Solutions for class #9 from Yosunism website

Yosunism website: http://grephysics.yosunism.com

Problem 55:

Electromagnetism⇒}Magnetic Force

The magnetic force of a wire is given by $\vec{F} = I\vec{l} \times \vec{B}$, where I is the current of the wire and l its length.

The field that produces the force on the loop is given by the long wire (see the previous problem for why). The field of that wire is given trivially by Ampere's Law to be $\vec{B} = \frac{\mu_0 I}{2\pi r}$, where r is the radial distance away from its center.

Only two wires from the loop contribute to the force, since the cross-product yields 0 force for the two horizontal components. Thus, the net force on the loop with current i with vertical components of length b is $|F_{left} + F_{right}| = |ib\frac{\mu_0 I}{2\pi}\left(\frac{1}{r} - \frac{1}{r+a}\right)|$. Combine the fraction to get choice (D).

YOUR NOTES:

Problem 57:

Electromagnetism⇒}Faraday Law

Faraday's Law has the induced voltage is given by the change in magnetic flux, as $V = -\frac{dB \cdot A}{dt}$. (The minus sign shows that the induced voltage opposes the change.)

Since the induced voltage has to be periodic (as the half-circle rotates around A), choices (D) and (E) are immediately eliminated.

The voltage changes from positive to negative in regions where the change in flux is slowing down, goes to 0, then speeds up again. Thus, choice (C) is out.

The change in flux is constantly increasing as the loop spins into the field, and it is constantly decreasing as it spins out of the field. This is choice (A).

YOUR NOTES:

Problem 64:

Electromagnetism⇒}Gauss Law

Gauss Law gives $\nabla\cdot\vec{E}=\rho/\epsilon_0$. Since the divergence of E in Cartesian coordinates is non-zero, there is a charge density in the region. QED

Thus, the total angular momentum is $j=2+3/2=7/2$, as in choice (A).

YOUR NOTES:

Problem 65:

Electromagnetism⇒}Small Oscillations

The force on the charge in the center due to the charges on both sides is $F=\frac{2Qq}{4\pi\epsilon_0 R^2}$.

Small oscillations have a form $\ddot{x}=-\omega_0^2 x$, which comes from $m\ddot{x}=-kx$.

Thus, the Coulomb Force above gives $m\ddot{y}=-\frac{2Qqy}{4\pi\epsilon_0 R^3}$. Note the compensating R on the denominator to account for the y.

Thus, the angular frequency is given by (E).

YOUR NOTES:

Problem 79:

Wave Phenomena⇒}Group Velocity

Recall that the group velocity is given by $v_g = \frac{d\omega}{dk}$and the phase velocity is given by $v_p = \omega/k$.

In the region between $k_1$and k_2, the derivative is a constant negative quantity (approximately just the derivative of a line with negative slope). However, $\omega/k$is positive in this region. Thus, the phase and group velocity are traveling in opposite directions. Thus, choose choice (A).

YOUR NOTES:

Problem 81:

Electromagnetism⇒}Resonant Frequency

The maximum steady-state amplitude (after transients die out) occurs at the resonant frequency, which is given by setting the impedance of the capacitor and inductor equal $X_C = X_L \Rightarrow \frac{1}{\omega C} = \omega L \Rightarrow \omega^2 = 1/(LC)$, as in choice (C).

YOUR NOTES:

Problem 83:

Electromagnetism⇒}Forces

Sum of the forces for one of the mass in the x (horizontal) and y (vertical) directions gives,

$$\sum F_x = 0 = T\sin\theta - kq^2/d^2$$
$$\sum F_y = 0 = T\cos\theta - mg
$$

For small angles, $\cos\theta \approx 1 \Rightarrow T \approx mg$. From the geometry, one can deduce that $\sin\theta = (d/2)/L$.

Thus, the x equation yields $T(d/2)/L = kq^2/d^2 \Rightarrow d^3 = 2kq^2 L/(mg)$ (since $T \approx mg$ from the y equation for small angles). This is choice (A).

YOUR NOTES:

Problem 84:

Electromagnetism⇒}Accelerating Charges

Elimination time:

(A) By the Larmor formula, one has $E \propto q^2 a^2$, where q is the charge and a is the acceleration. Since the charge is constant, this choice is true.

(B) This is also true by Larmor's formula.

(C) True. The energy radiated through a perpendicular unit area is given by the Poynting vector. and $E^2 \propto 1/r^2$far away. Also, less rigorously, one can arrive at the same result from recalling the surface area of a sphere, $4\pi r^2$, and thus any term in $\vec{S}$ proportional to $1/r^2$ will yield a finite, thus acceptable answer. (Thanks to the user astro_allison for this pointer. See p460ff of Griffiths, *Introduction to Electrodynamics*, 3rd Edition for more details.)

(D) False. It's a minimum in the plane.

(E) True, since far from the electron the field behaves as plane waves, with E_z and B_z both 0.

YOUR NOTES:

Problem 86:

Lab Methods⇒}Oscilloscopes

The discharge of the capacitor after it has been charged to V_0 is just $V(t)=V_0(1-e^{-\omega t})$, where $\omega=1/(RC)$. One can find C by knowing R and the sweep rate, which is related to t. (Solution due to David Latchman.) .

YOUR NOTES:

Problem 88:

Electromagnetism⇒}Capacitors

From the problem and the basic relation for capacitors $Q=CV$, one immediately deduces that the initial charge is $Q_0=C_0V_0$ and the final charge is $Q_f=\kappa C_0V_0$, and thus choice (C) is out.

The potential is constant $V_f=V_0$, and thus choices (A) and (B) are out.

The electric field for a parallel plate capacitor is given by $E=\sigma/\epsilon$. Since $E_0=\sigma_0/\epsilon_0$ and $E_f=\sigma_f/(\kappa\epsilon_0)$, the final field is *the same* as the initial field. (To wit: $\sigma=Q/A \Rightarrow \sigma \propto Q$.) Thus, (D) is false. (Thanks to the user whose alias is "poop" for pointing this out.)

From the definition of $D=\epsilon_0E_0+P=\epsilon E_0$, one has $D_0<D_f$, since $\epsilon_0<\kappa\epsilon_0$. Choice (E) is right.

YOUR NOTES:

Problem 92:

Electromagnetism⇒}Frequency

A three-pole magnet should produce three voltage peaks, and thus the frequency is 30 Hz. (Solution due to David Latchman.)

YOUR NOTES: