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UNIVERSITY OF ENERGY AND NATURAL RESOURCES, SUNYANI

SCHOOL OF ENGINEERING

DEPARTMENT OF COMPUTER AND ELECTRICAL ENGINEERING

LEVEL 200, END OF SECOND SEMESTER EXAMINATION, 2017/2018

Bachelor of Science (Computer Engineering and Electrical and Electronics Engineering)

ELNG 208 ELECTROMAGNETIC FIELD THEORY

May, 2018

Time: 2 Hrs : 45 Mins

Instructions: *The paper consists of two sections (A and B). Answer all questions in SECTION A and THREE (3) in SECTION B. Formula sheet attached.*

SECTION A – *Shade correctly the letter corresponding to the correct option from A to E on the Shading sheet provided. 1 mark per any correct answer. Correct shade is:* 01. ○A. ○B. ●C. ○D.

1. Electric charges of the same sign _____.
   A. Also have the same magnitude
   B. Attract each other
   C. Exert no forces on each other
   D. Repel each other
   E. None of these is correct

2. A positive charge of 63.0 nC is 15.0 cm from a negative charge of 45.0 nC. The force on one of the charges due to the other is approximately _____.
   A. 1.13×10^{-3} N
   B. 1.13×10^{-7} N
   C. 1.02×10^{7} N
   D. 1.25×10^{-13} N
   E. 1.02×10^{-6} N

3. Two small spheres, each with mass $m = 3.0$ g and charge q, are suspended from a point by threads of length $L = 0.22$ m. What is the charge on each sphere if the threads make an angle $\theta = 15°$ with the vertical? (*Figure 1*)
   A. 0.79 μC
   B. 75 mC
   C. 6.3 μC
   D. 2.9 μC
   E. 0.11 μC

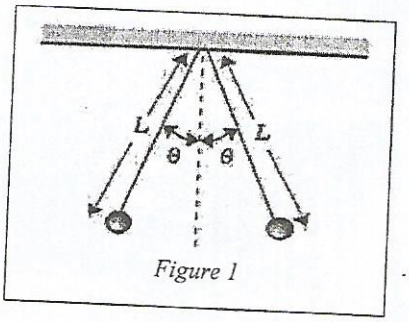

Figure 1

4. The phenomenon of magnetism is best understood in terms of _____.
   A. The existence of magnetic poles
   B. The magnetic fields associated with the movement of charged particles
   C. Gravitational forces between nuclei and orbital electrons
   D. Electrical fluids
   E. None of these is correct

5. Two positive charges (+8.0 mC and +2.0 mC) are separated by 300 m. A third charge is placed at distance r from the +8.0 mC charge in such a way that the resultant electric force on the third charge due to the other two charges is zero. The distance r is
   A. 0.25 km
   B. 0.20 km
   C. 0.15 km
   D. 0.13 km
   E. 0.10 km

6. Three charges, each of $Q = 3.2\times10^{-19}$ C, are arranged at three of the comers of a 20-nm square as shown. The magnitude of the electric field at D, the fourth comer of the square, is approximately (*Figure 2*)
   A. 1.4×10^{7} N/C
   B. 1.0×10^{11} N/C
   C. 3.6×10^{10} N/C
   D. 1.8×10^{7} N/C
   E. 30 N/C

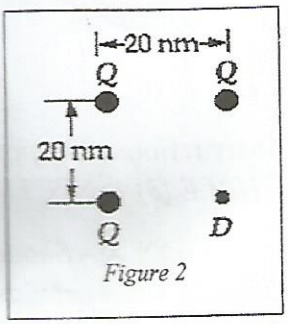

Figure 2

7. In *Figure 3*, the direction of the electric field at a point equidistant from 2 equally charged bodies A and B is indicated by a vector. The direction of the vector indicates that
   A. Both A and B are positive
   B. Both A and B are negative
   C. A is positive and B is negative
   D. B is positive and A is negative
   E. B is negative and A is neutral

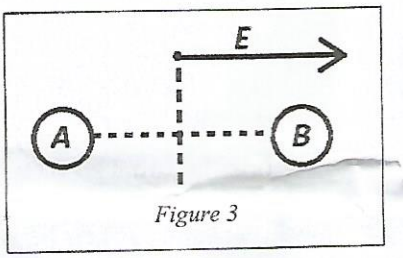

Figure 3

8. An electric field is $\vec{E} = (400)\hat{a}_n$ N/C for $x > 0$ and $\vec{E} = (-400)\hat{a}_n$ N/C for $x < 0$. A cylinder of length 30 cm and radius 10 cm has its centre at the origin and its axis along the x axis such that one end is at $x = +15$ cm and the other is at $x = -15$ cm. What is the net outward flux through the entire cylindrical surface?
   A. 0.50 kNm^2/C
   B. 0.25 MNm^2/C
   C. 2.5 kNm^2/C
   D. 25 Nm^2/C
   E. Zero

9. A positively charged particle is moving northward in a magnetic field. The magnetic force on the particle is toward the northeast. What is the direction of the magnetic field?
   A. Up
   B. West
   C. South
   D. Down
   E. This situation cannot exist

10. Which of the following statements is false?
   A. Electric field lines due to an electric dipole and magnetic field lines due a magnetic dipole have similar configuration.
   B. Electric field starts from a positive charge and ends at a negative charge.

C. Magnetic field starts at the north pole and ends at the south pole.
D. Magnetic poles always occur in pairs.
E. Magnetic fields result from the flow of charges.

11. A loop rest in the x-y plane. The z axis is normal to the plane and positive upward. The direction of the changing flux is indicated by the arrow on the z axis. The diagram that correctly shows the direction of the resultant induced current in the loop is (*Figure 4*) _____.

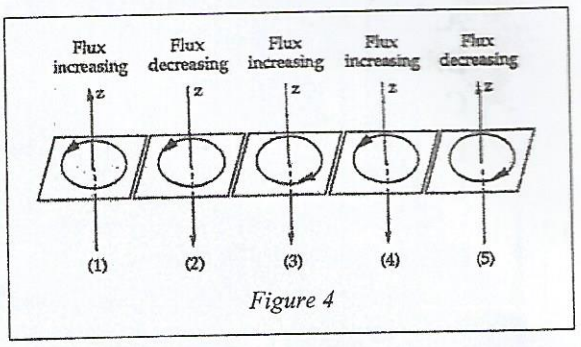

Figure 4

A. 1
B. 2
C. 3
D. 4
E. 5

12. Which law does the following statement express? "In all cases of electromagnetic induction, the induced voltages have a direction such that the currents they produce oppose the effect that produces them."
A. Maxwell's law
B. Gauss's law
C. Fleming's rule
D. Ampere's law
E. Lenz's law

13. A charged metal ball is lowered into an insulated metal can and permitted to touch the inside of the can. If the ball is withdrawn and hung on a stand, an uncharged ball will be attracted to (*Figure 5*) _____.

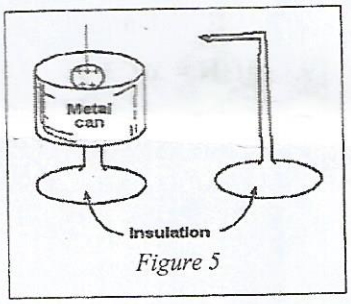

Figure 5

A. The outside of the can
B. The inside of the can
C. The outside and the inside of the can
D. The metal ball and the inside of the can
E. The metal ball, the inside of the can, and the outside of the can

14. Dielectric breakdown occurs in the air at an electric field strength of $E_{max} = 3\times10^{6}$ V/m. If the maximum charge that can be placed on a spherical conductor is 2×10^{-3} C before breakdown, calculate the diameter of the sphere.
A. 6.0 m
B. 4.9 m
C. 1.2 m
D. 2.5 m
E. 3.0 m

15. The potential on the surface of a solid conducting sphere of radius r = 20 cm is 100 V. The potential at r = 10 cm is _____.
A. 100 V
B. 50 V
C. 25 V
D. 0 V
E. Cannot be determined

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16. Two charges $Q_1 = +6\,\mu C$ and $Q_2 = -2\,\mu C$ are brought from infinity to positions on the x-axis of $x = -4$ cm and $x = +4$ cm, respectively. How much work was done in bringing the charges together?
    A. -1.80×10^6 J
    B. -1.35 J
    C. -16.9 J
    D. -9.00×10^5 J
    E. None of the above

17. Inside a hollow conducting sphere _____.
    A. Electric field is zeros
    B. Electric field is non-zero constant
    C. Electric field changes with magnitude of the charge
    D. Electric field changes with distance from the centre
    E. None of these

18. Given $\mathbf{B} = -9.3\mathbf{a}_x - 6\mathbf{a}_y + 2\mathbf{a}_z$, Find the projection of A along $\mathbf{a}_y$.
    A. -12
    B. -6
    C. 18
    D. 2
    E. Cannot be determined

19. If $\mathbf{R} = x\hat{a}_x + y\hat{a}_y + z\hat{a}_z$, the position vector of point (x, y, z) and $R = |\mathbf{R}|$, which of the following is incorrect?
    A. $\nabla \cdot \mathbf{R} = 1$
    B. $\nabla R = \mathbf{R}/R$
    C. $\nabla \times \mathbf{R} = 0$
    D. $\nabla^2(\mathbf{R} \cdot \mathbf{R}) = 6$
    E. None of the above

20. The dot product of a vector with itself gives _____.
    A. The square of the vector
    B. The square of the magnitude
    C. The angle between the vector and ground
    D. Reverse the unit vector of the multiplicand
    E. None of these

21. Two particles are held in equilibrium by the gravitational and electrostatic forces between them. Particle A has mass m_A, and charge q_A. Particle B has mass m_B and charge q_A. The distance between the charges is d. Which of the following changes will cause the charges to accelerate towards one another?
    A. m_A is doubled and m_B is halved
    B. m_A is doubled and m_B is doubled
    C. q_A is doubled and q_B is halved
    D. q_A is halved and m_A is halved
    E. Cannot be determined

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Section B – *Answer ALL questions in PART I and ONE in PART II*

Part I – Answer ALL questions

Question One **[15 Marks]**

a) Determine the total charge, Q

i. On line $0 < x < 5$ m if $\rho_L = 12x^3$, C/m.

ii. On the cylinder $\rho = 3,\ 0 < z < 4$ m if $\rho_S = \rho z^2$ nC/m^2.

iii. Within the sphere $r = 6$ m if $\rho_V = \dfrac{10}{r \sin\theta}$ C/m^3.

b) A current *I*, is uniformly distributed over a wire of circular cross section, with radius *a* (Fig. 1).

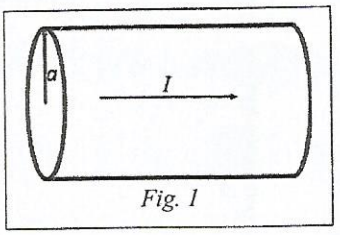

Fig. 1

i. Find the volume current density *J*.

ii. Suppose the current density in the wire is proportional to the distance from the axis, $J = kr$ (k is some constant), find the total current in the wire.

c) i. Find the magnetic field at the centre of a square loop, which carries a steady current *I*. Let *R* be the distance from centre to side.

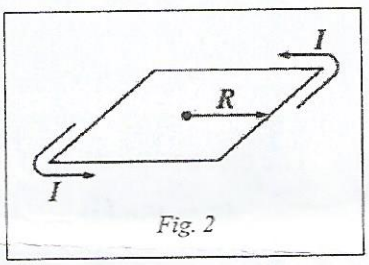

Fig. 2

ii. Find the field at the centre of a regular *n*-sided polygon, carrying a steady current *I*. Again, let *R* be the distance from the centre to any side.

iii. Check that your formula reduces to the field at the centre of a circular loop, in the limit $n \to \infty$.

Question Two **[15 Marks]**

a) A 650 mm length of coaxial cable with an inner radius of 1.5 cm and an outer radius of 5 cm. The space between the conductors is assumed to be filled with air. When connected to a charge source, the total charge on the inner conductor is 35 nC. Determine:

i. the charge density on each conductor.

ii. the $\vec{E}$ and $\vec{D}$ fields.

b) i. Given the magnetic field $\vec{H} = \rho^2 \hat{a}_\phi$, A/m, determine the total current *I* passing through the circular surface $0 \le \rho \le 1, 0 \le \phi \le 2\pi, z = 0$ in the $\hat{a}_z$ direction.

ii. Explain how electric energy is produced from a time varying magnetic field.

iii. State Ampere's circuital law.

iv. State three conditions defining a Gaussian surface.

c) A closed surface is defined by $\rho = 3, \rho = 5, \phi = 100^\circ, \phi = 130^\circ, z = 3$, and $z = 4.5$. Find:

i. The enclosed volume

ii. The total area of the enclosing surface

iii. The length of the longest straight line that lies entirely within the volume.

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Part II – Answer only ONE question in this part.

Question Three [10 Marks]

a) Given the points $M(0.1,-0.2,-0.1)$, $N(-0.2,0.1,0.3)$, and $P(0.4,0,0.1)$, find:

i. The vector $\mathbf{R}_{MN}$

ii. The Dot product $\mathbf{R}_{MN} \cdot \mathbf{R}_{MP}$

iii. The Scalar projection of $\mathbf{R}_{MN}$ on $\mathbf{R}_{MP}$

iv. The angle between $\mathbf{R}_{MN}$ and $\mathbf{R}_{MP}$

b) Given the magnetic vector potential $A = -\frac{\rho^2}{4} a_z$ Wb/m, calculate the total magnetic flux crossing the surface $\phi = \frac{\pi}{2}$, $1 \le \rho \le 2$ m, $0 \le z \le 5$ m.

Question Four [10 Marks]

a) The electric potential is given as $V(x,y,z) = 0.5(x^2 + y^2 + z^2)$ V.

i. Find the E field vector as a function of position

ii. Find the volume charge density ρ_v as a function of position.

b) A magnetic vector potential A is given by

$$\vec{A} = 50\rho^2 \hat{a}_z, \text{ Wb/m}$$

i. Find the magnetic field vectors B and H if the medium is vacuum

ii. Find the current density J