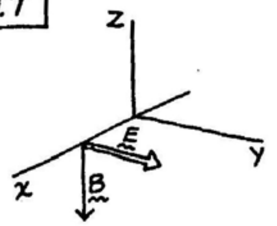
9.7



$$\omega = 2\pi f = 6.28 \times 10^8 \text{ sec}^{-1}$$

$$k = \omega / c = .0209$$

$$\mathbf{E} = \hat{y} E_0 \cos(.0209x + 6.28 \times 10^8 t)$$

$$\mathbf{B} = -\hat{z} E_0 \cos(.0209x + 6.28 \times 10^8 t)$$

9.8 $E_x = E_y = 0\ ;\ E_z = E_0 \cos kx \cos ky \cos \omega t$

$$\nabla \times \mathbf{E} = k E_0 (-\hat{x} \cos kx \sin ky + \hat{y} \sin kx \cos ky) \cos \omega t$$

$$\frac{\partial \mathbf{E}}{\partial t} = -\omega \hat{z} E_0 \cos kx \cos ky \sin \omega t$$

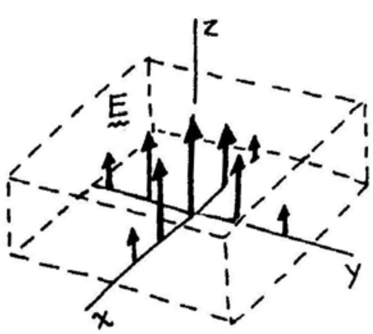
$$B_x = B_0 \cos kx \sin ky \sin \omega t\ ;\ B_y = -\sin kx \cos ky \sin \omega t\ ;\ B_z = 0$$

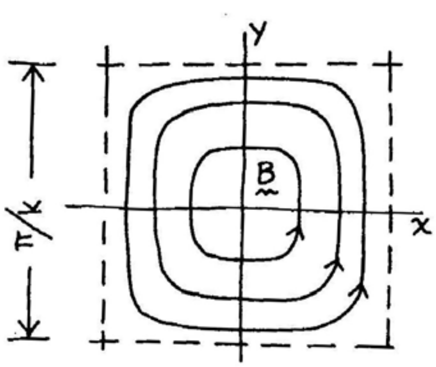
$$\nabla \times \mathbf{B} = \hat{z}\left(\frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y}\right) = -2k \hat{z} B_0 \cos kx \cos ky \sin \omega t$$

$$\frac{\partial \mathbf{B}}{\partial t} = \omega B_0 (\hat{x} \cos kx \sin ky - \hat{y} \sin kx \cos ky) \cos \omega t$$

$$\left.\begin{aligned} \nabla \times \mathbf{E} &= -\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t} \quad \text{gives: } B_0 = \frac{kc}{\omega} E_0 \\ \nabla \times \mathbf{B} &= \frac{1}{c}\frac{\partial \mathbf{E}}{\partial t} \quad \text{gives: } B_0 = \frac{\omega}{2kc} E_0 \end{aligned}\right\} 2k^2c^2 = \omega^2$$

$$\omega = \sqrt{2}\, ck \qquad B_0 = E_0 / \sqrt{2}$$



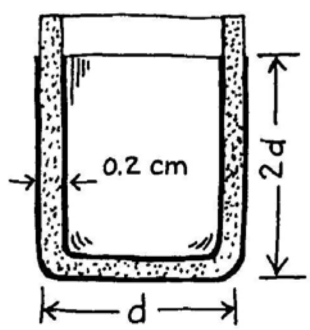


9.9 The mean energy density in a sinusoidal electromagnetic wave of amplitude E_0 is $E_0^2/8\pi$. (See Prob. 9.5 solution). $E_{rms} = E_0/\sqrt{2}$. If $E_{rms}^2/4\pi = 4 \times 10^{-13}$ erg, $E_{rms} = (4\pi \times 4 \times 10^{-13})^{\frac{1}{2}}$
$= 2.2 \times 10^{-6}$ statvolt/cm
$= 2.2 \times 10^{-6} \times 3 \times 10^4$ or 6.6×10^{-2} volt/meter.

A wave in which the energy density is 4×10^{-13} erg cm^{-3} is transporting energy with power density $4 \times 10^{-13} \times 3 \times 10^{10}$ or 1.2×10^{-2} erg cm^{-2}sec^{-1}, equivalent to 1.2×10^{-5} watt/m^2. If the kilowatt radiated by the transmitter is spread over a hemisphere of R meters radius, the power density there, in watt/m^2, is $10^3/2\pi R^2$. Setting this equal to 1.2×10^{-5} gives $R \approx 3000$ m, or 3 km.

If you want to do the whole calculation in SI, start with the given energy density 4×10^{-14} J m^{-3}.
This times c, 3×10^8 m sec^{-1}, gives us the power density 1.2×10^{-5} watt/m^2. To find E_{rms}, use Eq. 29:
$E_{rms} = (377 \times 1.2 \times 10^{-5})^{\frac{1}{2}} = 6.6 \times 10^{-2}$ volt m^{-1}.

10.2 Assume height = 2d (result will depend somewhat on proportions assumed).



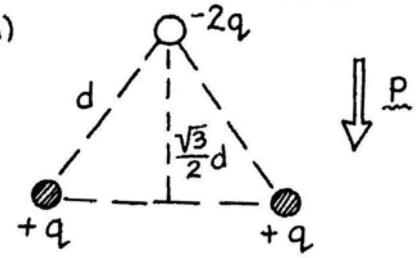
1 liter $= 10^3 \text{cm}^3 = 2d \times \frac{\pi}{4} d^2$, or $d = 8.6$ cm

area of capacitor $= \pi d \times 2d + \frac{\pi}{4} d^2 = \frac{9}{4}\pi d^2$
$= 522 \text{ cm}^2$

$$C = \frac{522 \times 4}{4\pi \times 0.2} = 830 \text{ cm}$$

This is the capacitance of a sphere of 830 cm radius, or about 54 feet diameter.

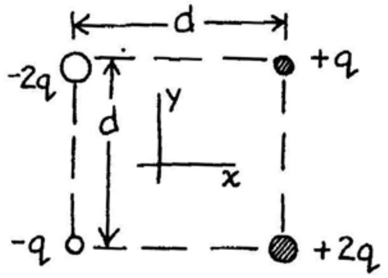
10.3 (a)



$$p = 2q\frac{\sqrt{3}}{2}d = \sqrt{3}qd$$

(b) $p = 0$

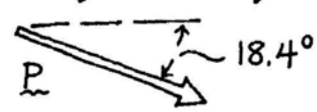
(c)



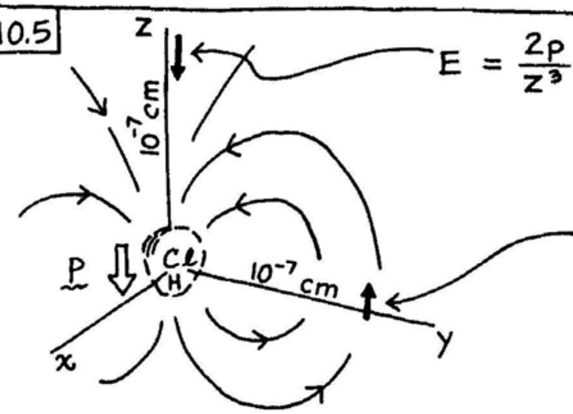
$$p_x = +3qd$$

$$p_y = -qd$$

$$p = \sqrt{10}\,qd = 3.16\,qd$$



10.5



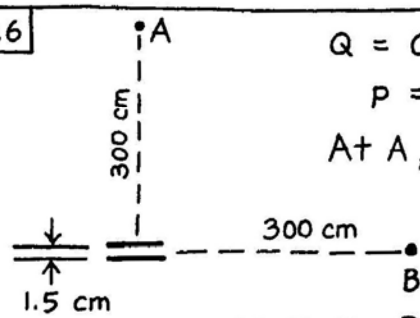
$$E = \frac{2p}{z^3} = \frac{2 \times 1.03 \times 10^{-18}}{(10^{-7})^3}$$

$$= 2.06 \times 10^3 \ \frac{\text{statvolts}}{\text{cm}}$$

$$E = \frac{p}{y^3}$$

$$= 1.03 \times 10^3 \ \frac{\text{statvolts}}{\text{cm}}$$

10.6



$$Q = CV = 250 \times 6 = 1500 \text{ esu}$$

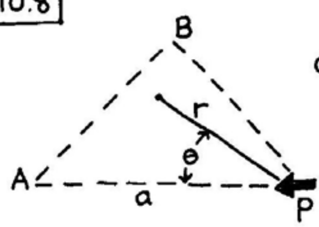
$$p = QS = 1500 \times 1.5 = 2250 \text{ esu - cm}$$

$$\text{At A, } E = \frac{2p}{r^3} = \frac{2 \times 2250}{(300)^3}$$

$$= 1.67 \times 10^{-4} \text{ statvolts/cm}$$

$$\text{At B, } E = \frac{p}{r^3} = 0.833 \times 10^{-4} \text{ statvolts/cm}$$

10.8

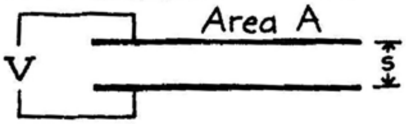


$$\phi = \frac{p\cos\theta}{r^2} \qquad \phi_A = \frac{p}{a^2}$$

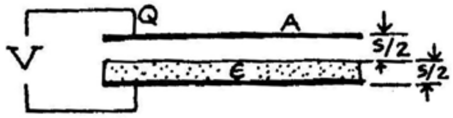
$$\phi_B = p \times \frac{.707}{(a^2/2)} = \frac{1.414\,p}{a^2}$$

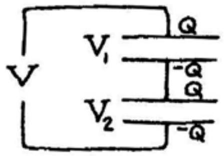
$$\text{work done} = \phi_B - \phi_A = \frac{0.414\,p}{a^2}$$

10.14



$$C_0 = \frac{A}{4\pi s}$$





$C_1 = 2C_0$

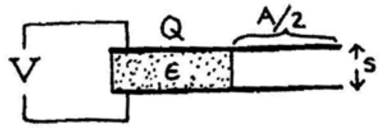
$C_2 = 2\epsilon C_0$

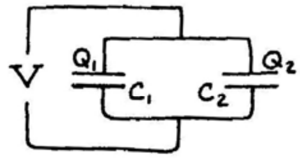
This is equivalent to two capacitors, C_1 and C_2 in series.

$$V_1 = \frac{Q}{C_1} = \frac{Q}{2C_0} \qquad V_2 = \frac{Q}{C_2} = \frac{Q}{2\epsilon C_0} \qquad V = V_1 + V_2 = \frac{Q}{2C_0}\left(1+\frac{1}{\epsilon}\right)$$

The capacitance of the combination is:

$$C = \frac{Q}{V} = \frac{2C_0}{1+\frac{1}{\epsilon}} = \frac{2\epsilon}{\epsilon+1}C_0$$





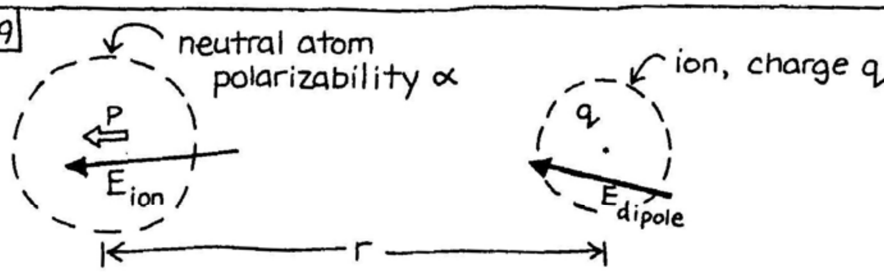
This is equivalent to two capacitors, C_1 and C_2 in parallel.

$$C_1 = \frac{\epsilon C_0}{2} \qquad C_2 = \frac{C_0}{2} \qquad Q_1 = C_1 V = \frac{\epsilon}{2}C_0 V \qquad Q_2 = C_2 V = \frac{C_0}{2}V$$

The capacitance of the combination is:

$$C = \frac{Q}{V} = \frac{Q_1+Q_2}{V} = \frac{\epsilon+1}{2}C_0$$

10.19



Field of ion, $E_{ion} = \frac{q}{r^2}$, induces dipole $p = \alpha E_{ion}$ in neutral atom. Field of induced dipole, $E_{dipole} = \frac{2p}{r^3}$,

causes force $F = qE_{dipole}$ on ion:

$$F = q\left(\frac{2p}{r^3}\right) = \frac{2q}{r^3} \times \frac{\alpha q}{r^2} = \frac{2\alpha q^2}{r^5}.$$

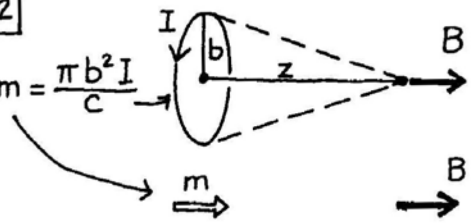
This force is attractive for either sign of q.

Work to separate from distance $r_1 = \int_{r_1}^{\infty} F\,dr = \frac{\alpha q^2}{2r_1^4}$

If $q = e$ and $\alpha = 27\times10^{-24}\,\text{cm}^3$ this is 4×10^{-14} erg for

$$r_1 = \left[\frac{27\times10^{-24}\times(4.8\times10^{-10})^2}{2\times10^{-14}}\right] = 9\times10^{-8}\,\text{cm}$$

11.2



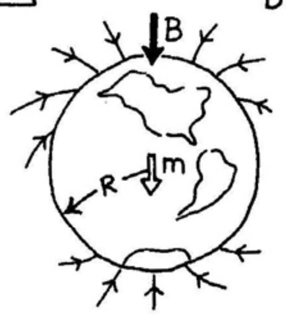
$$m = \frac{\pi b^2 I}{c}$$

$$B = \frac{2\pi b^2 I}{c(z^2+b^2)^{3/2}}$$

$$B = \frac{2m}{z^3} = \frac{2\pi b^2 I}{c z^3}$$

$$z^3/(z^2+b^2)^{3/2} > .99 \quad \text{if} \quad z > 12.2\, b$$

11.4



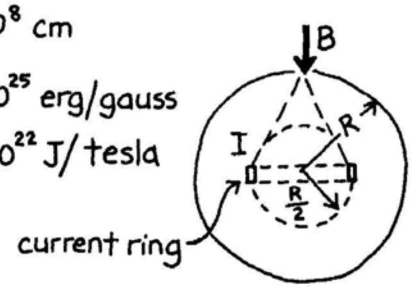
$B = .62$ gauss $= \dfrac{2m}{R^3}$

$R = 6 \times 10^8$ cm

$m = 6.7 \times 10^{25}$ erg/gauss

$= 6.7 \times 10^{22}$ J/tesla

$$B = \frac{4\pi I}{cR\,5^{3/2}}$$

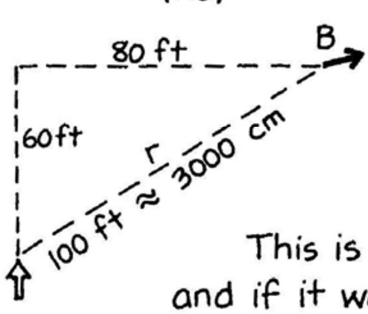


If m of current ring $= 6.7 \times 10^{25}$ erg/gauss, $I = 2.4 \times 10^9$ amp

If field B of current ring $= .62$ gauss, $I = 3.3 \times 10^9$ amp

11.5 To estimate roughly the magnetic dipole moment of the solenoid, let us suppose that it is equivalent to a point dipole which would produce, 20 cm away on its axis, a field strength B_z equal to that at the end of the solenoid, namely 18000 gauss. This is reasonable because the magnetic field configuration near the end of the solenoid and beyond looks not very different from a dipole field. On this assumption,

$$18000 = \frac{2m}{(20)^3}, \quad \text{or} \quad m = 7.2 \times 10^7 \text{ cgs units}$$



In order of magnitude,

$$B \approx \frac{m}{r^3} = \frac{7 \times 10^7}{27 \times 10^9}$$

$$= 2.5 \times 10^{-3} \text{ gauss}$$

This is small compared to the earth's field, and if it were perfectly steady could not be noticed. But if frequently switched on and off it might cause trouble.