Supplementary Problems – Week 2

S-1 A pendulum on Earth ($g_E = 9.8m/s^2$) has a period of 1 sec. What is its length? If you take it to the moon what will its period be there if $g_M = \frac{g_E}{6}$? If you want the period to be 1 sec on the moon by what factor must you change the length?

S-2 A spring-mass system is oscillating on a horizontal frictionless surface and its position is given by $x = 0.05\ m\ \cos\omega t$. For what values of x will (i) its kinetic energy be maximum, (ii) its potential energy be maximum (iii) its kinetic energy equal its potential energy.

S-3 If the system of problem S-2 is hung from a ceiling, what will be the change in its frequency? Why?

S-4 A wave on a stretched string is represented by

$$\vec{y} = 0.01\sin(6.28x - 12.56t)\hat{y}$$

where distances are in meters and times in seconds. (i) Is this longitudinal or transverse? (ii) What is its wavelength, frequency, velocity?

S-5 A sinusoidal wave of amplitude A and frequency ω carries

$$P = \frac{1}{2}A^2\omega^2\frac{T}{v}, \text{ where } v = \sqrt{\frac{T}{\mu}}$$

Joules of energy per second. Here T is the tension and v, the wave speed. Changing only one factor at a time how would P change if you (i) double A (ii) halve ω or (iii) increase T by a factor of 3.

Supplementary Problems – Week 3

S-6 The intensity of a periodic sound wave of amplitude s_m and frequency ω in a gas at pressure P_o is

$$I = \frac{1}{2} s_m{}^2 \omega^2 \frac{\gamma P_o}{v_s}$$

where $\gamma = \frac{C_P}{C_v}$ and v_s is the speed of sound. Calculate s_m for air if $P_o = 10^5 N/m^2$, $\gamma = 1.4$, $v_s = 330 m/s$ and $I = I_o = 10^{-12} Watt/m^2$; the quietest sound that can be heard.

S-7 A periodic sound wave can be thought of as a displacement wave

$$s = s_m \sin(kx - \omega t)$$

or a pressure wave

$$P = P_o - \gamma P_o s_m \cos(kx - \omega t)$$

Why is the pressure wave always $\frac{\pi}{2}$ out of phase with the displacement, that is, why is pressure variation maximum where displacement is zero and vice versa?

S-8 In air the speed of sound at room temperature is about $330 m/s$. What must be the wavelengths of mechanical waves to be called sound?

S-9 What is radiation? How do you distinguish between (i) heat radiation (ii) FM radio waves (iii) γ - rays?

S-10 The intensity of em waves from the sun is $1.4 kW/m^2$ just above the Earth's atmosphere. What is the amplitude of the $\underset{\rightarrow}{E}$-field in these waves?

Supplementary Problems – Week 7

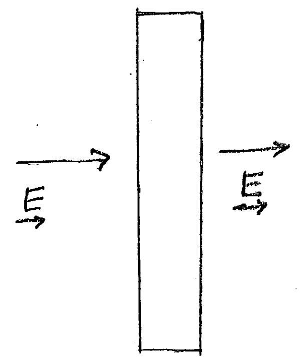
S-11 You are given a charge q and a device to measure force. How would you discover the presence of an $\underset{\rightarrow}{E}$-field?

S-12 A conducting sphere of diameter $1m$ carries a charge of $100\mu C$. Under stationary conditions, where would this charge be located? Why?

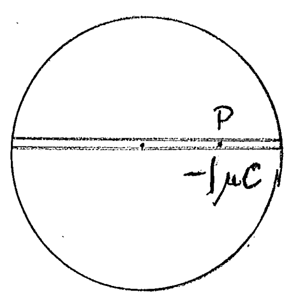
S-13 In problem S-12, what would be the force experienced by a point charge of $1\mu C$ if it was located at (i) $0.49m$ (ii) $0.51m$ from the center of the conducting sphere? Why?

S-14 Two equal charges of $+10\mu C$ are located at (x=0, y=0) and (x=1m, y=0). A charge of -1μC is held at (x=0.5m, y=0.001m). If you release the -1μC charge, what will its motion be? Why?

S-15 A conductor of thickness d is placed in a uniform $\underset{\rightarrow}{E}$-field, $\underset{\rightarrow}{E}$=100N/C $\hat{x}$ as shown. Under stationary conditions what are the charge densities that appear on its surface? Why?



S-16 An insulating sphere of radius 1m has a small diametric hole in it as shown. It carries a charge of 50 μC uniformly distributed over its volume. If we release a charge q=-1 μC at the point P what will be the motion of q? Why?



Supplementary Problems – Week 8

S-17 What is a conservative force? Give one example.

S-18 What is potential energy? (Do not write mgh).

S-19 Why is there a minus sign on the right side of the equation $\Delta U = -\vec{F}_E \cdot \Delta \vec{S}$?

S-20 In order to place a charge Q on a capacitor C_0 the battery must do $\frac{Q^2}{2C_0}$ Joules of work. Where does all this energy go? Why?

Supplementary Problems – Week 9

S-21 Current measures the flow of charge. In a conductor it is the "free" electrons that "flow". Copper is a monovalent metal, that is, it has one (1) free electron per atom. Cu has an atomic mass #64 [64gms of Cu have 6.02×10^{23} atoms] and a density of $8.9 gms/cm^3$. Calculate the number of free electrons (n_e) in one m^3 of copper.

S-22 Using the result of S-21, if there is a current of 1amp in a Cu wire of diameter 1mm, what will be the drift speed (V_D) of the electrons? [$|e| = 1.6\times10^{-19} C$] Why?

S-23 If in S-22 the diameter is doubled by what factor will V_D change? Why?

S-24 When the resistance(R) is independent of the current one writes the so-called Ohm's Law

$$V=IR \qquad \text{-- (1)}$$

Now $I = \vec{J}\cdot\vec{A}$ where $\vec{J}$ is the current density and A the area of the conductor, $R = \frac{l}{\sigma A}$ where l is the length and σ the electrical conductivity. Show that Eq. (1) implies the fundamental relationship $\vec{J} = \sigma\,\vec{E}$ where $\vec{E}$ is the field driving the current.

Supplementary Problems – Week 10

S-25 Write down the physical bases of Kirchhoff's laws.

S-26 Show that RC has the dimensions of time.

S-27 Why does the time constant τ of an RC-Circuit depend on both R and C.

Supplementary Problems- Week 11

S-28 How would you distinguish between an $\underset{\rightarrow}{E}$-field and a $\underset{\rightarrow}{B}$-field?

S-29 In a constant $\underset{\rightarrow}{B}$-field, $\underset{\rightarrow}{B} = B\hat{z}$ if we introduce a charge q with a velocity $\underset{\rightarrow}{v} = v\hat{x}$, the force $\underset{\rightarrow}{F_B} = q[\underset{\rightarrow}{v} \times \underset{\rightarrow}{B}]$ will make q go around in a circle. (i) How much work does the $\underset{\rightarrow}{B}$-field do on the charge, (ii) if you double v what is the change in the angular velocity of q? Justify your answers.

S-30 The Biot-Savart law tells us that a current I flowing through a conducting wire of length $\underset{\rightarrow}{\Delta \ell}$, produces a $\underset{\rightarrow}{B}$-field at $\underset{\rightarrow}{r}(\perp \underset{\rightarrow}{\Delta \ell})$ given by

$$\underset{\rightarrow}{\Delta B} = \frac{\mu_0}{4\pi} I \frac{\underset{\rightarrow}{\Delta \ell} \times \underset{\rightarrow}{r}}{r^3}$$

Show that the $\underset{\rightarrow}{B}$-field lines circulate around the current.

S-31 Since the $\underset{\rightarrow}{B}$-field due to a current swirls around it (like water circulates as it flows out of a bath tub) Ampere taught us that the circulation of the $\underset{\rightarrow}{B}$-field around a closed loop

$$\Sigma_C \underset{\rightarrow}{B} \cdot \underset{\rightarrow}{\Delta \ell}$$

is determined solely by the currents flowing through the surface on which the loop is drawn. That is,

$$\Sigma_C \underset{\rightarrow}{B} \cdot \underset{\rightarrow}{\Delta \ell} = \mu_0 \Sigma I_i$$

where μ_0 is a fundamental constant

$$\mu_0 = 4\pi \times 10^{-7} \frac{T-m}{A}$$

Supposing we have a single current I flowing along the y-axis. Please use ampere's law and the symmetry of the problem to show that the $\underset{\rightarrow}{B}$-field at a point P in the xz- plane is given by

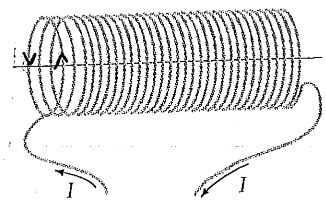
$$\underset{\rightarrow}{B}(r) = \frac{\mu_0 I}{2\pi r} \hat{\Phi}$$

where r is distance between P and the y-axis

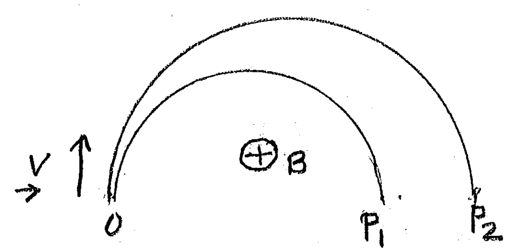
S-32 A tightly wound long solenoid consists of a large number of closely spaced rings with a common axis (see figure). It produces a uniform field inside it. Use Ampere's law to show that for the case shown (ccw current in solenoid)

$$\underset{\rightarrow}{B} = -\mu_0 n I \hat{x}$$

where n= No. of turns/meter of the solenoid. (n= N/L)

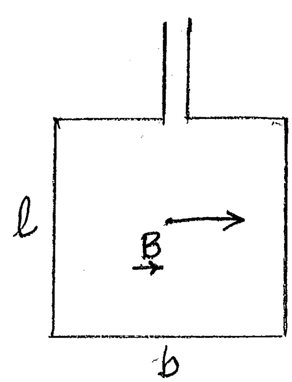


S-33 In a mass spectrometer the beam at 0 consists of two kinds of particles with same mass (M) but different charges q_1, q_2 entering with a velocity $\underset{\rightarrow}{v} = v\hat{y}$. For $\underset{\rightarrow}{B} = -B\hat{z}$ and the paths shown, what is the sign of the charge (+ive or –ive)? Where will the larger charge land, P_1 or P_2? Justify your answer.



S-34 Why do two parallel currents attract one another?

S-35 Shown is a coil of width b and length ℓ suspended vertically in a $\underset{\rightarrow}{B}$-field. How would you make it work like a motor? The coil is free to rotate about its vertical axis.



Supplementary Problems- Week 12

S-36 Why does a bar magnet attract a piece of Iron?

S-37 We have learnt that the total flux of the $\underset{\rightarrow}{B}$-field through any closed surface is always equal to zero. What does this tell you about the elementary generators of $\underset{\rightarrow}{B}$-field? Why?

S-38 What is the difference between a coulomb $\underset{\rightarrow}{E}$-field and a non-coulomb $\underset{\rightarrow}{E}$-field?

S-39 When Maxwell looked at the field equations

$$\Sigma_C \underset{\rightarrow}{B} \cdot \underset{\rightarrow}{\Delta \ell} = \mu_0 \Sigma I_i \qquad \text{-(1)}$$

and

$$\Sigma_C \underset{\longrightarrow}{E_{NC}} \cdot \underset{\rightarrow}{\Delta \ell} = -\frac{\Delta \Phi_B}{\Delta t} \qquad \text{-(2)}$$

where $\Phi_B = \underset{\rightarrow}{B} \cdot \underset{\rightarrow}{A}$ flux of $\underset{\rightarrow}{B}$ through area $\underset{\rightarrow}{A}$ and $\underset{\longrightarrow}{E_{NC}}$ is the non-coulomb $\underset{\rightarrow}{E}$ surrounding $\underset{\rightarrow}{A}$; he claimed that Eq (1) was "incomplete". Do you notice the reason for his concern?

S-40 What is the difference between a conduction current and a displacement current?

Supplementary Problems- Week 13

S-41 The energy densities of $\underset{\rightarrow}{E}$ and $\underset{\rightarrow}{B}$ fields are given by

$$\eta_E = \frac{1}{2}\varepsilon_0 E^2$$

$$\eta_B = \frac{B^2}{2\mu_0}\text{, respectively}$$

What is the relationship between η_E and η_B if E=cB where c=$\frac{1}{\sqrt{\mu_0\varepsilon_0}}$.

S-42 You are standing near a window and see a lightning flash and note that you hear the thunder 5secs. later. If the speed of sound is 330m/s, how far was the flash? Why?

S-43 Show that $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$ has the dimensions of velocity (LT^{-1}). $\varepsilon_0 = 9\times10^{-12}$ F/m, $\mu_0 = 4\pi\times10^{-7}$ H/m.

S-44 What is the flux of the Non-Coulomb $\underset{\rightarrow}{E}$-field through a closed surface? Why?

S-45 How would you make the coil shown in Prob. S-35 work like a generator?

S-46 In Prob. S-45 show that the generated emf is maximum(zero) when the flux of the $\underset{\rightarrow}{B}$-field through the coil is zero(maximum).

S-47 In order to establish a current I in an inductor L the battery must do $u_B = \frac{1}{2} L I^2$ Joules of work. Where does all this energy go? Why?