Advanced E&M

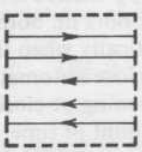
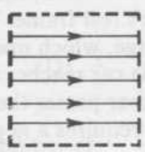
Problem 1:

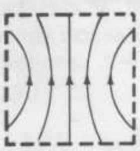
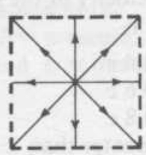
A system consists of two charged particles of equal mass. Initially the particles are far apart, have zero potential energy, and one particle has nonzero speed. If radiation is neglected, which of the following is true of the total energy of the system?

(A) It is zero and remains zero.
(B) It is negative and constant.
(C) It is positive and constant.
(D) It is constant, but the sign cannot be determined unless the initial velocities of both particles are known.
(E) It cannot be a constant of the motion because the particles exert force on each other.

Problem 2:

One of Maxwell's equations is $\nabla \cdot \mathbf{B} = 0$. Which of the following sketches shows magnetic field lines that clearly violate this equation within the region bounded by the dashed lines?

(A) 
(B) 

(C) 
(D) 

(E) 

Problem 3:

The exponent in Coulomb's inverse square law has been found to differ from two by less than one part in a billion by measuring which of the following?

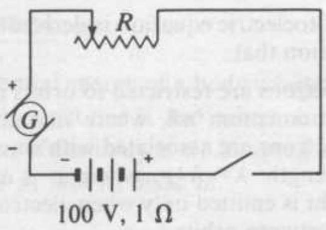
(A) The charge on an oil drop in the Millikan experiment
(B) The deflection of an electron beam in an electric field
(C) The neutrality of charge of an atom
(D) The electric force between two charged objects
(E) The electric field inside a charged conducting shell

Problem 4:

Which of the following statements most accurately describes how an electromagnetic field behaves under a Lorentz transformation?

(A) The electric field transforms completely into a magnetic field.
(B) If initially there is only an electric field, after the transformation there may be both an electric and a magnetic field.
(C) The electric field is unaltered.
(D) The magnetic field is unaltered.
(E) It cannot be determined unless a gauge transformation is also specified.

Problem 5:



The battery in the diagram above is to be charged by the generator G. The generator has a terminal voltage of 120 volts when the charging current is 10 amperes. The battery has an emf of 100 volts and an internal resistance of 1 ohm. In order to charge the battery at 10 amperes charging current, the resistance R should be set at

(A) 0.1 Ω (B) 0.5 Ω (C) 1.0 Ω
(D) 5.0 Ω (E) 10.0 Ω

Problem 6:

A sphere of radius R carries charge density proportional to the square of the distance from the center: $\rho = Ar^2$, where A is a positive constant. At a distance of $R/2$ from the center, the magnitude of the electric field is

(A) $A/4\pi\epsilon_0$

(B) $AR^3/40\epsilon_0$

(C) $AR^3/24\epsilon_0$

(D) $AR^3/5\epsilon_0$

(E) $AR^3/3\epsilon_0$

Problem 7:

A wire of diameter 0.02 meter contains 1×10^{28} free electrons per cubic meter. For an electric current of 100 amperes, the drift velocity for free electrons in the wire is most nearly

(A) 0.6×10^{-29} m/s

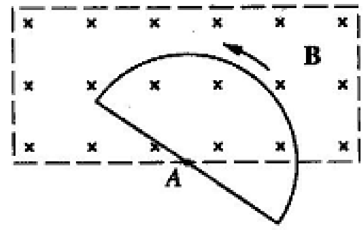
(B) 1×10^{-19} m/s

(C) 5×10^{-10} m/s

(D) 2×10^{-4} m/s

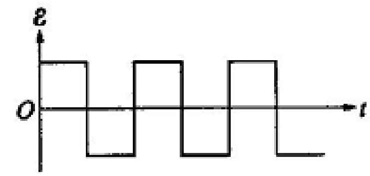
(E) 8×10^{3} m/s

Problem 8:

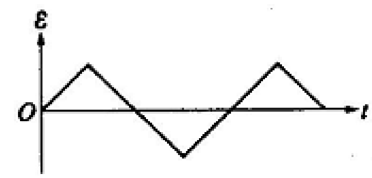


A uniform and constant magnetic field **B** is directed perpendicularly into the plane of the page everywhere within a rectangular region as shown above. A wire circuit in the shape of a semicircle is uniformly rotated counterclockwise in the plane of the page about an axis A. The axis A is perpendicular to the page at the edge of the field and directed through the center of the straight-line portion of the circuit. Which of the following graphs best approximates the emf $\mathcal{E}$ induced in the circuit as a function of time t?

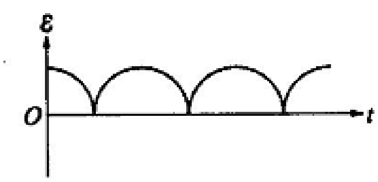
(A)



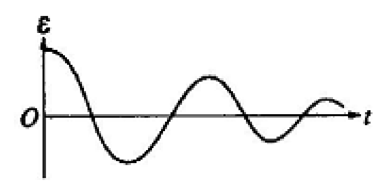
(B)



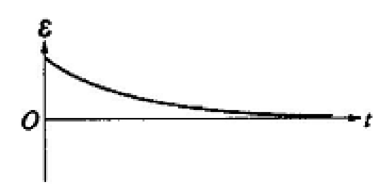
(C)



(D)

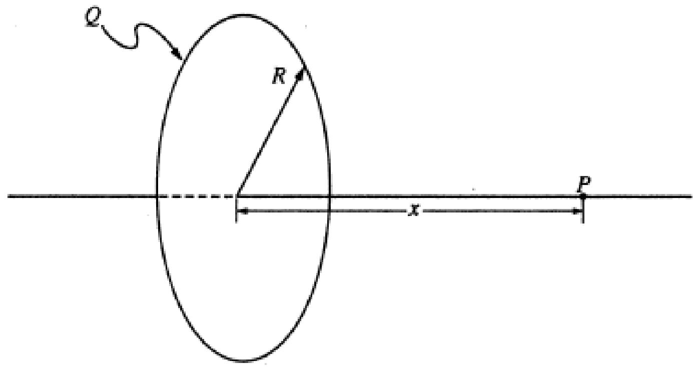


(E)



Problem 9:

Consider a non-conducting ring of radius R with charge Q uniformly spread out on it.



The electric potential at a point P, which is located on the axis of symmetry a distance x from the center of the ring, is given by

(A) $\dfrac{Q}{4\pi\varepsilon_0 x}$

(B) $\dfrac{Q}{4\pi\varepsilon_0\sqrt{R^2 + x^2}}$

(C) $\dfrac{Qx}{4\pi\varepsilon_0(R^2 + x^2)}$

(D) $\dfrac{Qx}{4\pi\varepsilon_0(R^2 + x^2)^{3/2}}$

(E) $\dfrac{QR}{4\pi\varepsilon_0(R^2 + x^2)}$

Problem 10:

Consider a non-conducting ring of radius R with charge Q uniformly spread out on it. Refer to the figure from the previous problem.

A small particle of mass m and charge $-q$ is placed at point P and released. If $R >> x$, the particle will undergo oscillations along the axis of symmetry with an angular frequency that is equal to

(A) $\sqrt{\dfrac{qQ}{4\pi\varepsilon_0 mR^3}}$

(B) $\sqrt{\dfrac{qQx}{4\pi\varepsilon_0 mR^4}}$

(C) $\dfrac{qQ}{4\pi\varepsilon_0 mR^3}$

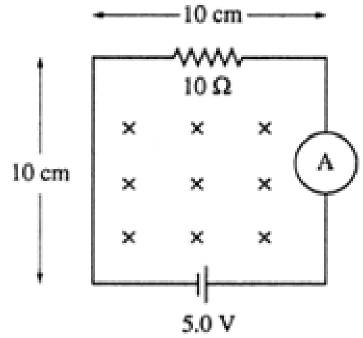
(D) $\dfrac{qQx}{4\pi\varepsilon_0 mR^4}$

(E) $\sqrt{\dfrac{qQx}{4\pi\varepsilon_0 m}}\dfrac{1}{R^2 + x^2}$

Problem 11:

The circuit shown is in a uniform magnetic field that is into the page and is decreasing in magnitude at the rate of 150 tesla/second. The ammeter reads

(A) 0.15 A
(B) 0.35 A
(C) 0.50 A
(D) 0.65 A
(E) 0.80 A

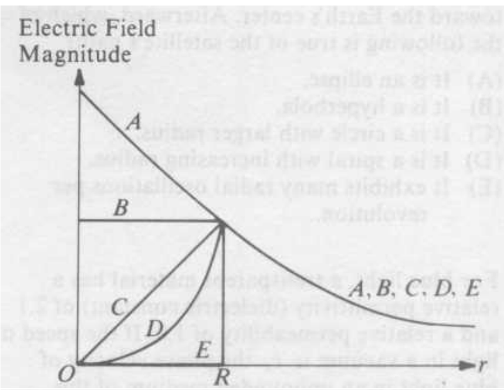


Problem 12:

A 5-ohm resistor and a 10-ohm resistor are connected in parallel to a battery. If heat is dissipated in the 5-ohm resistor at a rate of P, then the rate at which heat is dissipated in the 10-ohm resistor is

(A) P/2 (B) P (C) 2P (D) 4P (E) P/4

Problem 13:



An isolated sphere of radius R contains a uniform volume distribution of positive charge. Which of the curves on the graph above correctly illustrates the dependence of the magnitude of the electric field of the sphere as a function of the distance r from its center?

(A) A (B) B (C) C (D) D (E) E

Problem 14:

A point charge $-q$ coulombs is placed at a distance d from a large grounded conducting plane. The surface charge density on the plane a distance D from the point charge is

(A) $\frac{q}{4\pi D}$

(B) $\frac{qD^2}{2\pi}$

(C) $\frac{qd}{2\pi D^2}$

(D) $\frac{qd}{2\pi D^3}$

(E) $\frac{qd}{4\pi\epsilon_0 D^2}$

Problem 15:

In electrostatic problems, the electric field always satisfies the equation

(A) $\nabla\cdot\mathbf{E} = \nabla\times\mathbf{E}$.
(B) $\nabla\cdot\mathbf{E} = 0$.
(C) $\nabla\times\mathbf{E} = 0$.
(D) $\nabla(E^2) = 0$.
(E) $\nabla(\nabla\cdot\mathbf{E}) = \nabla\times\mathbf{E}$.