1. $Q_1 = 1\times10^{-5}$ C and $Q_2 = -1\times10^{-5}$ C point charges are located in free space at the Cartesian coordinates of (1, 3, −1) and (−3, 1, −2), respectively. (a) Find the force on a 1×10^{-5} C charge located at (3, 1, −2). All distances are in meters. (5%) (b) Find the force on a triangular loop with a side length of b placed with a distance d to an infinite straight wire, as illustrated in Fig. 1. Both the loop and the wire carry a steady current I. (5%) (c) As shown in Fig. 2, the region $z < 0$ is occupied by a perfect conductor. A point charge Q is located at (0, 0, d) above an infinite grounded conducting plane, where $d > 0$. Find the induced surface charge density ρ_s on the surface of the conducting plane. (5%)

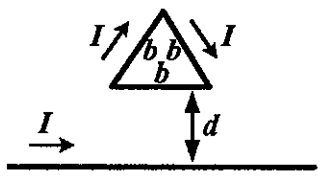

Fig. 1

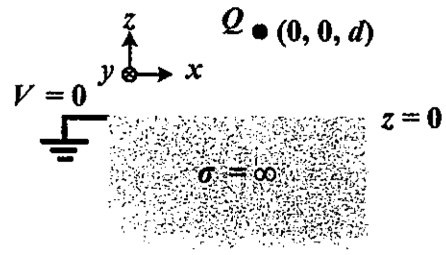

Fig. 2

2. Current $4I$ flows along a straight wire from a point charge $q_1(t)$ at the point (0, 0, 0) to a point charge $q_2(t)$ at the point (2, 2, 2). Find the line integral of the magnetic field $\vec{H}$ around the triangular closed path having the vertices at (0, 0, 3), (3, 0, 0), and (0, 3, 0) and traversed in that order. (10%)

3. As shown in Fig. 3, a sinusoidally time-varying uniform plane wave incident normally from free space onto the interface $z = 0$. (a) Find a minimum value of the frequency for which a wave at that frequency or any integer multiple of that frequency experiences no reflection at the interface $z = 0$. (10%) (b) Find the maximum value of the period of a nonsinusoidal periodic wave for which reflection does not occur at the interface $z = 0$. (5%)

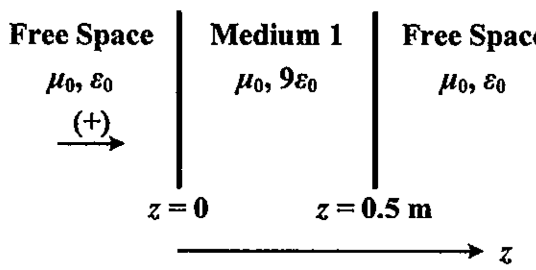

Fig. 3

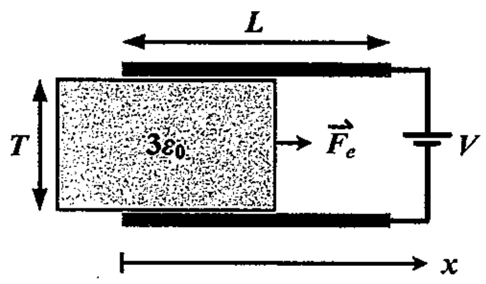

Fig. 4

4. As shown in Fig. 4, a dielectric slab of permittivity $3\varepsilon_0$ sliding between the plates of a parallel-plate capacitor experiences a mechanical force $\vec{F}_e$ of electrical origin. The width of the plates normal to the page is w. Fringing fields at the edges of the plates are neglected. Find the expression for $\vec{F}_e$. (10%)

5. A transmission line is short circuited at the load. (a) Illustrate the voltage and current distributions along the line. (5%) (b) Find out how the input impedance changes with the frequency. (5%)

6. Explain how to numerically apply the finite difference method to solve the Laplace's equation. (10%)

7. Consider an air-filled rectangular metallic waveguide of dimensions $a = 2.54$ mm and $b = 1.27$ mm. (a) Find out the frequency range for single-mode operation. (5%) (b) Draw the electric field lines and the magnetic field lines for the fundamental mode. (5%)

8. Given the phasor of the vector potential induced by a Hertzian dipole at the origin

$$\overline{A}(r) = \frac{\mu I l}{4\pi r} e^{-j\beta r} \hat{z}$$

(a) Derive the magnetic field $\overline{H}(r)$. (4%)

(b) Derive the electric field $\overline{E}(r)$. (4%)

(c) Derive the instantaneous Poynting vector in the far field. (3%)

(d) Derive the radiation resistance. (3%)

(e) Derive the directivity as a function of (θ, ϕ). (3%)

(f) Explain the difference between gain and directivity of an antenna. (3%)

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