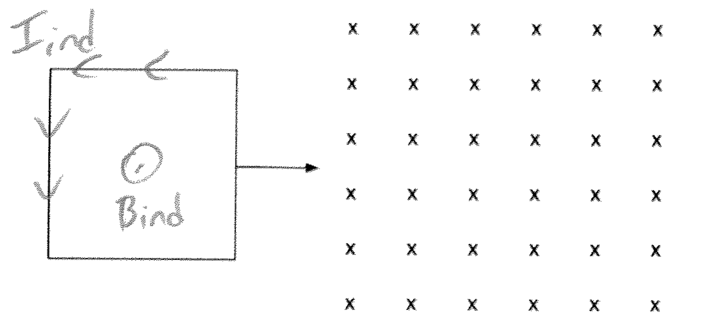
Physics 10164 - Exam 3B

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box and remember to include correct units and significant figures.

1. (30 pts) A square loop 55 cm on a side is moving in the +x direction at a rate of 1.5 m/s. It enters a region of a uniform 3.3 T magnetic field pointing into the page.

(18) a) As it enters the field, determine the direction of induced current in the square loop (show your reasoning, step-by-step).



$\Delta\Phi_B = \otimes$, increasing

$B_{ind} = \odot$

$I_{ind} = CCW$

(12) b) What is the magnitude of the average induced EMF in the loop while it is entering the magnetic field (the time it takes to do so can be found since you know the length of the side of the loop and its speed)?

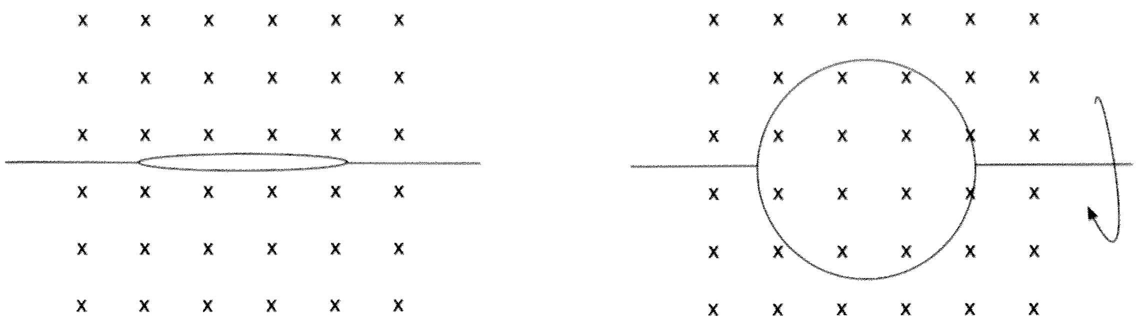
$$\Delta t = \frac{0.55\,m}{1.5\,m/s} = 0.367\,s$$

$$\mathcal{E}_{ind} = \frac{\Delta\Phi_B}{\Delta t} = \frac{B\,\Delta A\cos\theta}{\Delta t} \text{ or } \frac{\Delta B\,A\cos\theta}{\Delta t}$$

$$= \frac{(3.3)(.55^2)(1)}{.367} = 2.7\text{ Volts}$$

2. (40 pts) A generator provides voltage ε_{max} = 34 with a frequency of 30 Hz. Below, the circular generator coil is shown edge-on (at t = 0, shown on the left, the area vector is parallel to the page and perpendicular to the external magnetic field which points into the page).

(6) a) If the circular coil is oriented edge-on as shown at t = 0 (shown on left), at what time t will the coil have completed 1/4 of a turn (shown at right)?

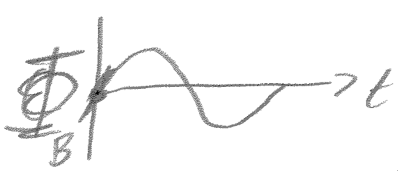


$f = 30\ Hz = \frac{1}{T}$

$T = \frac{1}{30} = .0333$

$\frac{1}{4}T = .00833\ s$

(10) b) What will be the voltage provided by the coil at the instant when t = 0? Explain.



At $t=0$, $\Phi_B = 0$ + slope $\left(\frac{\Delta\Phi_B}{\Delta t}\right)$ is max

Since $\mathcal{E}_{ind} = N\frac{\Delta\Phi_B}{\Delta t}$, $\mathcal{E}_{ind}$ is max $= 34V$

(10) c) What will be the voltage provided by the coil at the instant it has completed 1/4 of a turn? Explain.

At $t = \frac{1}{4}T$, Φ_B = max, so slope $\left(\frac{\Delta\Phi_B}{\Delta t}\right) = 0$

so $\mathcal{E}_{ind} = 0$

d) For reference from the previous page, ε_{max} = 34 with a frequency of 30 Hz. The coil is the voltage source for an RLC circuit with R = 12 Ohms, C = 150 μF and L = 0.35 H.

(8) (i) What is the maximum current for this circuit at its current frequency?

(3) (ii) What is the resonant frequency for this circuit?

(3) (iii) What is the maximum current for this circuit when it is operated at its resonant frequency?

(i) $R = 12$

$$X_C = \frac{1}{2\pi(30)(150\times10^{-6})} = 35.37\,\Omega$$

$$X_L = 2\pi(30)(.35) = 65.97\,\Omega$$

$$Z = \sqrt{12^2 + (65.97 - 35.37)^2} = 32.9\,\Omega$$

$$I_{max} = \frac{\varepsilon_{max}}{Z} = \frac{34}{32.9} = 1.03\,A$$

(ii) $$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(.35)(150\times10^{-6})}} = 21.97\,Hz$$

or $22\,Hz$

(iii) At $f = f_0$, $Z = R = 12\,\Omega$

$$I_{max} = \frac{34}{12} = 2.8\,A$$

#3. (30 pts) An alternating current circuit has an voltage source $\varepsilon(t) = 170 \sin(120\pi t)$, a 21 Ohm resistor, and a 0.034 H inductor.

(12) a) What is the maximum current for this circuit?

(18) b) The current oscillates back and forth sinusoidally over time. At the instant when the current is zero, what is (i) the voltage drop across the resistor, (ii) the voltage drop across the inductor, and (iii) the voltage drop across the source?

a) $\mathcal{E}_{max} = 170$

$2\pi f t = 120\pi t$

$2f = 120$

$f = 60$

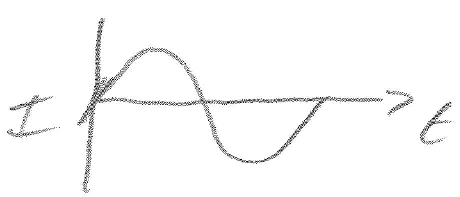
$R = 21\,\Omega$

$X_L = 2\pi(60)(.034) = 12.82\,\Omega$

$Z = \sqrt{R^2 + X_L^2} = 24.6\,\Omega$

$I_{max} = \frac{170}{24.6} = 6.9\,A$

b) When $I = 0$, slope $\left(\frac{\Delta I}{\Delta t}\right) = max$



$\Delta V_R = IR$ so these are in phase, If $I = 0$, then $\Delta V_R = 0$

At $t = 0$, slope $\left(\frac{\Delta I}{\Delta t}\right) = max$. Since $\Delta V_L = L\frac{\Delta I}{\Delta t}$,

$\Delta V_L = max = I_{max} X_L = 88.5\,V$

Loop rule $\Delta V_R + \Delta V_L + \Delta V_\varepsilon = 0$ at $t = 0$, so $\Delta V_\varepsilon = 88.5\,V$