Physics III
ISI B.Math
Mid Semester Exam September 28, 2011

Total Marks: 80. Time: 3 hours
Answer ALL Questions
For Question 5, Provide your answers in the question sheet and submit along with rest of the answer sheets. Indicate justifications of your answers also in the space provided. If you need more space, use extra answer sheets but clearly indicate the question you are answering. Answers without justification will not be given full credit

Unless specified otherwise, the electrostatic potential is to be assumed to be "zero at infinity"

Question 1. Total Marks:6+9

a. For a grounded conducting sphere centered at the origin with radius a and a point charge q located at $(b, 0, 0)$, $b > a$, find the force between them.

b. For an isolated conducting sphere of radius a centered at the origin with total charge Q and a point charge $q$located at $(b, 0, 0), b > a$ find the force between them.(First handle the case when Q=0 and then for non zero Q)

Question 2. Total Marks: 7+8

A nonconducting spherical shell of radius a and negligible thickness is centered at the origin.It carries a net positive charge $+3Q$. A second larger spherical shell is also centered at the origin and has inner radius b and outer radius c. The outer shell is made of conducting material and carries no net charge.
a. Determine $V(r)$ as function of r. Plot $V(r)$ vs. r.

b. Calculate the total electrostatic energy of the system.

Question 3. Total Marks:5+6+4

a.) Which of the following vector fields can represent an electrostatic field?

i) $\lambda(xy\vec{i} + 2yz\vec{j} + 3xz\vec{k})$
ii) $\lambda(y^2\vec{i} + (2xy + z^2)\vec{j} + 2yz\vec{k})$
where λ is a constant with appropriate units.

b.) The surface of a solid conducting material is parameterized by $x = (R + r\cos v)\cos u, y = (R + r\cos v)\sin u, z = r\sin v$, where $0 \leq u, v < 2\pi$. Find the direction of the electric field immediately outside the surface if it is positively charged. What will be the direction of the electric field if it is negatively charged?

c.) Find out the surface charge density on the surface of the conducting material assuming that the magnitude of the electric field just outside is E.

Question 4. Total Marks:2+2+4+7

Write the expression for current density $\vec{j}$ in the follow situations.

a. For a moving charge located at $r = 0$ when $t = 0$ and moving with a constant velocity $\vec{v}$

b. For a uniformly charged sphere of radius r and total charge Q rotating with constant angular velocity ω

c. Explain in which of the above situations the laws of magnetostatics will be applicable. Justify your answer.

d. A wire carrying current I runs down the +ve y axis towards the origin and then out to infinity along the +ve x axis. Determine the magnetic field in the region of space $x > 0, y > 0, z = 0$

WRITE YOUR NAME:

Question 5. Total Marks:2x10=20

a. If the electric potential is given as $V(x, y, z) = xy - 3z^{-2}$ then the y component of the electric field is given by
i) $x + y$
ii) y
iii) x
iv) $-x$
v) $x - 6z$

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b. If five equal positive charges are placed on the x axis at equal spacing, then the force on the last but one charge on the right is
i) zero
ii) possibly in the +y direction
iii) possibly in the -y direction
iv) to the right
v) to the left

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c. There are three charges q, 2q, and 3q are held fixed at the points (1,0,0), (0,1,0) and (0,0,1) respectively. The charge at (0,0,1) is released and it "escapes to infinity". Ignoring electromagnetic waves created by this, what would be the kinetic energy of the escaped charge?
i) $7q^2/4\sqrt{2}\pi\epsilon_0$
ii) zero
iii) $q^2/4\sqrt{2}\pi\epsilon_0$
iv) $\sqrt{2}q^2/4\pi\epsilon_0$
v) $5q^2/4\sqrt{2}\pi\epsilon_0$

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d. If the coulomb force was discovered to be of the form $(\frac{qQ}{r^2}\exp(-\lambda r))\hat{r}$ then the ratio of the total electric flux out of spheres with r_2 and r_1 will be
i) 1 ii) 4π, iii) $4\pi\lambda(r_1 - r_2)$, iv) $\exp(\lambda(r_1 - r_2))$ v) $\exp(4\pi\lambda(r_1 - r_2))$

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e. A surface is constructed so that at all points on the surface, the electric field points inward. The following must be the case:
i) Net +ve charge inside
ii) Surface is an equipotential
iii) Net -ve charge inside
iv) The electric field must be parallel to the surface element $d\vec{a}$

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f. A thin uniformly charged spherical shell of radius $r = a$ caries net charge q. Consider the two statements. 1. The electric potential inside the sphere is a non zero constant. 2. The potential and its derivative are continuous at $r = a$. Which of the following statements is true?

i) Both 1 and 2 are true
ii) Both 1 and 2 are false
iii) 1 is true, 2 is false
iv) 1 is false, 2 is true

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g. A charged wire in the shape of a unit circle is centered around the origin and lying in x-y plane. The line charge density if given as $\lambda \cos\theta$ where *lambda* is a constant with appropriate units and θ is the angular coordinate of a point on the wire. If we write the potential $V(r,\theta,\phi) = A + \frac{B}{r} + \frac{C}{r^2} + ...$, then which of the following is true?

i) $A = 0, B = 0, C \neq 0$
ii) $A = 0, B \neq 0, C \neq 0$
iii) $A \neq 0, B = 0, C \neq 0$
iv) $A \neq 0, B \neq 0, C \neq 0$

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h. Similar charged wire as in the above except that in this case the line charge density if given as λx^2 where *lambda* is a constant with appropriate units and x is the x coordinate of a point on the wire. If we write the potential $V(r,\theta,\phi) = A + \frac{B}{r} + \frac{C}{r^2} + ...$, then which of the following is true?

i)$A = 0, B = 0, C \neq 0$
ii) $A = 0, B \neq 0, C \neq 0$
iii) $A \neq 0, B = 0, C \neq 0$
iv) $A \neq 0, B \neq 0, C \neq 0$

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i. Two parallel square plates are at rest in a particular frame of reference. In this frame each surface is of dimension L^2 and they carry equal and opposite uniform surface charge σ. Another frame of reference is moving parallel to one of the sides of the plates. Given that in the moving frame the length of the plate parallel to the motion is seem to be γL where $\gamma < 1$ and the length perpendicular to the motion is unchanged, what will be the value of surface charge density σ' seen in the moving frame?

i) $\sigma' = \sigma$
ii) $\sigma' = \gamma\sigma$
iii) $\sigma' = \gamma^2\sigma$
iv) $\sigma' = \sigma/\gamma$
v) $\sigma' = \sigma/\gamma^2$

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j. A charge moving with velocity v parallel to a infinite long current carrying conductor feels a magnetic force given by Lorentz force law. A person moves along with the charge with the same velocity . To this person, the charge is no longer moving and it will appear to experience the following:
i) Same magnetic force as before
ii) Zero magnetic force but an electric force of same magnitude
iii) Zero magnetic force and zero electric force
iv) A reduced non zero magnetic field plus a compensating electric field