BITS Pilani, Dubai Campus

Dubai International Academic City, Dubai, U.A.E

I Year II Semester 2010-2011

COMPREHENSIVE EXAM (Close Book)

Course No.: PHY C132

Max. Marks: 120

Weightage: 40%

Course Title: Physics II

Date: 26.05.2011

Duration: 3 Hrs

Note: Cylindrical:

Divergence $\nabla \cdot \mathbf{v} = \frac{1}{r}\frac{\partial}{\partial r}(r v_r) + \frac{1}{r}\frac{\partial v_\phi}{\partial \phi} + \frac{\partial v_z}{\partial z}$

Curl $\nabla \times \mathbf{v} = \left(\frac{1}{r}\frac{\partial v_z}{\partial \phi} - \frac{\partial v_\phi}{\partial z}\right)\hat{\mathbf{r}} + \left(\frac{\partial v_r}{\partial z} - \frac{\partial v_z}{\partial r}\right)\hat{\boldsymbol{\phi}} + \frac{1}{r}\left(\frac{\partial}{\partial r}(r v_\phi) - \frac{\partial v_r}{\partial \phi}\right)\hat{\mathbf{z}}$

Spherical:

Divergence $\nabla \cdot \mathbf{v} = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 v_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(\sin\theta\, v_\theta) + \frac{1}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi}$

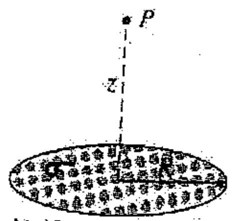
Curl $\nabla \times \mathbf{v} = \frac{1}{r\sin\theta}\left[\frac{\partial}{\partial \theta}(\sin\theta v_\phi) - \frac{\partial v_\theta}{\partial \phi}\right]\hat{\mathbf{r}} + \frac{1}{r}\left[\frac{1}{\sin\theta}\frac{\partial v_r}{\partial \phi} - \frac{\partial}{\partial r}(r v_\phi)\right]\hat{\boldsymbol{\theta}} + \frac{1}{r}\left[\frac{\partial}{\partial r}(r v_\theta) - \frac{\partial v_r}{\partial \theta}\right]\hat{\boldsymbol{\phi}}$

{$c = 2.998 \times 10^8\ \mathrm{m \cdot s^{-1}}$; $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{N\,A^{-2}}$; $\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F \cdot m^{-1}}$;

$h = 6.63 \times 10^{-34}$ J·s; $e = 1.602 \times 10^{-19}$ C; $m_e = 9.1 \times 10^{-31}$ kg; $m_p = 1.67 \times 10^{-27}$ kg}

PART A (Blue answerbook)

1. Find the electric field at a distance z above the center of the charge distribution shown in the figure below (disk of radius R) [10]



Uniform surface charge

2. Using Gauss's law, find the electric field inside a sphere which carries a charge density proportional to the distance from the origin, $\rho = Ar$, for some arbitrary constant A. [10]

3. A sphere of radius R carries a polarization [10]

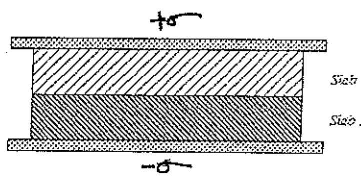
$$\vec{P}(r) = k\vec{r}$$

where k is a constant and $\vec{r}$ is the vector from the center.

a) Calculate the bound charges σ_b and ρ_b.

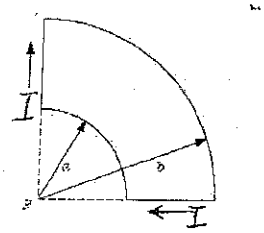
b) Find the field inside and outside the sphere.

4. The space between the plates of a parallel-plate capacitor (see Figure below) is filled with two slabs of linear dielectric material. Each slab has thickness s, so that the total distance between the plates is $2s$. Slab 1 has a dielectric constant of 2, and slab 2 has a dielectric constant of 1.5. The free charge density on the top plate is σ and on the bottom plate is $-\sigma$. [10]
   a) Find the electric displacement $\vec{D}$ in each slab.
   b) Find the electric field $\vec{E}$ in each slab.
   c) Find the polarization $\vec{P}$ in each slab.
   d) Find the potential difference between the plates.
   e) Find the location and amount of all bound charge.

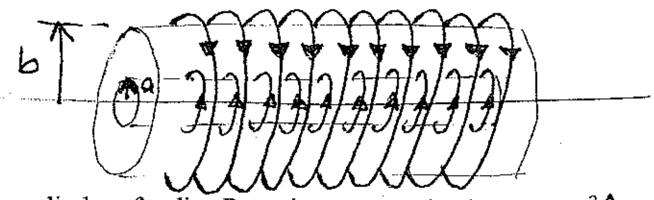


PART B (Green answerbook)

5. Find the magnetic field at point P for the steady current configurations shown in figure below [10]

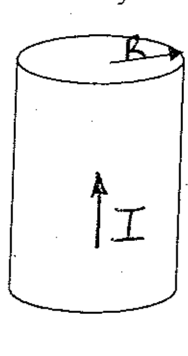


6. Two long coaxial solenoids each carry current I, but in opposite directions, as shown in figure below. The inner solenoid (radius a) has n_1 turns per unit length, and the outer one (radius b) has n_2. Find B in each of the three regions: (i) inside the inner solenoid, (ii) between them, and (iii) outside both. [10]



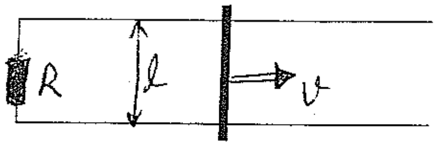
7. A long circular cylinder of radius R carries a magnetization $M = ks^2\hat{\phi}$, where k is a constant, s is the distance from the axis, and $\hat{\phi}$ is the azimuthal unit vector. Find the magnetic field due to M for points inside and outside the cylinder. [10]

8. A long copper rod of radius R carries a uniformly distributed (free) current I (figure below). Find H inside and outside the rod. [10]



PART C (Brown answerbook)

9. A metal bar of mass m slides frictionlessly on two parallel conducting rails a distance ℓ apart (figure below). A resistor R is connected across the rails and a uniform magnetic field B, pointing into the page, fills the entire region. [10]



(a) If the bar moves to the right at speed v, what is the current in the resistor? In what direction does it flow?
(b) What is the magnetic force on the bar? In what direction?
(c) If the bar starts out with speed v_o at time $t = 0$, and is left to slide, what is its speed at a later time t?

10. Find the self inductance of a toroidal coil with rectangular cross-section (inner radius a, outer radius b, height h), which carries a total of N turns. [10]

11. (a) A sodium surface is illuminated with light of wavelength 300 nm. The work function for sodium metal is 2.46 eV. Find [10]
    i) The max kinetic energy of the ejected photoelectrons
    ii) The cutoff wavelength for sodium.

    (b) X-rays of wavelength $\lambda_o = 0.2000$ nm are scattered from an electron at an angle of 45° to the incident beam. Calculate the new wavelength.

12. Assume that the uncertainty in position of an object is $\Delta x = 1.5 \times 10^{-11}$ m.
    (a) Determine the minimum uncertainty in the momentum. Find the corresponding minimum uncertainty in speed of the object, if the object is [10]
    (i) An electron
    (ii) A ball of mass 2.2×10^{-3} kg. {Take $\Delta x \Delta p = h/2\pi$}

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I Year II Semester 2010-2011

TEST 2 (Open Book)

Course No. PHY C132 **Course Title:** Physics II

Date: 08-05-2011 **Max. Marks:** 60

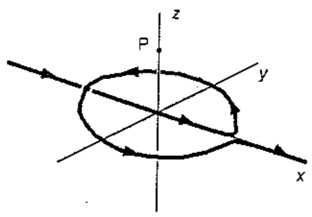
Weightage: 20% **Duration:** 50 min

Note: Please underline the final answer very clearly.

1. A proton is fired into a uniform magnetic field B, of magnitude 0.500T, at a speed of 300m/s at an angle of 30^0 to B. Find the acceleration of the proton and radius of the circular path. [6]

2. A long horizontal straight wire of length L carries a current I from left to right. Using Biot-Savart Law, calculate the magnetic field at a distance z above the end of the wire. [6]

3. A long wire carrying a current I runs along the x-axis and takes a circular detour (in the x-y plane) of radius a centered on the origin as shown in the figure. Find the magnetic field vector (magnitude and direction) at point P which lies on the z-axis at $z = +a$. [12]



4. Consider a hypothetical situation, where a cylinder of radius a having magnetization (A/s) φ where A is a constant and s is the distance from the axis. Calculate (with proper direction)
   a) Volume current density
   b) Surface current density
   c) Magnetic field inside the wire
   d) Magnetic field outside the wire [3x4=12]

5. A 25cm long solenoid has 10 turns per unit length. Each turn carries a current 0.5 A. Initially it is empty (vacuum).

a) What is the auxiliary field inside the solenoid?

b) When it is filled with a linear media, the field becomes 1.4 T. What is the relative permeability of the material

c) What is the Magnetization of the material?

d) If the number density of atoms in the material is 8.49×10^{28} atoms/m^3, find the average magnetic moment of the atoms. [3x4=12]

6. A conducting circular loop of area 2.5×10^{-3} m^2 is placed perpendicular to a magnetic field which varies as $B = 0.20 \, \text{Sin} \, (50 \, \pi t)$ T. (a) Find the charge flowing through any cross-section of the conducting wire during the time t = 0 to t = 40ms. (b) If the resistance of the loop is 10Ω, find the thermal energy developed in the loop in this period. [12]

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I Year II Semester 2010-2011

TEST 1 (Closed Book)

Course No. PHY C132 **Course Title:** Physics II

Date: 20-03-2011 **Max. Marks:** 75

Weightage: 25% **Duration:** 50 min

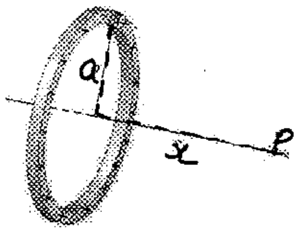
<u>Note:</u> **Please underline the final answer very clearly.**

Divergence in spherical coordinates:

$$\nabla \cdot \mathbf{v} = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 v_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(\sin\theta\, v_\theta) + \frac{1}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi}$$

1. Two point charges of magnitude 3.0 nC and 6.0 nC are separated by a distance of 0.30m. Find the magnitude of the electric force each exerts on the other. [5]

2. A ring of radius a has a uniform positive charge per unit length, with a total charge Q. Calculate the electric field at a point P on the axis of the ring at a distance x from the center of the ring. [10]



3. A hollow spherical shell carries charge density

   $\rho = A/r^2\,\hat{r}$, in the region $a \leq r \leq b$

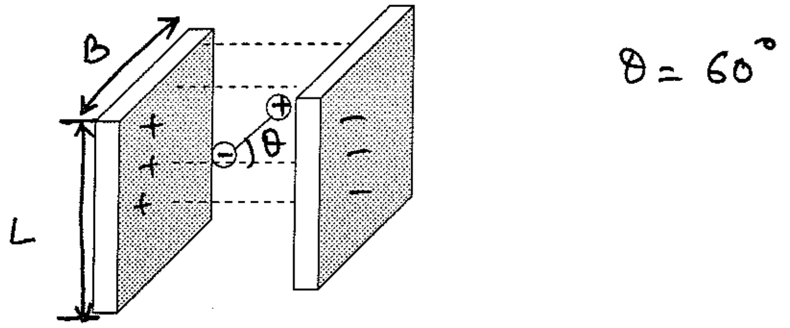
   a. Find electric field in the region i) r<a, ii) a<r<b, iii) r>b [9]

   b. Find the total energy stored in the spherical shell. [6]

4. a) Find the capacitance of two concentric spherical metal shells with radii a and b (b>a).

b) The plates of a spherical capacitor have radii 38.0 mm and 40.0 mm. Calculate its capacitance. What must be the plate area of a parallel-plate capacitor with the same plate separation and capacitance? [5+5+5]

5. In the following figure, a dipole is placed between two plates of a capacitor that carries a charge of 20C on each plate that has a dimensions L=2.5cm and B=1.5cm and the separation of0 .75cm between the plates. The charge on the dipole is 2C each separated by 0.25 cm. Calculate the torque experienced by the dipole. [6]



6. A sphere of radius carries a polarization **P** (r) = P_O **r** /ε_O, where P_o and ε_o are constants and **r** is the vector from the center. Calculate the bound surface and volume charge densities and the total bound charge. [9]

7. A spherical conductor, of radius *a*, carries a charge *Q*. It is surrounded by linear dielectric material out to a radius *b*. If the polarization of the material is given as $P=k/r^2\ \hat{r}$, find the electric field in the regions (using Electric Displacement vector). [15]

   i. r<a

   ii. b>r>a

   iii. r>b

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SEC. :

A

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I Year II Semester 2010-2011

QUIZ 2 (Closed Book)

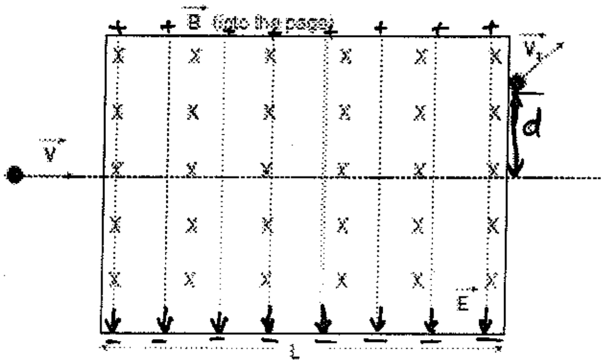
Course No. PHY C132 **Course Title:** Physics II

Date: 11-04-2011 **Max. Marks:** 21

Weightage: 7% **Duration:** 20 min

NOTE: Some questions may have multiple answers. In order to get full credit you need to tick all the correct answers.

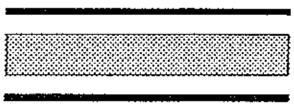
Q1. The figure below, depicting a positively charged particle deflected upward a distance d in a region of length L. Uniform magnetic and electric fields are contained in the region specified by the box. The magnetic field is directed perpendicular to the plane of the page and is directed into the page. The electric field is directed down the page.



Which of the following statement(s) is (are) true?
I. The electric field does positive work.
II. The electric field does no work.
III. The electric field does negative work.
IV. The speed of the particle is such that $v > E/B$.
V. The speed of the particle is such that $v = E/B$.
VI. The speed of the particle is such that $v < E/B$.

Q2. Suppose you have enough linear dielectric material of dielectric constant, ε_r, to half-fill a parallel plate capacitor (as shown in the figure below). The plates have a length L and width w and are separated by a distance d

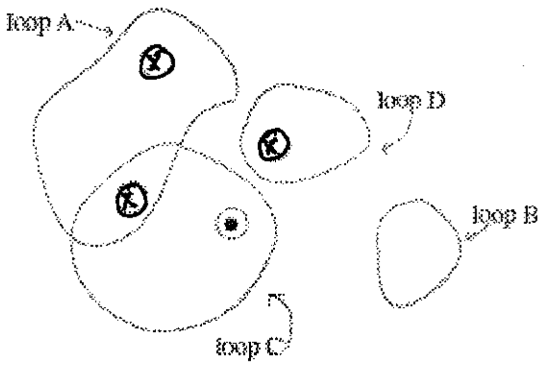
Does the capacitance increase or decrease?



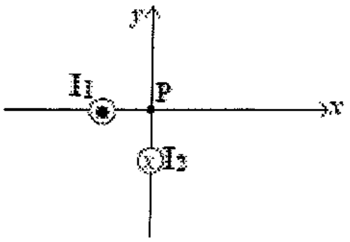
Ans:

Q3. Consider four equal currents going into or out of the page as indicated in the figure below. Rank the line integral of the magnetic field $\int B \cdot dl$ (from greatest to least) taken in the clockwise direction.

(a) A = B = C = D
(b) A > C > B > D
(c) D > B > C > A
(d) B = C > D > A
(e) A > D > C = B



Q4. The figure below shows two long wires carrying equal currents I_1 and I_2 flowing in opposite directions. Which arrow correctly represents the direction of the magnetic field at the origin of the coordinate system defined in the figure? Point P is located at an equal distance d from each wire.



(a) 

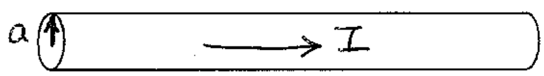
(b)

(c) 

(d) 

(e) 0

Q5. A uniform current 'I' flows on the surface of a cylindrical wire of radius 'a'. Calculate the surface current density.



Ans:

Q6. A negative charge $-q$ is moving parallel to a long straight wire carrying a constant current as illustrated in the figure below. Which arrow correctly describes the direction of the magnetic force experienced by the charge?

(a) ⊗(into the page)

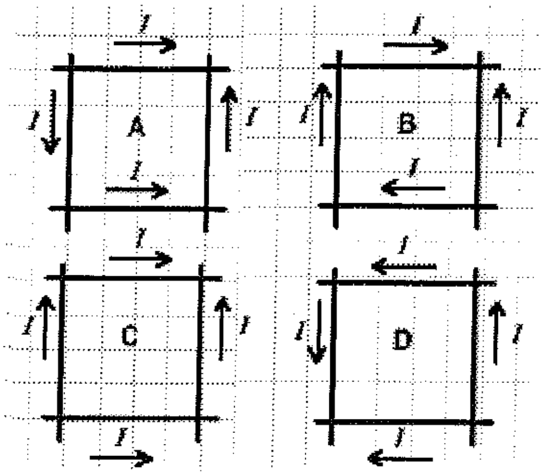
(b) ← (away from the wire)

(c) → (towards the wire)

(d) ⊙(out of the page)

(e) 0

Q7. The figure below shows four different sets of wires that cross each other without actually touching. The magnitude of the current is the same in all four cases, and the directions of current flow are as indicated. For which configuration will the magnetic field at the center of the square formed by the wires be equal to zero?



(a) A.
(b) B.
(c) C.
(d) D.

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B

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I Year II Semester 2010-2011

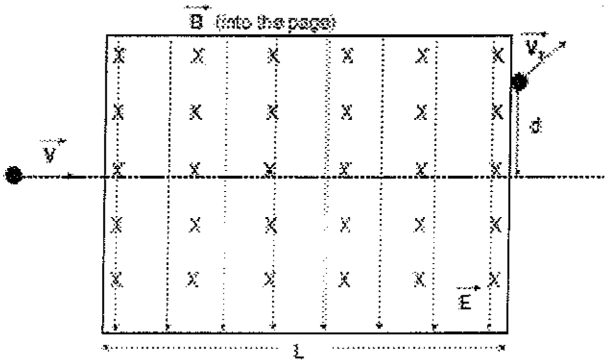
QUIZ 2 (Closed Book)

Course No. PHY C132 | **Course Title:** Physics II

Date: 11-04-2011 | **Max. Marks:** 21

Weightage: 7% | **Duration:** 20 min

Q1. The figure below, depicting a negatively charged particle deflected upward a distance d in a region of length L. Uniform magnetic and electric fields are contained in the region specified by the box. The magnetic field is directed perpendicular to the plane of the page and is directed out the page. The electric field is directed down the page.



Which of the following statement(s) is (are) true?

I. The electric field does positive work.

II. The electric field does no work.

III. The electric field does negative work.

IV. The speed of the particle is such that $v > E/B$.

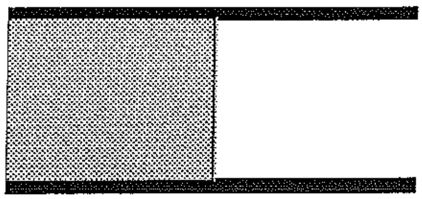
V. The speed of the particle is such that $v = E/B$.

VI. The speed of the particle is such that $v < E/B$.

Q2. Suppose you have enough linear dielectric material of dielectric constant, εr, to half-fill a parallel plate capacitor (as shown in the figure below)

a) By what fraction does the capacitance change?

b) Does the capacitance increase or decrease? – Yes (increase)

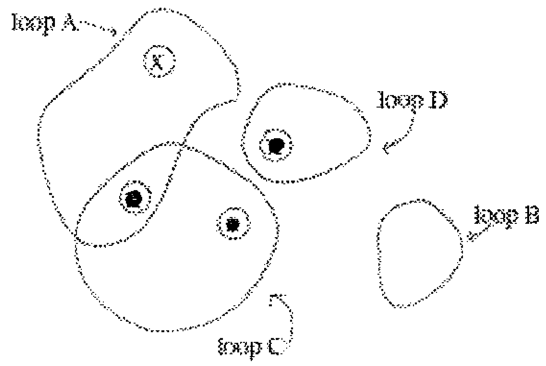


Ans:

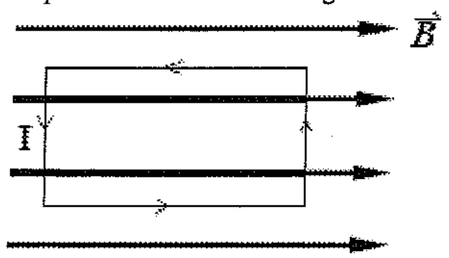
Q3. Consider four equal currents going into or out of the page as indicated in the figure below. Rank the line integral of the magnetic field ∫B·dl (from greatest to least) taken in the clockwise direction.

(a) A = B = C = D
(b) A > C > B > D
(c) D > B > C > A
(d) B = C > D > A
(e) A > D > C = B

C > D > A = B



Q4. A rectangular loop of wire of length l and width w carrying current I is placed in a uniform magnetic field ~B as shown in the figure below. The magnetic field is parallel to the plane containing the loop. Which of the following statement(s) is (are) correct?



I. The current loop experiences a net force.
✓ II. The current loop experiences no net force.
III. The magnetic dipole moment of the current loop, m, points into the page.
✓ IV. The magnetic dipole moment of the current loop, m, points out of the page.
V. The current loop experiences no net torque.
✓ VI. The current loop experiences a net torque.

Q5. A uniform current 'I' flows through the volume of a cylindrical wire of radius 'a'. Calculate the volume current density.

Ans:

$$J_b = \frac{I}{\pi a^2}$$

Q6. A negative charge −q is moving parallel to a long straight wire carrying a constant current as illustrated
in the figure below. Which arrow correctly describes the direction of the magnetic force experienced by the charge?

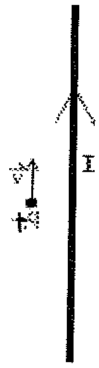
(a) ⊗(into the page)

(b) ⟵

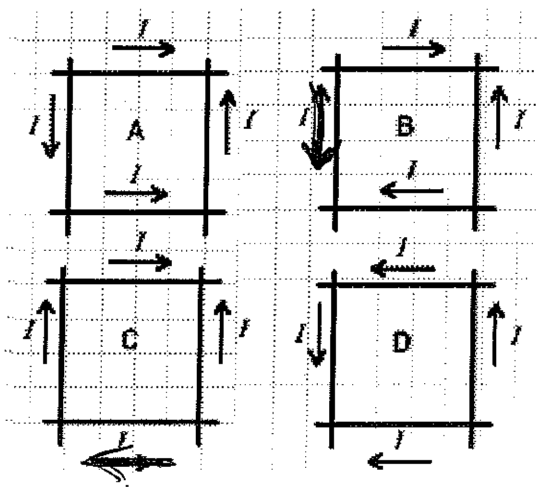
(c) ⟶

(d) ⊙(out of the page)

(e) 0



Q7. The figure below shows four different sets of wires that cross each other without actually touching.
The magnitude of the current is the same in all four cases, and the directions of current flow are as indicated. For which configuration will the magnetic field at the center of the square formed by the wires be equal to zero?



(a) A.
(b) B.
(c) C.
(d) D.

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I Year II Semester 2010-2011

QUIZ 1 (Closed Book)

Course No. PHY C132 **Course Title:** Physics II

Date: 07-03-2011 **Max. Marks:** 24

Weightage: 8% **Duration:** 25 min

Note: Please underline the final answer very clearly.

In spherical coordinates:

$$\nabla \cdot A = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 A_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(A_\theta \sin\theta) + \frac{1}{r\sin\theta}\frac{\partial(A_\phi)}{\partial\phi}$$

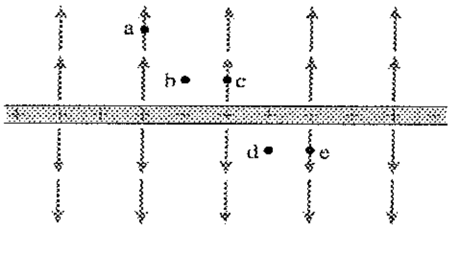
Q1. Find ∇. V for the following vector field

$$V = (y^2 + z^2)(x + y)\ \hat{x} + (z^2 + x^2)(y + z)\ \hat{y} + (x^2 + y^2)(z + x)\ \hat{z}$$

Q2. Is this a possible electric field? Show mathematically: $\mathbf{E} = k(xy\ \hat{x} + 2yz\ \hat{y} + 3xz\ \hat{z})$

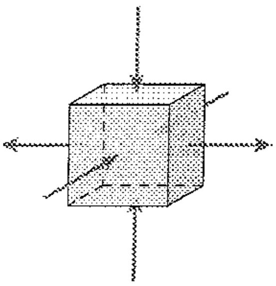
Q3. Suppose the electric field in some region is found to be $\mathbf{E} = kr^3\hat{\mathbf{r}}$, in spherical coordinates (k is some constant). Find the charge density ρ.

Q4. Rank in order, from largest to smallest, the electric field strengths E_a to E_e at these five points near an infinite plane of charge.



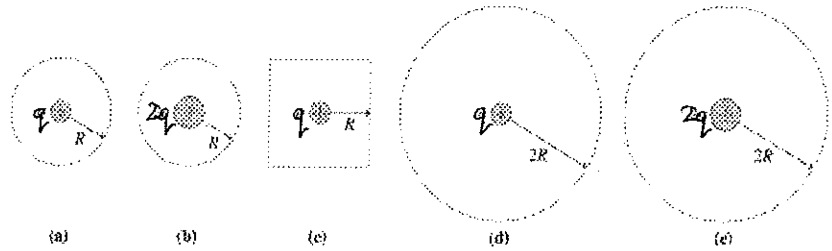
1. $E_a = E_b = E_c = E_d = E_e$
2. $E_a > E_c > E_b > E_e > E_d$
3. $E_b = E_c = E_d = E_e > E_a$
4. $E_a > E_b = E_c > E_d = E_e$
5. $E_e > E_d > E_c > E_b > E_a$

Q5. The arrows here depict the Electric Flux. This box contains



1. a net positive charge.
2. no net charge.
3. a net negative charge.
4. a positive charge.
5. a negative charge.

Q6. These are two-dimensional cross sections through three-dimensional closed spheres and a cube. Rank order, from largest to smallest, the electric fluxes F_a to F_e through surfaces a to e.



1. $\Phi_a > \Phi_c > \Phi_b > \Phi_d > \Phi_e$
2. $\Phi_b = \Phi_e > \Phi_a = \Phi_c = \Phi_d$
3. $\Phi_e > \Phi_d > \Phi_b > \Phi_c > \Phi_a$
4. $\Phi_b > \Phi_a > \Phi_c > \Phi_e > \Phi_d$
5. $\Phi_d = \Phi_e > \Phi_c > \Phi_a = \Phi_b$

Q7. Two spherical cavities, of radii a and b, are hollowed out from the interior of a (neutral) conducting sphere of radius R. At the center of each cavity a point charge is placed - call these charges q_a and q_b .

(a) Find the surface charges σ_a , σ_b, and σ_R?

(b) What is the field outside the conductor?

(c) What is the field within each cavity?