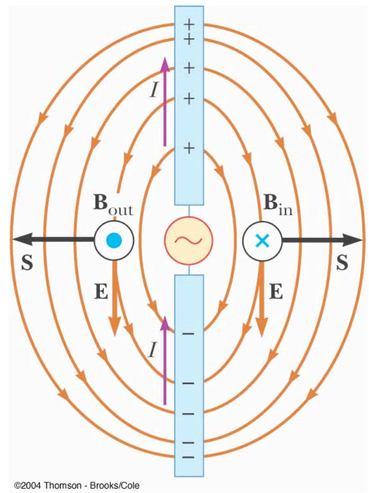
Physics 202,   Fall 2007
Homework 10

Problem 1:

If the antenna in Figure 34.10 represents the source of a distant radio station, what would be the best orientation for your portable radio antenna located to the right of the figure?



(_) perpendicular to the page
(_) left-right along the page
(o) up-down along the page

Comment: The antenna needs will pick up mpst signal is the orientation is in the same axis orientation (up-down) as the Electric field vector.
Additional comment: If, of course the antenna were a magnetic loop antenna the areal vactor should point in or our of the page to pick up the mengetic component.

Problem 2:

An interplanetary dust particle of radius 1 mm is influenced by the force of gravity from the sun and the force due to radiation pressure from the sun's light. The net force on such a particle is determined to be F_1. The net force on a similar particle of the same density but of radius 2 mm will be approximately which of the following?

(o) $8F_1$
(_) $4F_1$
(_) $F_1/8$
(_) $2F_1$
(_) $F_1/2$
(_) $F_1/4$
(_) F_1

Answer:

For a particle of this size, the gravitational force totally dominates the force cause by the radiation pressure.
Example 34.3 more or less gives the answer. The radiation pressure equals the gravitational force for a particle of 0.2μm diameter.
If the particle's diameter is 1 mm (5000 times bigger) we can derive the answer by scaling.
- Gravitational force G ~ mass 0f particle ~ volume particle ~ radius^3

- Radiation pressure P ~ planar cross section of particle ~ radius^2
That means:
G(1mm) = 5000^3 * G(0.2 μm)
$F_{radiation}$(1 mm) = 5000^2 * F(0.2μm) = (1/5000) G(1mm)

Thus, the gravitational force totally dominates, therefore we can ignore the radiation pressure.
The gravitational force of a 2mm particle is 8 times larger, because it has 8 times the mass.

Problem 3:

You are located far from a radio station antenna on a line that is at an angle of 30° from the axis of the antenna, at point P, as shown. To improve your reception of the radio signal, you should do which of the following?
(o) Move to either point; the radio signal will be better and equally strong at both locations.
(_) Stay where you are; the signal will not improve by moving to points A or B.
(_) Move to point A, a location that is exactly halfway closer to the antenna on the same line.
(_) Move to point B, a location that is the same distance from the antenna but on a line that is 90° from the antenna axis.

Comment:
The answer is an immediate consequence of the dependence: $\sin(\theta)/r^2$

Problem 4: (also textbook 34.5)

(a) $f\lambda = c$

or $f(50.0\text{ m}) = 3.00 \times 10^8\ \text{m/s}$

so $\boxed{f = 6.00 \times 10^6\ \text{Hz} = 6.00\ \text{MHz}}$.

(b) $\dfrac{E}{B} = c$

or $\dfrac{22.0}{B_{\max}} = 3.00 \times 10^8$

so $\mathbf{B}_{\max} = \boxed{-73.3\hat{\mathbf{k}}\ \text{nT}}$.

(c) $k = \dfrac{2\pi}{\lambda} = \dfrac{2\pi}{50.0} = 0.126\ \text{m}^{-1}$

and $\omega = 2\pi f = 2\pi\left(6.00 \times 10^{6} \text{ s}^{-1}\right) = 3.77 \times 10^{7} \text{ rad/s}$

$$\mathbf{B} = \mathbf{B}_{\max}\cos(kx - \omega t) = \boxed{-73.3\cos\left(0.126x - 3.77 \times 10^{7} t\right)\hat{\mathbf{k}} \text{ nT}}.$$

Problem 5:

$$S_{av} = \frac{P}{4\pi r^2} = \frac{4.00 \times 10^{3} \text{ W}}{4\pi\left(4.00 \times 1609 \text{ m}\right)^2} = 7.68 \ \mu\text{W/m}^2$$

$$E_{\max} = \sqrt{2\mu_0 c S_{av}} = 0.076\,1 \text{ V/m}$$

$$\Delta V_{\max} = E_{\max} L = (76.1 \text{ mV/m})(0.650 \text{ m}) = \boxed{49.5 \text{ mV (amplitude)}}$$ or 35.0 mV (rms)

(The problem is a little simplified, of course. The antenna must have the correct orientation. The assumption of isotropic emission is also not quite realistic.)

Problem 6:

Assuming that the antenna of a 10 kW radio station radiates spherical electromagnetic waves, compute the maximum value of the magnetic field 5.0 km from the antenna, and compare this value with the surface magnetic field of the Earth. (Assume = 5 * 10^{-5} T.)

$$I = \frac{B_{\max}^2 c}{2\mu_0} = \frac{P}{4\pi r^2}$$

$$B_{\max} = \sqrt{\left(\frac{P}{4\pi r^2}\right)\left(\frac{2\mu_0}{c}\right)} = \sqrt{\frac{\left(10.0 \times 10^{3}\right)(2)\left(4\pi \times 10^{-7}\right)}{4\pi\left(5.00 \times 10^{3}\right)^2\left(3.00 \times 10^{8}\right)}} = \boxed{5.16 \times 10^{-10} \text{ T}}$$

Since the magnetic field of the Earth is approximately 5×10^{-5} T, the Earth's field is some 100 000 times stronger.

Problem 7:

A possible means of space flight is to place a perfectly reflecting aluminized sheet into orbit around the Earth and then use the light from the Sun to push this "solar sail." Suppose a sail of area 6.00 * 10^5 m^2 and mass 6000 kg is placed in orbit facing the Sun. Ignore all gravitational effects, assume that the acceleration calculated in part (b) remains constant, and assume a solar intensity of 1340 W/m^2.

(a) The radiation pressure is

$$\frac{2\left(1\,340\ \mathrm{W/m^2}\right)}{3.00\times10^{8}\ \mathrm{m/s^2}} = 8.93\times10^{-6}\ \mathrm{N/m^2}.$$

Multiplying by the total area, $A = 6.00\times10^{5}\ \mathrm{m^2}$ gives: $F = \boxed{5.36\ \mathrm{N}}$.

(b) The acceleration is: $a = \frac{F}{m} = \frac{5.36\ \mathrm{N}}{6\,000\ \mathrm{kg}} = \boxed{8.93\times10^{-4}\ \mathrm{m/s^2}}$.

(c) How long does it take the sail to reach the Moon, 3.84 10^8 m away?

It will arrive at time t where $d = \frac{1}{2}at^2$

or

$$t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2\left(3.84\times10^{8}\ \mathrm{m}\right)}{\left(8.93\times10^{-4}\ \mathrm{m/s^2}\right)}} = 9.27\times10^{5}\ \mathrm{s} = \boxed{10.7\ \text{days}}.$$

Problem 8:

Determine the frequency and classification of an electromagnetic wave with wavelength equal to the following:

(a) your height

$$f = \frac{c}{\lambda} = \frac{3\times10^{8}\ \mathrm{m/s}}{1.7\ \mathrm{m}}\ \boxed{\sim10^{8}\ \mathrm{Hz}}\ \boxed{\text{radio wave}}$$

(b) the thickness of a sheet of paper

1 000 pages, 500 sheets, is about 3 cm thick so one sheet is about $6\times10^{-5}\ \mathrm{m}$ thick.

$$f = \frac{3.00\times10^{8}\ \mathrm{m/s}}{6\times10^{-5}\ \mathrm{m}}\ \boxed{\sim10^{13}\ \mathrm{Hz}}\ \boxed{\text{infrared}}$$

Problem 9:

A radar pulse returns to the receiver after a total travel time of 6.00 10^{-4} s. How far away is the object that reflected the wave?

$$\text{Time to reach object} = \frac{1}{2}(\text{total time of flight}) = \frac{1}{2}\left(4.00\times10^{-4}\ \mathrm{s}\right) = 2.00\times10^{-4}\ \mathrm{s}.$$

Thus, $d = vt = \left(3.00 \times 10^{8} \text{ m/s}\right)\left(2.00 \times 10^{-4} \text{ s}\right) = 6.00 \times 10^{4} \text{ m} = \boxed{60.0 \text{ km}}$.

Problem 10:

A dish antenna having a diameter of 20.0 m receives (at normal incidence) a radio signal from a distant source, as shown in Figure P34.51. The radio signal is a continuous sinusoidal wave with amplitude E_{max} = 0.500 μV/m. Assume the antenna absorbs all the radiation that falls on the dish.

(a) $B_{\max} = \dfrac{E_{\max}}{c} = \boxed{6.67 \times 10^{-16} \text{ T}}$

(b) $S_{\text{av}} = \dfrac{E_{\max}^2}{2\mu_0 c} = \boxed{5.31 \times 10^{-17} \text{ W/m}^2}$

(c) $\mathcal{P} = S_{\text{av}} A = \boxed{1.67 \times 10^{-14} \text{ W}}$

(d) $F = PA = \left(\dfrac{S_{\text{av}}}{c}\right) A = \boxed{5.56 \times 10^{-23} \text{ N}}$ ($\cong$ the weight of 3 000 H atoms!)