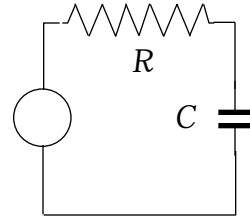


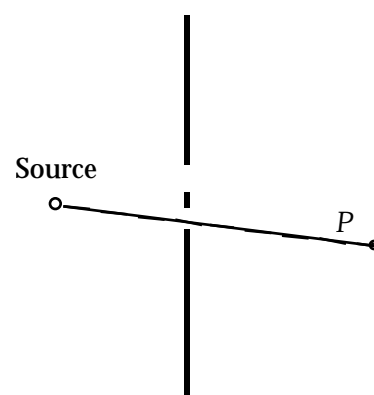
Part I. Answer each question with a brief statement, using a mathematical equation where appropriate.

1. State Maxwell's equations for the electromagnetic field.
2. Explain what is meant by (a) conservation of charge, (b) quantization of charge.
3. A positively charged particle moves with velocity  $\mathbf{v}$  in a region where there are uniform fields  $\mathbf{E}$  and  $\mathbf{B}$ . Indicate possible directions for  $\mathbf{E}$ ,  $\mathbf{B}$ , and  $\mathbf{v}$  such that the particle moves in a straight line with constant speed.
4. Explain the operation of a lightning rod in protecting a tall building from damage by lightning.
5. Explain what electrostatic "shielding" is and how it is accomplished.
6. The dashboard voltmeter in a car reads the terminal voltage of the battery, for which the emf is 12 V. When the battery powers the starter motor to start the car the voltmeter reads 10 V, but for a few minutes after the car's motor starts the voltmeter reads 14 V. Explain.
7. Coaxial cables are frequently used to carry very high-frequency alternating currents. What property of the cable makes it valuable for this purpose?
8. If the switch controlling the current to a large electromagnet is suddenly opened, a large and dangerous arc is likely to jump across the open switch. Explain.

9. In the circuit shown, the EMF is 100 V (rms) with  $\omega = 1000 \text{ rad/s}$ ,  $R = 1000 \text{ } \Omega$ , and the average power supplied by the generator is 2 W. Find  $C$ .



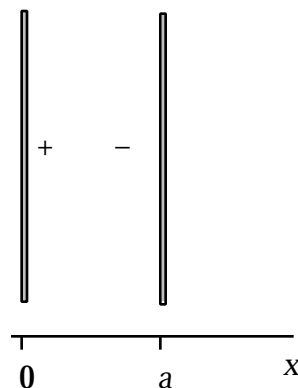
10. An object 5 cm high is placed 5 cm from a positive lens of focal length 10 cm. Give the location, type, orientation, and size of the image.
11. Explain, drawing a few rays, why an object on the bottom of a swimming pool appears closer to the surface than it actually is..
12. When viewed by the reflected light, the “nonreflecting” surface of a lens appears reddish-violet. Explain.
13. You are given two positive lenses, one of focal length 80 cm, the other 10 cm. Sketch the arrangement by which you would make a refracting telescope from these lenses, locating the focal points carefully
14. Shown is a double slit arrangement and a point source of light. If the upper slit were closed, light travelling straight through the lower slit would make the intensity large at point  $P$ . With both slits open it is dark at  $P$ . Explain.



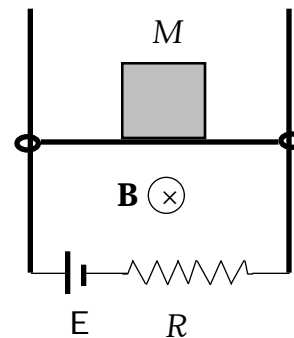
15. Why is the sky blue on a clear day?

**Part II.** Work the problems in the space provided, indicating your method clearly.

1. Two parallel nonconducting sheets (of negligible thickness) have uniform surface charges as shown.
  - (a) Find  $E_x$  as a function of  $x$ , for  $x > 0$ .
  - (b) Take  $V = 0$  at  $x = 0$  and find  $V$  as a function of  $x$ , for  $x > 0$ .
  - (c) If the space between the sheets were filled with dielectric of constant  $\epsilon$ , how would your answers to (a) and (b) change?

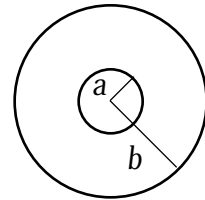


2. A primitive motor consists of a battery of EMF  $E$ , a resistance  $R$ , and a wire of length  $l$  (with negligible mass) arranged as shown so that it can slide vertically without friction, carrying the load  $M$ . The entire region has a constant and uniform  $B$ -field directed into the page. The load is lifted at constant speed  $v$ . Give all answers in terms of  $E$ ,  $R$ ,  $l$ ,  $M$ ,  $B$  and  $g$ .
  - (a) What must be the current in the wire to lift the load at constant speed?
  - (b) At what speed  $v$  do the wire and the load move? [What EMF is caused by the moving wire?]
  - (c) How much power does the battery supply?



3. A coaxial cable, consisting of an inner wire of radius  $a$  and an outer conducting sheath of radius  $b$ , carries current in the circuit shown. Also shown below is a cross-section of the cable, looking toward the resistor.
- What is  $\mathbf{B}$  (magnitude and direction) as a function of  $r$ , the radial distance from the axis of the cable, in the region between the wire and the sheath?
  - What direction is  $\mathbf{E}$  in the region between the wire and the sheath? [Hint: which conductor is at higher potential?]
  - What direction is the Poynting vector in that region? Explain the significance of this direction.

[Give all answers in terms of  $E$ ,  $R$  and  $r$ . Indicate directions on the cross-section diagram.]



4. The antenna section of a radio is a series  $LCR$  circuit with the antenna signal serving as the generator. Let  $R = 100 \ \Omega$ ,  $L = 0.01 \text{ H}$ , and let the antenna be producing a signal with rms voltage  $50 \text{ mV}$  at angular frequency  $\omega = 6 \times 10^6 \text{ rad/s}$ .
- To “tune” to this frequency what should be the value of  $C$ ?
  - What will be the average power supplied by the antenna in this case?
  - With  $C$  fixed at this value, what will be the average power supplied by the antenna for a  $50 \text{ mV}$  signal at  $\omega = 6.2 \times 10^6 \text{ rad/s}$ ?

5. The objective lens of a microscope has focal length 1 cm and the lens opening has diameter 2 mm. What is the closest distance between two points in the object that are just resolved by this instrument? [Recall that the object is placed just beyond the focal point, and use light of 500 nm wavelength.]
6. An unpolarized light beam of intensity  $I_0$  is reflected at the Brewster angle from a horizontal plate of glass. The reflected beam has intensity  $0.1 I_0$ .
- (a) What is the angle between the normal to the glass surface and the E-vector of the reflected wave?
  - (b) The reflected beam now passes through a polaroid filter with its transmission axis making angle  $30^\circ$  with the horizontal. What is the intensity of the beam as it emerges from the filter?