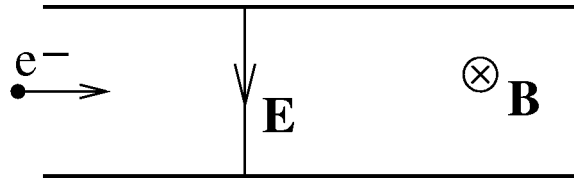


Problem 9 (5 points)

A parallel plate capacitor (in vacuum) is placed in a uniform magnetic field \vec{B} of strength 0.1 T. The direction of the magnetic field is parallel to the plates as indicated in the figure. The capacitor is charged to provide a uniform electric field \vec{E} of 10^5 V/m in the direction shown. An electron enters the capacitor from the left with a speed of 3×10^6 m/sec; its direction of motion is at right angles to both the magnetic field and the electric field as shown.



- (3) What is the net force in Newtons (magnitude and direction) that the electron experiences as it enters the capacitor?
- (2) If we could change the strength of the electric and/or magnetic field, would it then be possible for this electron to pass through the capacitor in a straight line (thus undeflected)? Explain your answer.

Problem 8

(a)

$$\frac{Q}{C} + R \frac{dQ}{dt} = V_0$$

(b) For the given $Q(t) = CV_0(1 - e^{-t/\tau})$, we have

$$\frac{Q}{C} + R \frac{dQ}{dt} = V_0(1 - e^{-t/\tau}) + (RCV_0/\tau)e^{-t/\tau} = V_0 \quad \text{if } \tau = RC.$$

(c) The current in the resistor is

$$I(t) = \frac{dQ}{dt} = (CV_0/\tau)e^{-t/\tau} = (V_0/R)e^{-t/\tau}.$$

(d)

$$U_C(t_1) = \frac{1}{2}Q(t_1)V_C(t_1) = \frac{Q^2(t_1)}{2C} = \frac{1}{2}CV_0^2(1 - e^{-t_1/\tau})^2$$

(e) The time-dependent power dissipated in the resistor is

$$P(t) = I^2(t)R = (V_0^2/R)e^{-2t/\tau}.$$

The heat dissipated in the resistor between $t = 0$ and t_1 is

$$W = \int_0^{t_1} P(t) dt = \frac{V_0^2}{R} \int_0^{t_1} e^{-2t/\tau} dt = \frac{-\tau V_0^2}{2R} e^{-2t/\tau} \Big|_0^{t_1} = \frac{1}{2}CV_0^2(1 - e^{-2t_1/\tau}).$$

Problem 9

(a) The electric force $q\mathbf{E}$ is directed upward (remember, the electron is negatively charged) and has magnitude $F_E = (1.6 \times 10^{-19})(10^5) = 1.6 \times 10^{-14}$ N. The magnetic force $q\mathbf{v} \times \mathbf{B}$ is directed downward and has magnitude $F_B = (1.6 \times 10^{-19})(3 \times 10^6)(0.1) = 4.8 \times 10^{-14}$ N. $F_B > F_E$, so the net force is directed downwards and has magnitude $F = F_B - F_E = 3.2 \times 10^{-14}$ N.

(b) If we adjust the field strengths E and B to satisfy $E = vB$ (v = electron speed), the electric and magnetic forces will be of equal magnitude. Since the two forces are oppositely directed, they will balance one another, and the electron will be able to pass through the capacitor undeflected. (As an example, if we increase E to 3×10^5 V/m while holding B fixed, both forces will have a magnitude of 4.8×10^{-14} N.)

Problem 10(a) Poynting flux: $S = 10^3$ W/m². Area: $A = 10^{-4}$ m². Time interval: $\Delta t = 30$ s.

$$\text{Energy absorbed} = SA\Delta t = (10^3)(10^{-4})(30) = 3 \text{ J}.$$

(b) Radiation pressure: $P = S/c$ for the case of total absorption. Force on surface:

$$F = PA = SA/c = \frac{(10^3)(10^{-4})}{(3 \times 10^8)} \simeq 3.3 \times 10^{-10} \text{ N}.$$