Review Questions

27-17 (direction of F,B,v)
27-28 (helical path)
27-44 (measuring q/m)
27-69 (moving rail type)

28-7 (vectors, magnetic field of wire)
28-28 (field inside coils, ampere's law) Now try doing 30-13!
28-37(a) (Biot-Savart)

29-2, 4, 25(a) (Faraday's law)
29-33 (motional EMF)

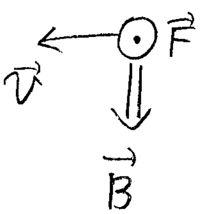
30-3 (Mutual Inductance)
30-6 (Self Inductance)
30-13 (see above)
30-29 (LR circuits)
30-53, 62 (LRC circuits)

31: Questions 1, 7, 13 (Maxwell's Eq and E&M waves)

PHY122 Workshop #6

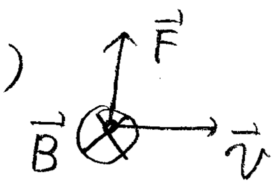
27-17

(a)



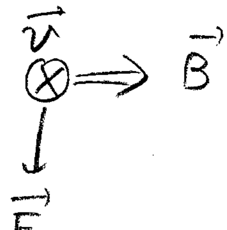
(downward)

(b)



(Into the page)

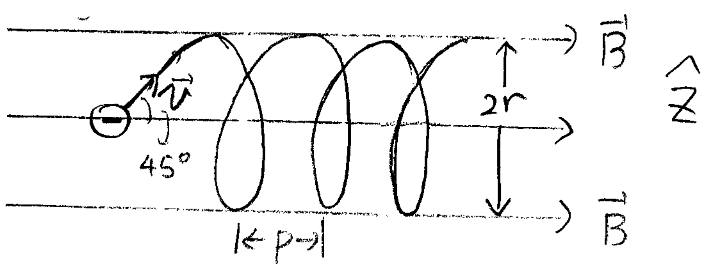
(c)



(To the right)

27-28

$$\vec{v} = \vec{v}_\perp + v_{\parallel}\hat{z}$$



The centripetal force is caused by the magnetic field, and is given by Eq. 27-5b.

$$F = qvB\sin\theta = qBv_\perp = m\frac{v_\perp^2}{r} \Rightarrow r = \frac{mv_\perp}{qB}$$

$$\therefore r = \frac{(9.11\times10^{-31}\text{kg})(3\times10^{6}\text{m/s})\sin 45^\circ}{(1.6\times10^{-19}\text{C})(0.28\text{T})} \simeq \boxed{4.3\times10^{-5}\text{m}}$$

The component of the velocity that is parallel to the magnetic field is unchanged, and so the pitch is that velocity component, $v_{\parallel}$, times the period of the circular motion.

$$T = \frac{2\pi r}{v_\perp} = \frac{2\pi \frac{m\cancel{v_\perp}}{qB}}{\cancel{v_\perp}} = \frac{2\pi m}{qB}$$

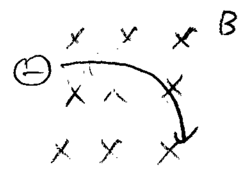
$$p = v_\parallel T = (v\cos 45^\circ)\left(\frac{2\pi m}{qB}\right) = 3.0\times10^6\,\mathrm{m/s}\,\cos 45^\circ\,\frac{2\pi\,(9.11\times10^{-31}\,\mathrm{kg})}{(1.6\times10^{-19}\,\mathrm{C})(0.28\,\mathrm{T})}$$

$$= \boxed{2.7\times10^{-4}\,\mathrm{m}}$$

27-44 READ Giancoli 27-7 and see Fig. 27-30

For a moving charge in a uniform magnetic field,

$$evB = m\frac{v^2}{r}$$

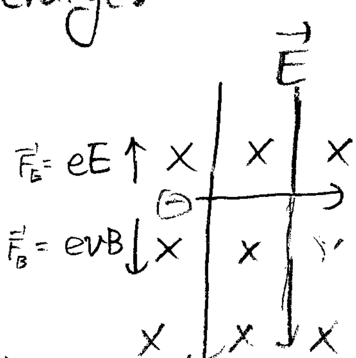


$$\boxed{\frac{e}{m} = \frac{v}{Br}}$$

Now, E field is applied to balance the electric force with the magnetic force on a charge.

$$eE = evB$$

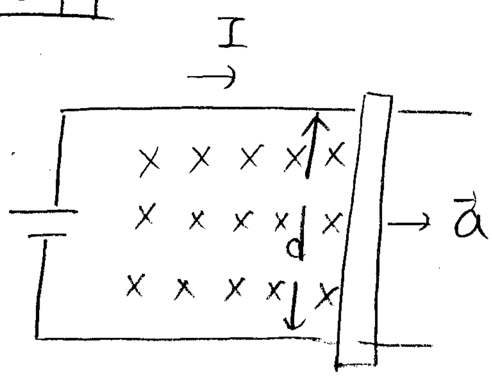
$$\Rightarrow \boxed{v = \frac{E}{B}}$$



Plugging it in the equation above yields Eq. 27-13

$$\frac{e}{m} = \frac{v}{Br} = \frac{E/B}{Br} = \frac{E}{B^2 r} = \frac{260\,\mathrm{V/m}}{(0.46\,\mathrm{T})^2(0.0080\,\mathrm{m})} = \boxed{1.5\times10^5\,\mathrm{C/kg}}$$

$\boxed{27\text{-}69}$



(B-field should point into the page for the direction of the force to be to the right!)

The accelerating force on the bar is due to the magnetic force on the current.

$$F_{net} = ma \iff a = \frac{F_{net}}{m} = \frac{IdB}{m} \quad - \text{①}$$

$$v^2 = \cancel{v_0^2}^{\,0} + 2a\Delta x \Rightarrow a = \frac{v^2}{2\Delta x} \quad - \text{②}$$

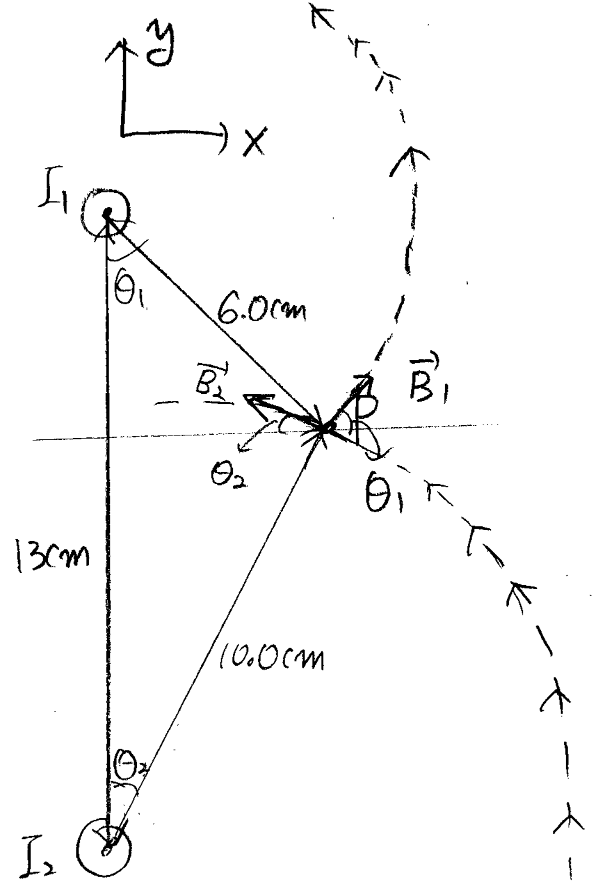
Combining ① & ②, we can solve for I

$$\frac{IdB}{m} = \frac{v^2}{2\Delta x} \Rightarrow I = \frac{m}{dB}\frac{v^2}{2\Delta x} = \frac{(1.5\times10^{-3}kg)(25m/s)^2}{(0.24m)(1.8T)\,2\,(1.0m)}$$

$$= \boxed{1.1A}$$

④

28-7



$$B_1 = \frac{\mu_0 I_1}{2\pi r_1} = \frac{(4\pi\times10^{-7}\,T\cdot m/A)(35A)}{2\pi\,(0.060m)} = 1.174\times10^{-4}\,T$$

$$B_2 = \frac{\mu_0 I_2}{2\pi r_2} = \frac{(4\pi\times10^{-7}\,T\cdot m/A)(35A)}{2\pi\,(0.100m)} = 7.00\times10^{-5}\,T$$

By the law of cosines,

$$\cos\theta_1 = \frac{(13cm)^2+(6.0cm)^2-(10.0cm)^2}{2\times(6.0cm)\times(13.0cm)} = 0.673$$

$$\theta_1 = \text{Arccos}\,(0.673) = 47.7^\circ$$

Similarly, $\theta_2 = 26.3^\circ$

Since $\vec{B} = \vec{B}_1 + \vec{B}_2$,

$$B_x = B_1\cos\theta_1 - B_2\cos\theta_2 = (1.174\times10^{-4}T)\cos 47.7^\circ - (7.0\times10^{-5}T)\cos 26.3^\circ$$

$$= 1.626\times10^{-5}\,T$$

$B_y = B_1 \sin\theta_1 + B_2 \sin\theta_2 = (1.174\times10^{-4}\,T)\sin 47.7° + (7.00\times10^{-5}\,T)\sin 26.3°$

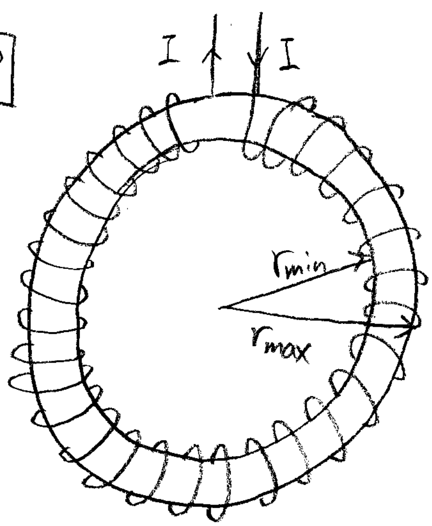
$= 1.178\times10^{-4}\,T$

$|\vec{B}| = \sqrt{B_x^2 + B_y^2} = \sqrt{(1.626\times10^{-5}\,T)^2 + (1.178\times10^{-4}\,T)^2} = \boxed{1.19\times10^{-4}\,T}$

$\theta = \tan^{-1}\dfrac{B_y}{B_x} = 82.2°$

$\vec{B} = 1.19\times10^{-4}\,T\,(\cos 82.2°, \sin 82.2°)$

28-28



SEE Ex. 28-10

From the result in Ex. 28-10, the magnetic field inside a toroid is given by

$$B = \frac{\mu_0 N I}{2\pi r}$$

Thus,

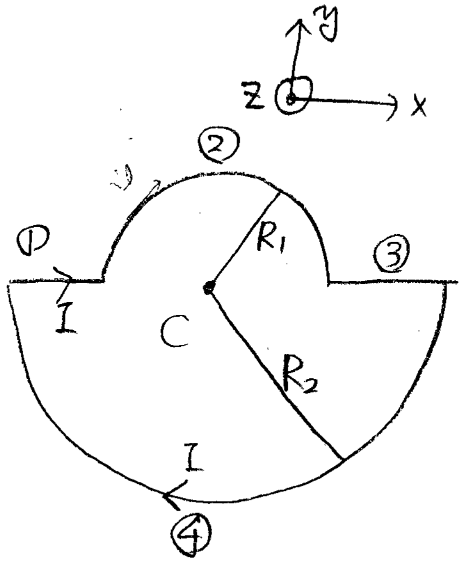
$$B_{min} = \frac{\mu_0 N I}{2\pi r_{max}} = \frac{(4\pi\times10^{-7}\,T\cdot m/A)(687)(25.0\,A)}{2\pi\times 0.270\,m} = 12.7\times10^{-3}\,T$$

$$B_{max} = \frac{\mu_0 N I}{2\pi r_{min}} = \frac{(4\pi\times10^{-7}\,T\cdot m/A)(687)(25.0\,A)}{2\pi\times 0.250\,m} = 13.7\times10^{-3}\,T$$

$$\boxed{12.7\times10^{-3}\,T < B < 13.7\times10^{-3}\,T}$$

28-37

(a)



Use Biot-Savart Law

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

$$\vec{B} = \vec{B}_{①} + \vec{B}_{②} + \vec{B}_{③} + \vec{B}_{④}$$

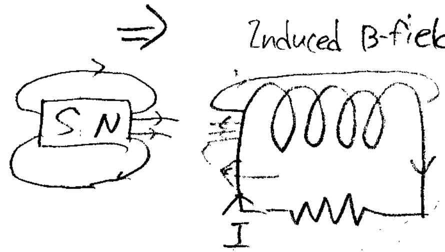
$\vec{B}_{①} = \vec{B}_{③} = 0$ since $d\vec{l} \parallel \hat{r}$

$$\vec{B}_{②} = \int_{\text{PATH②}} d\vec{B}_{②} = \int_{\text{PATH②}} \frac{\mu_0 I}{4\pi} \frac{d\vec{l} \times \hat{r}}{r^2} = \int_0^{\pi} \frac{\mu_0 I (-\hat{z}) \cancel{R_1} d\theta}{4\pi R_1^{\cancel{2}}} = -\frac{\mu_0 I}{4R_1} \hat{z}$$

$$\vec{B}_{④} = \int_{\text{PATH④}} d\vec{B}_{④} = \int_{\text{PATH④}} \frac{\mu_0 I}{4\pi} \frac{d\vec{l} \times \hat{r}}{r^2} = \int_0^{\pi} \frac{\mu_0 I (-\hat{z}) \cancel{R_2} d\theta}{4\pi R_2^{\cancel{2}}} = \frac{-\mu_0 I}{4R_2} \hat{z}$$

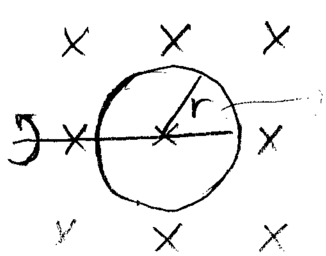
$$\therefore \vec{B} = \vec{B}_{②} + \vec{B}_{④} = -\frac{\mu_0 I}{4}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)\hat{z} \quad (\text{into the page})$$

29-2



To oppose the increase of the flux, flux produced by the induced current must be to the left, so the induced current in the resistor will be from right to left.

29-4

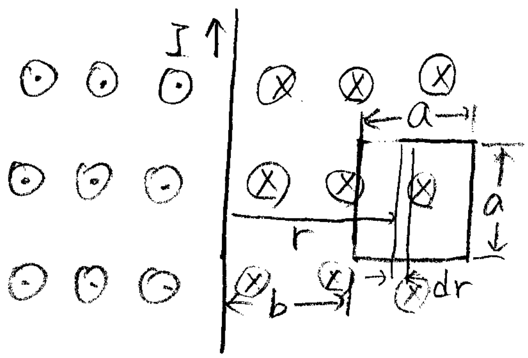


From Eq. 29-2b, $\mathcal{E} = -N \frac{d\Phi_B}{dt}$

$$\mathcal{E}_{av} = -\frac{\Delta \Phi_B}{\Delta t} = -\frac{\Phi_B|_{at\ t=0.2s} - \Phi_B|_{t=0s}}{0.2s}$$

$$= -\frac{0 - B\pi r^2}{0.2s} = \frac{(1.5T)\pi(0.110m)^2}{0.2s} = \boxed{0.29V}$$

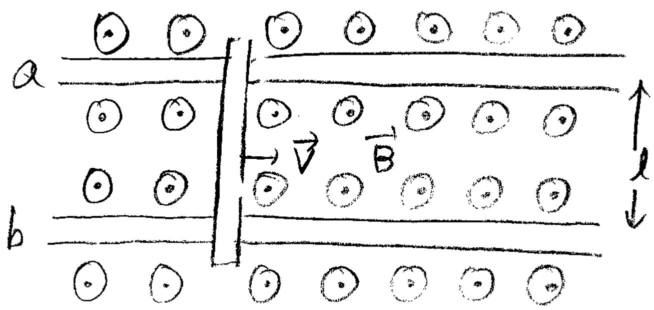
29-25 (a)



$$\Phi_B = \int B\,dA = \int_b^{b+a} \frac{\mu_0 I}{2\pi r}\,a\,dr$$

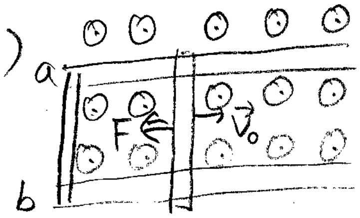
$$= \frac{\mu_0 I a}{2\pi} \ln r \Big|_b^{b+a} = \boxed{\frac{\mu_0 I a}{2\pi} \ln\left(\frac{b+a}{b}\right)}$$

29-33



(a) As the rod moves through the magnetic field, an emf will be built up across the rod, but no current can flow. Without the current, there is no force to oppose the motion of the rod, so yes, the rod travels at constant speed.

(b)



$v(t=0) = v_0$

$\boxed{\text{SEE Ex 29-8}}$

$$F = -I\ell B = -\left(\frac{B\ell v}{R}\right)\ell B = -\frac{B^2\ell^2}{R} v$$

Since $F = ma = m\dfrac{dv}{dt}$,

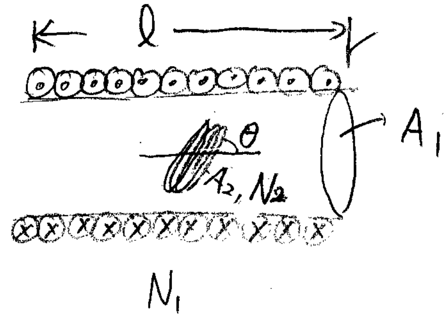
$$m\frac{dv}{dt} = -\frac{B^2\ell^2}{R} v \iff \frac{dv}{v} = -\frac{B^2\ell^2}{mR} dt$$

$$\int_{v_0}^{v(t)} \frac{dv}{v} = -\int_{t=0}^{t} \frac{B^2 l^2}{mR} dt$$

$$\Rightarrow \ln\left(\frac{v(t)}{v_0}\right) = -\frac{B^2 l^2}{mR} t$$

$$\Rightarrow \boxed{v(t) = v_0 e^{-\frac{B^2 l^2}{mR} t}}$$

$\boxed{30-3}$



Assuming the outer solenoid carries current I_1, the B-field inside the outer solenoid is

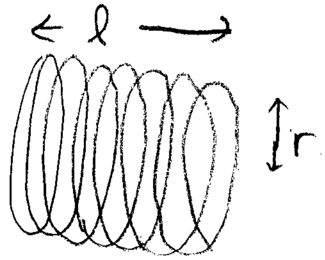
$$B = \mu_0 n I_1 = \mu_0 \frac{N_1}{l} I_1$$

By Eq. 30-1,

$$M = \frac{N_2 \Phi_{21}}{I_1} = \frac{N_2}{I_1} B A_2 \sin\theta = \frac{N_2}{\cancel{I_1}} A_2 \sin\theta \, \mu_0 \frac{N_1}{l} \cancel{I_1}$$

$$= \boxed{\frac{\mu_0 N_1 N_2 A_2 \sin\theta}{l}}$$

$\boxed{30-6}$



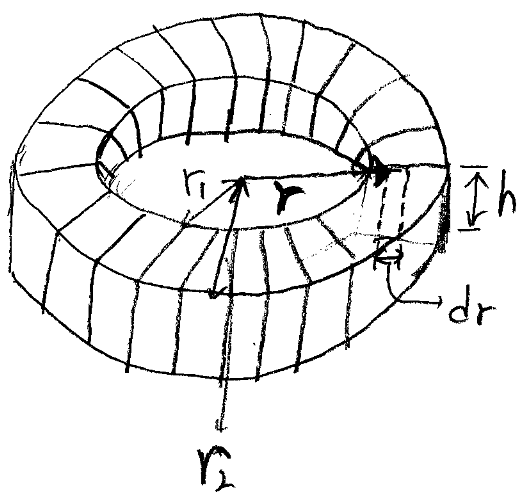
$\boxed{\text{SEE Ex. 30-3}}$

We assume this coil as a solenoid. By Eq. 30-4,

$$L = \frac{N\Phi_B}{I} = \frac{N}{I} BA = \frac{N}{\cancel{I}}\left(\mu_0 \frac{N}{l} \cancel{I}\right) A = \frac{\mu_0 N^2 A}{l}$$

$$\Rightarrow N = \sqrt{\frac{Ll}{\mu_0 A}} = \sqrt{\frac{(130\times10^{-3}\,H)(0.30m)}{(4\pi\times10^{-7}\,T\cdot m/A)\,\pi(0.021m)^2}} \cong \boxed{4700 \text{ turns}}$$

$\boxed{30-13}$



$dA = h\,dr$

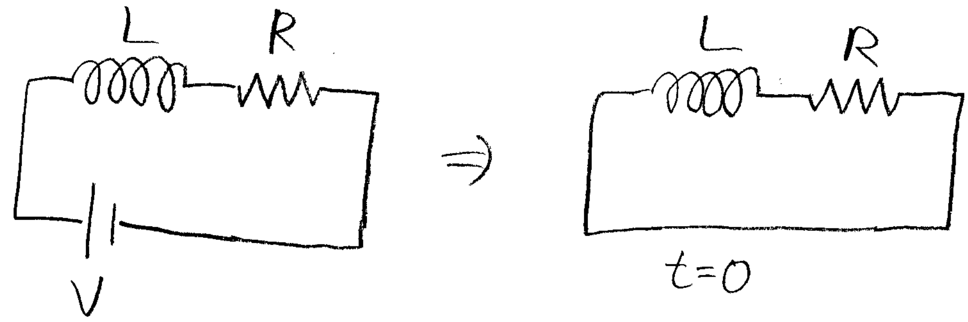
The magnetic field inside a toroid is given by $B = \frac{\mu_0 N I}{2\pi r}$

where r is a distance from the center. (SEE Ex 28-10 & Prob 28-28)

$$L = \frac{N}{I}\Phi_B = \frac{N}{I}\int_{r_1}^{r_2} B\,dA = \frac{N}{\cancel{I}}\int_{r_1}^{r_2} \frac{\mu_0 N \cancel{I}}{2\pi r} h\,dr = \frac{\mu_0 N^2 h}{2\pi}\int_{r_1}^{r_2}\frac{dr}{r}$$

$$= \frac{\mu_0 N^2 h}{2\pi} \ln\left(\frac{r_2}{r_1}\right)$$

$\boxed{30-29}$



First, using Kirchhoff's loop rule in the steady state (no voltage drop across the inductor) to determine I_0,

$$V - I_0 R = 0 \Rightarrow I_0 = \frac{V}{R}$$

This will be the maximum current after the battery is removed.

Again using Kirchhoff's loop rule, with the current given by Eq. 30-11

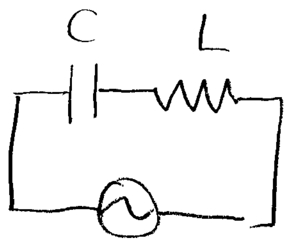
$$\mathcal{E} - IR = 0 \Rightarrow \mathcal{E} = (I_0 e^{-t/\tau})R = I_0 R e^{-\frac{t}{L/R}}$$

$$= V e^{-\frac{R}{L}t} = (12.0\,V)\, e^{-\frac{2.2\times10^3\,\Omega}{18\times10^{-3}\,H}t}$$

$$= \underline{(12\,V)\, e^{-(1.22\times10^5\,s^{-1})t}}$$

$$\underline{\mathcal{E}_{Max} = 12\,V \quad \text{when } t = 0}$$

30-53



We use the rms voltage across the resistor to determine the rms current through the circuit.

$$I_{rms} = \frac{V_{R,rms}}{R}$$

Then, using this rms current and the rms voltage across the capacitor in Eq. 30-25, we determine the frequency.

$$V_{C,rms} = I_{rms} X_C = \frac{I_{rms}}{2\pi f C}$$

$$\Rightarrow f = \frac{I_{rms}}{2\pi C V_{C,rms}} = \frac{V_{R,rms}}{2\pi C R V_{C,rms}} = \frac{(3.0V)}{2\pi (1.0\times10^{-6}C)(750\Omega)(2.7V)}$$

$$= \boxed{240Hz}$$

Since the voltages in the resistor and capacitor are not in phase, the rms voltage across the power source will not be the sum of their rms voltages.

$\boxed{30-62}$ From Eq. 30-32, the resonant frequency will be

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} = \frac{1}{2\pi}\sqrt{\frac{1}{(26.0\times10^{-6}H)(3800\times10^{-12}F)}} = \boxed{5.1\times10^{5}Hz}$$

$\boxed{Q.31-1}$

1)

$\vec{E}$: increasing

$\vec{B}$ field will be clockwise since the direction of the displacement current $(\propto \frac{d\Phi_E}{dt})$ is away from you due to the increase of $\vec{E}$ field away.

2)

$\vec{E}$: decreasing

$\vec{B}$-field is still clockwise since the direction of the displacement current $(\propto \frac{d\Phi_E}{dt})$ is still away from you.

Q.31-7

EM waves are self-propagating and can travel through a perfect vacuum. Sound waves are mechanical waves which require a medium, and therefore cannot travel through a perfect vacuum.

Q. 31-13

Yes, although the wavelengths for radio waves will be much longer than for sound waves, since the radio waves travel at the speed of light.

$$\lambda_{radio} = \frac{c}{f}$$

$$\lambda_{sound} = \frac{343\ m/s}{f}$$