Electricity and magnetism, 18-8-2017

The exam consists of two parts. The first part is multiple-choice, with one correct answer per question. You only have to give the answer. Every correct answer is worth 0.25 points, up to a total of 2 points. The second part consists of open questions. For these you have to derive the requested answer from the information given. Answers without derivation are considered as wrong. The total number of points for the open questions is 8.

1) Two identical small charged spheres are a certain distance apart, and each one initially experiences an electrostatic force of magnitude *F* due to the other. With time, charge gradually leaks off of both spheres. When each of the spheres has lost half its initial charge, the magnitude of the electrostatic force will be
A) 1/16 *F.*
B) 1/8 *F*.
C) 1/4 *F*.
D) 1/2 *F*.

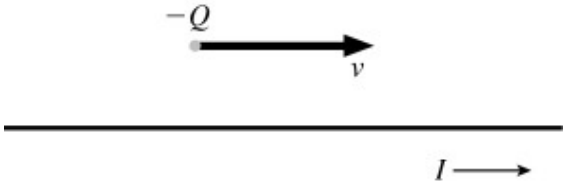
2 Under electrostatic conditions, the electric field just outside the surface of any charged conductor
A) is always parallel to the surface.
B) is always zero because the electric field is zero inside conductors.
C) is always perpendicular to the surface of the conductor.
D) is perpendicular to the surface of the conductor only if it is a sphere, a cylinder, or a flat sheet.
E) can have nonzero components perpendicular to and parallel to the surface of the conductor.

3) Suppose you have two point charges of opposite sign. As you move them farther and farther apart, the potential energy of this system relative to infinity
A) increases.
B) decreases.
C) stays the same.

4) When two or more capacitors are connected in parallel across a potential difference
A) the potential difference across each capacitor is the same.
B) each capacitor carries the same amount of charge.
C) the equivalent capacitance of the combination is less than the capacitance of any of the capacitors.
D) All of the above choices are correct.
E) None of the above choices are correct.

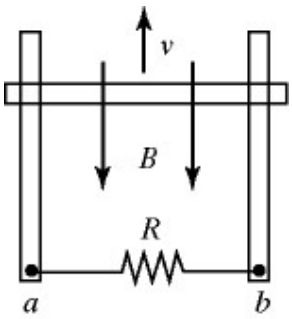
5) When a potential difference of 10 V is placed across a certain solid cylindrical resistor, the current through it is 2 A. If the diameter of this resistor is now tripled, the current will be
A) 2/9 A.
B) 2/3 A.
C) 2 A.
D) 3 A.
E) 18 A.

6) A negatively charged particle is moving to the right, directly above a wire having a current flowing to the right, as shown in the figure. In which direction is the magnetic force exerted on the particle?



A) into the page
B) out of the page
C) downward
D) upward
E) The magnetic force is zero since the velocity is parallel to the current.

7) In the figure, a copper bar is in contact with a pair of parallel metal rails and is in motion with velocity *v*. A uniform magnetic field is present pointing downward, as shown. The bar, the rails, and the resistor *R* are all in the same plane. The induced current through the resistor *R* is

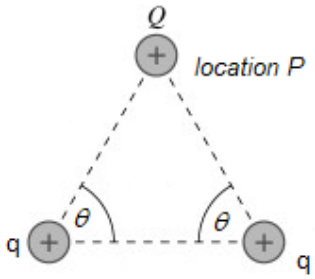


A) from *a* to *b*.
B) from *b* to *a*.
C) There is no induced current through the resistor.

8) The energy per unit volume in an electromagnetic wave is
A) equally divided between the electric and magnetic fields.
B) mostly in the electric field.
C) mostly in the magnetic field.
D) all in the electric field.
E) all in the magnetic field.

Open questions.

9) In the figure below a configuration of charges is given: two charges q at the baseline of a triangle and a charge Q at location *P.*



a) What is the magnitude and direction of the force on the charge Q? (0.25 points)

We now add a charge at one of the sides of the triangle, such that it cancels the force on charge Q from the two charges q.

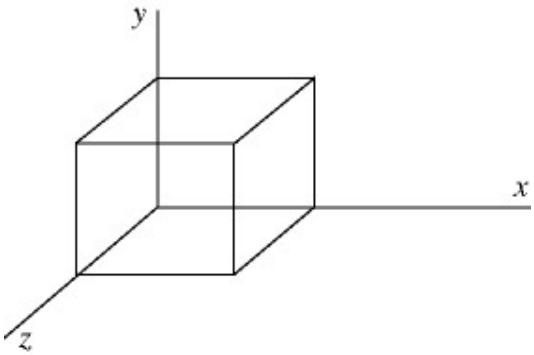
b) What is the required charge and where should we put it? (0.25 points)

We remove the charge Q.

c) What is the electric potential (relative to infinity) at location P? (0.25 points)

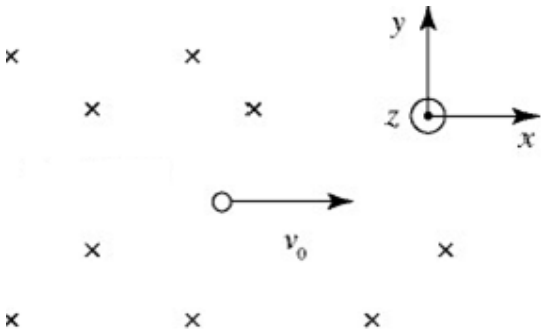
d) Does the potential energy of a positive particle increase or decrease if it is brought from point P vertically downwards to the baseline of the triangle? (0.25 points)

10) The cube of insulating material shown in the figure has one corner at the origin. Each side of the cube has length L. It is observed that there is an electric field $\vec{E} = \alpha y \hat{j}$ that is in the $+y$ direction and whose magnitude depends only on y. Use Gauss's law to calculate the net charge enclosed by the cube. (1.5 points)



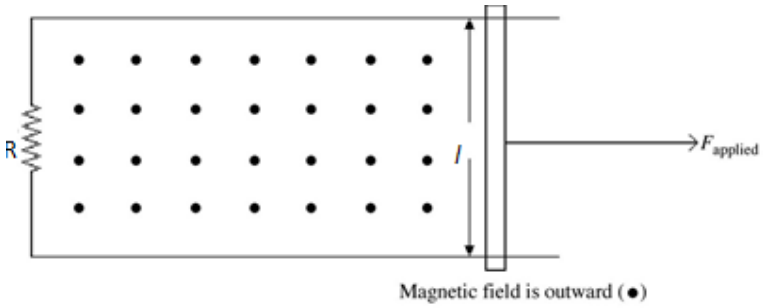
11) An air-filled capacitor is formed from two long conducting cylindrical shells with length L that are coaxial and have radii of R and 2R. The electric potential of the inner conductor with respect to the outer conductor is -Vcyl. Derive the energy of this capacitor in terms of L, R and Vcyl. (2 points)

12) A uniform magnetic field of magnitude B in the negative *z*-direction is present in a region of space, as shown in the figure. A uniform electric field is also present. A stream of electrons that is projected with an initial velocity *v0* in the positive *x*-direction passes through the region without deflection.



a) What is the electric field vector in the region? (0.5 points)
b) The electric field is due to a charged conducting plate, located below the moving particle. The speed of the electrons suddenly doubles. What should we do with the charge density at the conducting plate to avoid deflection of the particle? (0.5 points)

13) A conducting bar moves along frictionless conducting rails connected to a resistor *R* as shown in the figure. The length of the bar is *l* and a uniform magnetic field *B* is applied perpendicular to the paper pointing outward, as shown.



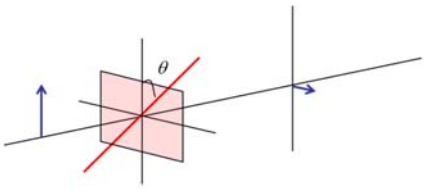
a) What is the applied force required to move the bar to the right with a constant speed v? (0.5 points)

b) At what rate is energy dissipated in the resistor? (0.5 points)

We now put a closed conducting loop with a certain resistance inside the rectangular frame.

b) Describe qualitatively what will happens. (0.5 points)

14) Given two polarization filters, each with a *different* transmission angle. One of the filters is given in the figure below. We want to rotate the polarization of incoming vertically polarized light to horizontal by putting the second filter behind the first one. At which transmission angle θ do we get the largest intensity of horizontally polarized light? (1 point)



a) What does the transmission angle of the second filter has to be? (0.25 points)
b) At which transmission angle θ do we get the largest intensity of horizontally polarized light? (0.75 points)