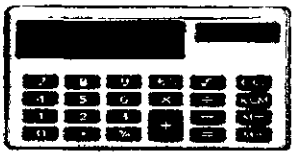
UNIVERSITY EXAMINATIONS



UNIVERSITEITSEKSAMENS

UNISA university of south africa

PHY1506 (475498) October/November 2014

ELECTROMAGNETISM AND HEAT (PHYSICS)

Duration 2 Hours 100 Marks

EXAMINERS :
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SECOND PROF M BRAUN

Use of a non-programmable pocket calculator is permissible.

Closed book examination.

Instructions :

- This paper consists of two sections SECTIONA (30%) and SECTION B (70%)
- Answer all the questions in both sections
- Answer section A (multiple choice questions) on the mark reading sheet provided.
- Answer section B (written solutions) in the examination booklet provided.
- The mark allocation for each question is indicated in brackets to the right of each question
- The constants and formulae are given at the end of Section B may be used without proof.
- This paper consists of 7 pages plus a page of instructions for completing the mark reading sheet.

[TURN OVER]

SECTION A (Multiple choice questions)
(Each question in this section carries 3 marks TOTAL. [30])

1. An ideal gas is at a pressure 1.00×10^5 N/m^2 and occupies a volume 2.00 m^3. If the gas is compressed to a volume 1.00 m^3 while the temperature remains constant, what will be the new pressure in the gas?
   1) 0.500×10^5 N/m^2
   2) 4.00×10^5 N/m^2
   3) 1.00×10^5 N/m^2
   4) 2.00×10^5 N/m^2
   5) The answer depends on the mass of the gas particles

2. The figure shows a pV diagram for 0.95 mol of gas that undergoes the process 1 → 2. The gas then undergoes an isochoric heating from point 2 until the pressure is restored to the value it had at point 1. What is the final temperature of the gas?
   1) -160°C
   2) 15°C
   3) 390°C
   4) 120°C
   5) 135 °C

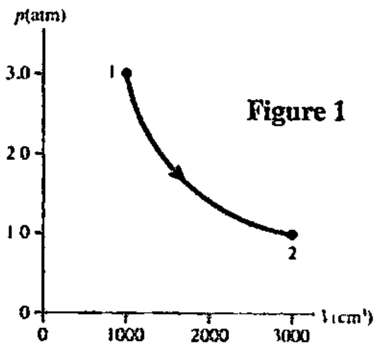

Figure 1

3. A sample of an ideal gas is slowly compressed to one-half its original volume with no change in temperature. What happens to the average speed of the molecules in the sample?
   1) It becomes 1/4 as great
   2) It becomes 4 times as great.
   3) It becomes 2 times as great.
   4) It becomes 1/2 as great
   5) It does not change

4. A heat engine with an efficiency of 30.0% performs 2500 J of work. How much heat is discharged to the lower temperature reservoir?
   1) 5830 J
   2) 8330 J
   3) 750 J
   4) 1350 J
   5) 7080 J

5. When two point charges are 2.0 cm apart, each one experiences a 1.0-N electric force due to the other charge. If they are moved to a new separation of 8.0 cm, the electric force on each of them is:
   1) 1.0 N
   2) 4.0 N.
   3) 16 N
   4) 0.25 N.
   5) 0.063 N.

[TURN OVER]

6. The figure below shows three electric charges labeled Q_1, Q_2, Q_3, and some electric field lines in the region surrounding the charges. What are the signs of the three charges?

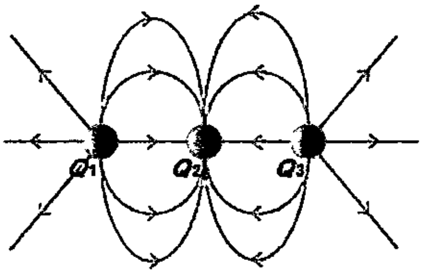

Figure 2

1) Q_1 is positive, Q_2 is negative, Q_3 is positive.
2) Q_1 is negative, Q_2 is positive, Q_3 is negative.
3) Q_1 is positive, Q_2 is positive, Q_3 is negative.
4) All three charges are negative.
5) All three charges are positive.

7 A nonuniform electric field is directed along the x-axis at all points in space. This magnitude of the field varies with x, but not with respect to y or z. The axis of a cylindrical surface, 0.80 m long and 0.20 m in diameter, is aligned parallel to the x-axis, as shown in the Figure below. The electric fields E_1 and E_2, at the ends of the cylindrical surface, have magnitudes of 6000 N/C and 1000 N/C respectively, and are directed as shown in the Figure. What is the net electric flux passing through the cylindrical surface?

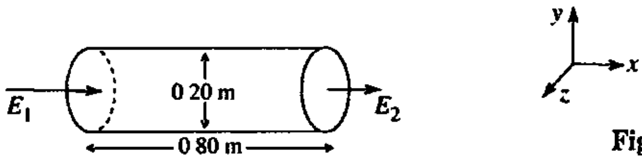

Figure 3

1) 0 00 N · m^2/C
2) -160 N m^2/C
3) -350 N m^2/C
4) +350 N · m^2/C
5) +160 N m^2/C

8 A negative charge is moved from point A to point B along an equipotential surface Which of the following statements must be true for this case?
1) The negative charge performs work in moving from point A to point B.
2) Work is required to move the negative charge from point A to point B.
3) No work is required to move the negative charge from point A to point B
4) The work done on the charge depends on the distance between A and B.
5) Work is done in moving the negative charge from point A to point B.

[TURN OVER]

9. An electron traveling toward the north with speed 4.0×10^5 m/s enters a region where the Earth's magnetic field has the magnitude 5.0×10^{-5} T and is directed downward at 45° below horizontal. What is the magnitude of the force that the Earth's magnetic field exerts on the electron?
    1) 2.3×10^{-18} N
    2) 3.2×10^{-18} N
    3) 2.3×10^{-19} N
    4) 3.2×10^{-19} N
    5) 2.3×10^{-20} N

10 In the Figure below, a bar magnet moves away from the solenoid. The direction of the induced current through the resistor *R* is

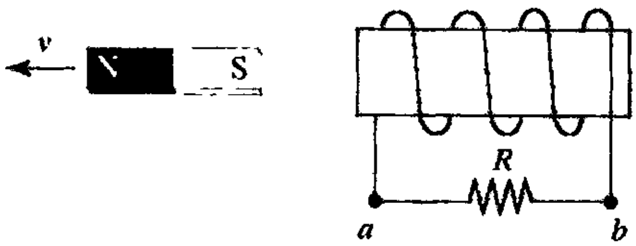

Figure 4

1) from *b* to *a*
2) from *a* to *b*
3) there is no induced current through the resistor.
4) cannot be determined
5) none of the above

[TURN OVER]

SECTION B (Written solutions [70])

1 Five grams of nitrogen gas at an initial pressure of 3.0 atm and at 20°C undergo an isobaric expansion until the volume is tripled. The gas pressure is then decreased at constant volume until the original temperature is reached. Finally, the gas is isothermally compressed until it returns to its initial volume.

(a) Calculate the final gas pressure (10)

(b) Show the full three-step process on a pV diagram by using appropriate scales on both axes. (4)

[14]

2 (a) The Figure below shows a circuit of a flashlight bulb, rated 3.0V/1.5W, and ideal wires with no resistance. The right wire of the circuit, which is 1 cm long, is pulled at a constant speed v through a perpendicular magnetic field of strength 0.10 T

(i) What speed must the wire have to light the bulb to at 1.5 W? (4)

(ii) What force is needed to keep the wire moving? (3)

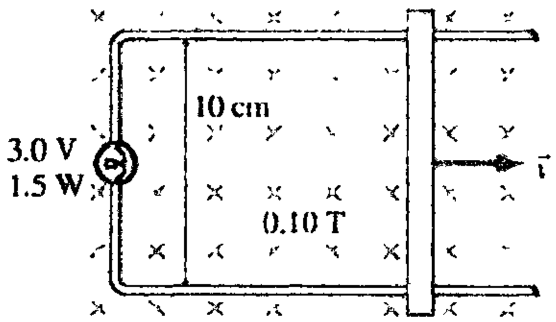

Figure 5

(b) A rectangular wire loop of 10 turns is lying in a horizontal plane parallel to a uniform magnetic field, as shown in the Figure below. The current in the loop is 2.0 A. The loop is free to rotate about a nonmagnetic axle through its center. Calculate the magnetic field strength needed to just prevent the loop from rotating about the axle if a 50 g mass is hung from one edge of the loop as shown in the Figure. (7)

[14]

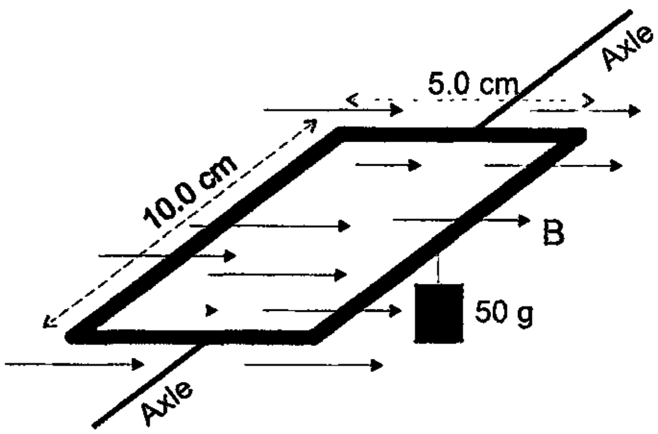

Figure 6

[TURN OVER]

3 (a) State and explain Faraday's law of electromagnetic induction. (6)

(b) A square loop measuring $20\text{ cm} \times 20\text{ cm}$ is lying in a horizontal plane perpendicular to a uniform magnetic field whose magnitude is given by $B = 4t - 2t^2$ (where B is in Tesla and t is the time in seconds) Calculate the current in the loop at $t = 0$ s and $t = 2.0$ s if its resistance is 0.1 Ω (8)

[14]

4. A solid non-conducting Sphere of radius $R = 5.60\text{cm}$ has a non-uniform charge distribution of volume density given by

$$\rho = \left(14.1\text{p}C/\text{m}^3\right)\frac{r}{R},$$

where r is the radial distance from the sphere's centre

(a) Calculate the total charge on the sphere. (8)

(b) Determine the magnitude of the electric field at $\vec{E}$ at $r = R$ (6)

[14]

5. (a) State Kirchhoff's current law and voltage law (4)

(b) Three resistors, $R_1 = 300\ \Omega$, $R_2 = 100\ \Omega$ and $R_3 = 200\ \Omega$ are connected to two ideal batteries, as shown in the figure below Calculate the current through and potential difference across R_2. (10)

[14]

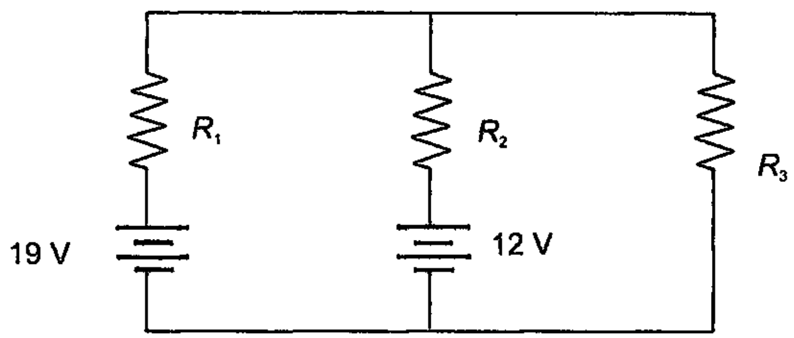

Figure 7

[TURN OVER]

Formulae

$Q = mc\Delta T$

$Q = k\dfrac{A\Delta Tt}{L}$

$Q = \sigma T^4 At$

$PV = \dfrac{2}{3}N\overline{KE}$

$KE = \dfrac{3}{2}kT$

$W = nRT\ln\left(\dfrac{V_f}{V_i}\right)$

$W = \dfrac{3}{2}nR\left(T_i - T_f\right)$

$PV = nRT$

$C = \dfrac{\kappa\varepsilon_0 A}{d}$

$\vec{F} = q\vec{v}\times\vec{B}$

$d\vec{E} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{dq}{r^3}\vec{r}$

$d\vec{B} = \dfrac{\mu_0}{4\pi}\dfrac{id\vec{s}\times\hat{\mathbf{r}}}{r^3}$

$\int \vec{B}\ d\vec{A} = \Phi_B$

$\vec{\tau} = \vec{\mu}\times\vec{B}$

$\mathcal{E} = \left|\dfrac{d\Phi}{dt}\right|$

Constants

$k_B = 1\ 38\times10^{-23} J/K$

$R = 8\ 3J/(\text{mol K})$

$N_A = 6\ 0\times10^{23}\text{mol}^{-1}$

$m_e = 9\ 1\times10^{-31}\text{kg}$

$m_p = 1\ 7\times10^{-27}\text{kg}$

$e = 1.6\times10^{-19}\text{C}$

$k = 9\times10^9\text{Nm}^2/\text{C}^2$

$\varepsilon_0 = 8.85\times10^{-12}\text{F/m}$

$\mu_0 = 1.26\times10^{-6}\text{H/m}$

$c = 3\ 0\times10^8\text{m/s}$

Mathematics

Surface Area of a sphere A=$4\pi r^2$

Volume of a Sphere: V=$\dfrac{4}{3}\pi r^3$

$\int\dfrac{dr}{r} = \ln r + \text{constant}$

$\int\dfrac{dr}{r^2} = \dfrac{1}{r} + \text{const}$