rectangular loop at t = 0 s.

$$\Phi_i = B_i A \cdot \cos\theta = (1\,T)(0.35m)(0.75m)\cos 0^\circ = 0.2625\ T\text{-}m$$

**(7 pts)** (b) Calculate the **final** magnetic flux through the rectangular loop at t = 0.5 s.

$$\Phi_f = B_f A \cos\theta = (0.5\,T)(0.35m)(0.75m)\cos 0^\circ = 0.13125\ T\text{-}m$$

**(7 pts) (c)** Calculate the induced emf (electromotive force), $\epsilon$.

$$\mathcal{E} = \left| -N\frac{\Delta\Phi}{\Delta t} \right| = \left| \frac{0.13125\,Wb - 0.2625\,Wb}{(0.5 - 0)\,s} \right| = 0.262\ V$$

**(7 pts)** (d) What is the **direction of the induced current** in the loop?

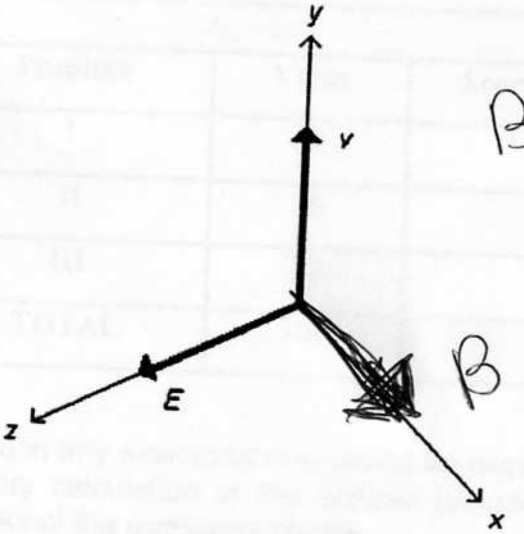
clockwise (flux decreases into paper and hence the induced current should increase it)

**(7 pts)** (e) Calculate the **magnitude of the induced current** in the loop.

$$I = \frac{\mathcal{E}}{R} = \frac{0.262\,V}{12.5\,\Omega} = 0.021\,A$$

**Problem #3. (30 points)**

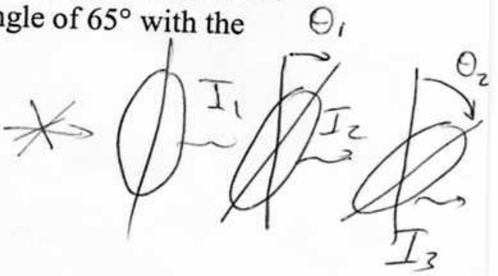
**(7 pts)** (a) An electromagnetic wave propagates along the +y direction as shown in the figure. If the E-field at the origin is along the +z direction, what is the direction of the B-field?




B along +x

Answer: ______________________________

**What follows is not related to part (a) above.**
An unpolarized light beam of light of intensity $I_o = 100\ W/m^2$ passes through three polarizers. The transmission axis of the second polarizer makes an angle of 20° with the transmission axis of the first polarizer. And the transmission axis of the third polarizer makes an angle of 65° with the transmission axis of the first polarizer.




**(7 pts)** (b) What is the intensity $I_1$ of the light after the first polarizer?

$$I_1 = \frac{I_o}{2} = \frac{100\ W/m^2}{2} = 50\ \frac{W}{m^2}$$

because unpolariz

**(8 pts)** (c) What is the intensity $I_2$ of the light after the second polarizer?

$$I_2 = I_1 \cos^2\theta_1 = 50\ \frac{W}{m^2} \cos^2 20^\circ = 44.15\ \frac{W}{m^2}$$

**(8 pts)** (d) What is the intensity $I_3$ of the light beam after the third polarizer?

$$I_3 = I_2 \cos^2(65^\circ - 20^\circ) = \left(44.15\ \frac{W}{m^2}\right) \cos^2 45^\circ = 22.07\ \frac{W}{m^2}$$