MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
SEPTEMBER 2014

SUBJECT:	PHYSICS
DATE:	6th September 2014
TIME:	9.00 a.m. to 12.00 noon

A list of useful formulae and equations is provided. Take the acceleration due to gravity $g = 9.81\ m\ s^{-2}$ ***unless otherwise stated.***

SECTION A

Attempt all <u>10 questions</u> in this section. Each question carries 5 marks. This section carries 50% of the total marks for this paper.

1. An archer pulls at the midpoint of the bowstring with a horizontal force of 170 N such that the arrow is drawn backwards 35 cm (see Figure 1).
   a. Calculate the angle that each half of the bowstring makes with the horizontal.

   [2 marks]

   b. What is the tension in the bowstring?

   [3 marks]

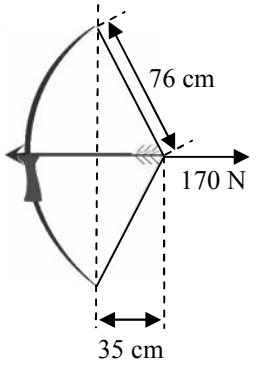


Figure 1

2. Table 1 shows the thermometric property values of two different types of thermometers, at different temperatures.

	Resistance of platinum resistance thermometer	**Pressure recorded using a constant volume gas thermometer**
Steam point 100°C	$75.000\ \Omega$	1.10×10^{7} Pa
Ice point 0°C	$63.000\ \Omega$	8.00×10^{6} Pa
Room temperature	$64.992\ \Omega$	8.51×10^{6} Pa

Table 1

   a. Calculate the room temperature as shown on the scale of the **two** thermometers. Give your answers in Kelvin.
   b. Explain why the answers to part (a) are not the same.

[4, 1 mark]

3. In the movie "Gravity", the astronaut reaches the International Space Station (ISS) for cover from space debris and to replenish her suit with oxygen. The ISS follows an orbit, that is on average, 450 km above the surface of Earth. Calculate:
   a. the orbital speed of the ISS;
   b. the time taken for the ISS to complete one orbit.

[3, 2 marks]

4. A metal ball bearing is dropped in a large measuring cylinder filled with liquid soap. The ball bearing accelerates for approximately 5 seconds after which it reaches a terminal velocity of $0.22\ \text{m s}^{-1}$. It continues to move with terminal velocity until it reaches the bottom.
   a. During the first 5 seconds, are the forces acting on the metal ball in equilibrium? Explain.
   b. Draw a velocity-time graph that shows how the velocity of the ball bearing changed from the moment it was released clearly indicating any velocity and time values on your graph.

[2, 3 marks]

5. An electron beam, in a vacuum, is projected horizontally through a magnetic field with a speed of $1.80\times10^{7}\ \text{m s}^{-1}$ as shown in Figure 2. The length of the magnet pole faces is $2.4\ \text{cm}$ and there is a magnetic field of $0.20\times10^{-2}\ \text{T}$ between them.

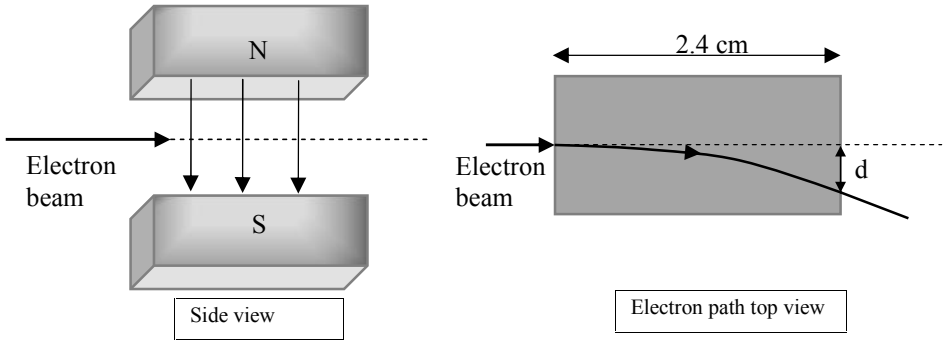


Figure 2

   a. Calculate the force on a single electron as it enters the magnetic field.
   b. Determine the time it takes the electron to travel between the magnetic poles.
   c. Calculate the sideways displacement, d, of an electron before leaving the magnetic field region.

[2, 1, 2 marks]

6. A $0.400\ \text{kg}$ mass is rotating in a circular path of radius $0.90\ \text{m}$ on a friction-free table. It is attached by a string to a peg at the centre of the circle.
   a. Draw a free-body force diagram for the mass.
   b. Calculate the force, which the string exerts on the mass when the mass is moving at a constant speed of $2.45\ \text{ms}^{-1}$.

[3, 2 marks]

7. A Uranium ($^{238}_{92}\text{U}$) nucleus decays by emitting an α particle to form Thorium. The atomic masses of Uranium-238, Thorium-234 and Helium-4 are $238.0507\ \text{u}$, $234.0436\ \text{u}$ and $4.0026\ \text{u}$ respectively.
   a. Write down the nuclear equation that represents the decay.
   b. Find the maximum kinetic energy that the α particle can have assuming that the parent nucleus was initially at rest and that the daughter nucleus was also at rest when produced.

[2, 3 marks]

8. When a mass m is loaded on the platform attached to the top end of a spring, the latter is compressed by a distance d (see Figure 4).
   a. Given that the spring constant is k, write down an equation that relates the mass m to the compression d.
   b. The mass is pushed down a further distance of 0.04 m and then released. The mass performs simple harmonic motion.
      i. State one condition necessary for simple harmonic motion to take place.
      ii. When does the mass m have the largest velocity as it oscillates?
      iii. Given that the periodic time of the oscillation is 6 seconds, calculate the maximum acceleration that the mass undergoes during the oscillatory motion.

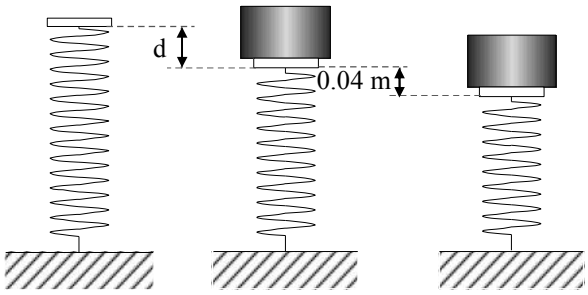


Figure 3

[1, 1, 1, 2 marks]

9. A laser that emits 690 nm red light is used to illuminate two parallel slits. Interference fringes are observed on a screen that is 3.30 m away from the slits. The distance between two bright fringes on either side of the centre fringe is 1.80 cm.
   a. Calculate the distance between the slits?
   b. What happens to the pattern observed if the distance between the slits is decreased?
   c. The red light laser is now replaced with one that emits green light. Does this affect the distance between the bright fringes? Explain. **[2, 1, 2 marks]**

10. Four resistors are connected to a cell as shown in Figure 5.
    a. Find the total resistance in the circuit.
    b. Calculate the current through the resistor R_2.

[3, 2 marks]

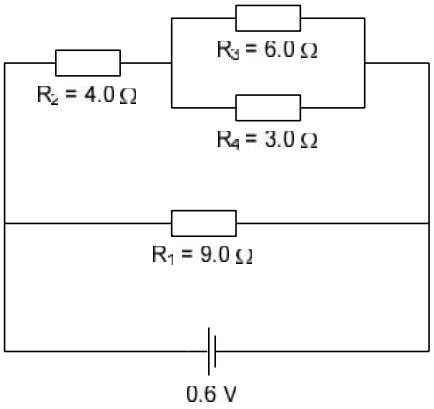


Figure 4

Please turn the page for Section B

SECTION B

This question carries 14% of the total mark of this paper and <u>must be attempted.</u>

11. Viscosity is a measure of a fluid's resistance to flow. Figure 6 shows the setup of an experiment used to determine the viscosity of oil at room temperature. Oil flows through the capillary tube of length, L, and cross-sectional area A and is collected in the flask.

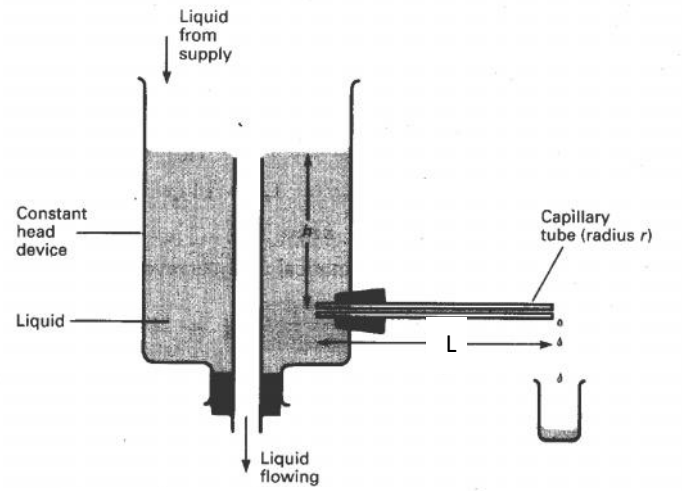


Figure 5

The pressure, p, of oil that flows out of the capillary tube is changed by increasing the height h. The volume, V, of oil that flows into the beaker in time t is recorded every time the pressure p is changed .

The equation relating the viscosity, η, with the pressure of oil and the volume flow rate is:

$$\eta = \frac{A^2}{8\pi L} \times \frac{t}{V} \times p$$

The capillary tube has a diameter of 0.008 m and a length, L, of 0.60 m. The oil used has a density, ρ, of $920\ \text{kg m}^{-3}$.

h / m	V / x10^{-6} m^3	t / s	$\left(\frac{t}{V}\right)$ / s m^{-3}	$\left(\frac{1}{p}\right)$ / Pa^{-1}
0.20	151.20	300		
0.30	206.81	300		
0.40	302.40	300		
0.50	370.02	300		
0.60	423.72	300		

Table 2

a. Copy Table 2 and fill in the missing values. (Hint: $p = h\rho g$)

[5 marks]

b. Plot a graph of $\left(\frac{1}{p}\right)$ / Pa^{-1} on the y-axis against $\left(\frac{t}{V}\right)$ / s m^{-3} on the x-axis.

[5 marks]

c. Write the given equation in the form $y = mx + c$, explaining your working. Use the graph to determine the value of the viscosity of oil, η, including its units.

[3 marks]

d. If the experiment was carried out using oil at a higher temperature, would you expect the value for the viscosity of oil to be greater or smaller? Explain your answer.

[1 mark]

SECTION C

Answer any two questions from this section. Each question carries 18 marks. This section carries 36% of the total mark for this paper.

12. A student sets up the apparatus shown in Figure 7 to investigate electromagnetic induction. When the switch is closed, a strong magnetic field is produced by the coil.

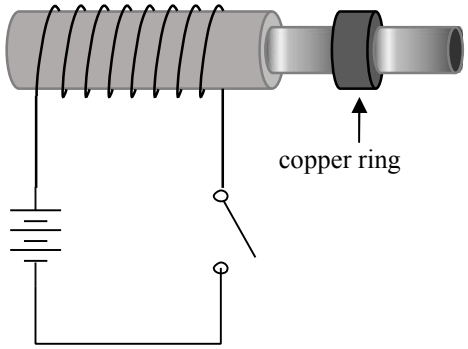
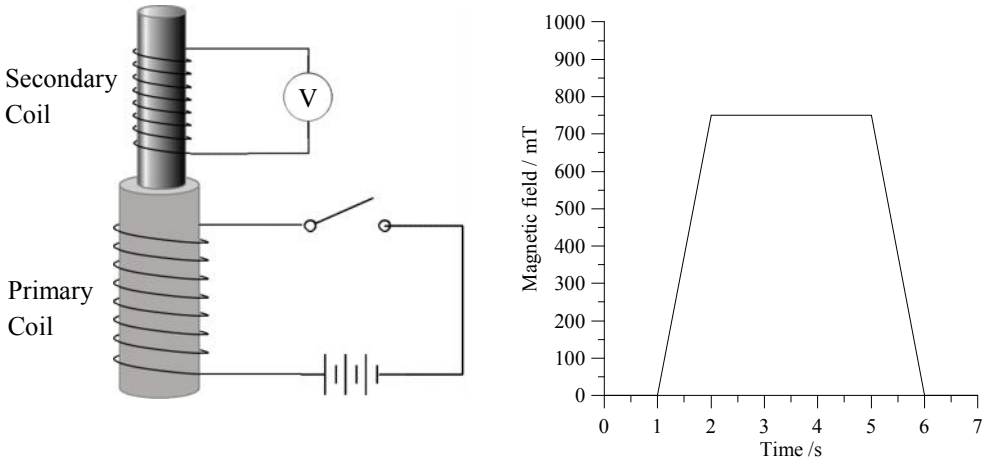


Figure 6

a. Referring to the laws of electromagnetic induction:
   i. Explain what will happen to the copper ring as the switch is closed;
   ii. Explain what will happen to the copper ring when the current in the circuit becomes steady;
   iii. Explain what will happen to the copper ring as the switch is now opened;
   iv. Would your answers to (i) and (iii) change if the power supply terminals were reversed? Explain.

[2, 2, 2, 3 marks]

b. The student removes the copper ring and replaces it with a secondary coil connected to a voltmeter, as shown in Figure 8 (a). The secondary coil has 1000 turns and a cross-sectional area of $2\,\text{cm}^2$.



(a) (b)

Figure 7

Given that the magnetic field through the primary coil is changed with time as shown in Figure 8 (b):

   i. Explain which part of the graph is related to when the induced voltage V is at its maximum value;
   ii. Using the same time scale as in Figure 8b, show how the induced voltage V in the secondary coil varies with time;
   iii. Calculate the flux linkage for the secondary coil;

[2, 4, 3 marks]

13.

a. Figure 9 shows some of the energy levels of the hydrogen atom. Energy may be absorbed by the hydrogen atom resulting in excitation or ionisation. Transitions of the electron in the hydrogen atom from a high energy level to a lower one result in the emission of electromagnetic radiation.

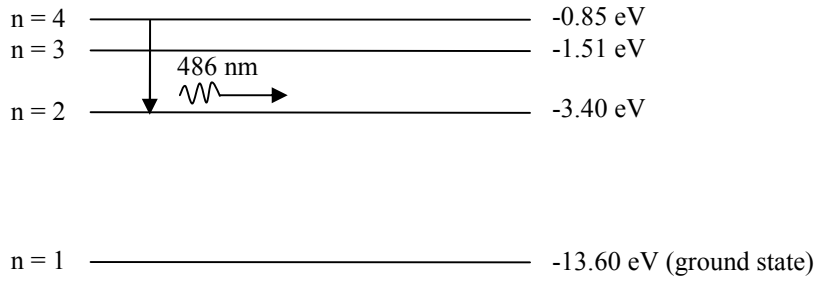


Figure 8

i. Explain what is meant by the terms *excitation* and *ionisation*.

[4 marks]

ii. Why is the energy level labelled -13.6 eV called the ground state?

[2 marks]

iii. Calculate the ionisation energy of a hydrogen atom. Express your answer in Joules.

[2 marks]

iv. Calculate the potential difference required to just provide a free electron with enough energy to ionize a hydrogen atom upon colliding with it.

[2 marks]

b. Figure 9 shows an electron transition which results in the emission of light of wavelength 486 nm . Copy the diagram and on it draw arrows to show:

i. a transition which results in the emission of light of a shorter wavelength, labelling this transition L;

ii. a transition which results in the emission of a longer wavelength, labelling this transition R;

iii. a transition which results from the absorption of energy by an electron, labelling this transition A.

[1, 1, 1 mark]

c. Calculate the energy change which an electron has to undergo in order for light of wavelength 486 nm to be emitted during a transition. Express your answer in electronvolts (eV).

[2 marks]

d. An atom of hydrogen in the ground state is bombarded by an electron having energy equal to 1.89 eV . Comment on whether this bombardment will have any effect on the state of the atom.

[3 marks]

14.

a. A gas is enclosed in a cylinder fitted with a moveable piston, as shown in Figure 10. The change in internal energy of the gas is related to the heat supplied to the gas and to the work done on the gas by the first law of thermodynamics.

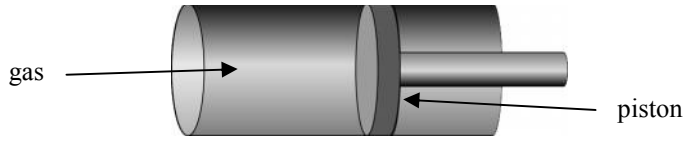


Figure 9

i. Write down a mathematical expression that represents the first law of thermodynamics, identifying clearly any terms used.

[3 marks]

ii. Explain what is meant by the term *internal energy of a gas*.

[2 marks]

iii. Describe how the internal energy of the gas enclosed in the cylinder may be decreased.

[1 mark]

b. The gas undergoes changes of pressure and volume in the order described in the table below:

Initial State	Final State	Change
A	B	isobaric expansion from $0.001\,\mathrm{m}^3$ to $0.004\,\mathrm{m}^3$
B	C	isochoric process with a decrease in pressure from 3.50×10^5 Pa to 1.50×10^5 Pa

i. Sketch a P-V diagram illustrating these two changes in the state of the gas, distinguishing clearly between the two processes.

ii. Calculate the work done on the gas in going from A to C.

iii. The internal energy of the gas increases by 100 J, in going from A to C. Calculate the heat supplied to the gas during this process.

[2, 2, 2 marks]

c. An electric kettle contains $1\,\mathrm{kg}$ of water in it that has just started to boil off. Given that the densities of water and steam are $1000\,\mathrm{kg\,m^{-3}}$ and $0.590\,\mathrm{kg\,m^{-3}}$ respectively and the atmospheric pressure is 1.01×10^5 Pa , calculate:

i. the volume occupied by the water before it starts boiling;

ii. the volume occupied by the steam when all water has boiled off;

iii. the change in volume when all the water changes into steam;

iv. the work done against atmospheric pressure to produce this change in volume;

v. the increase in internal energy of the molecules when $1.0\,\mathrm{kg}$ of water evaporates, given that the latent heat of vaporization of water is $2.26\times10^6\,\mathrm{J\,kg^{-1}}$.

[1, 1, 1, 1, 2 marks]

15.

a. Sketch the current-voltage characteristics of:
   i. a copper wire at constant temperature, and
   ii. a filament lamp.

[2, 2 marks]

b. The graph in Figure 11 shows the current-voltage characteristics for an ohmic resistor R and a germanium diode D.

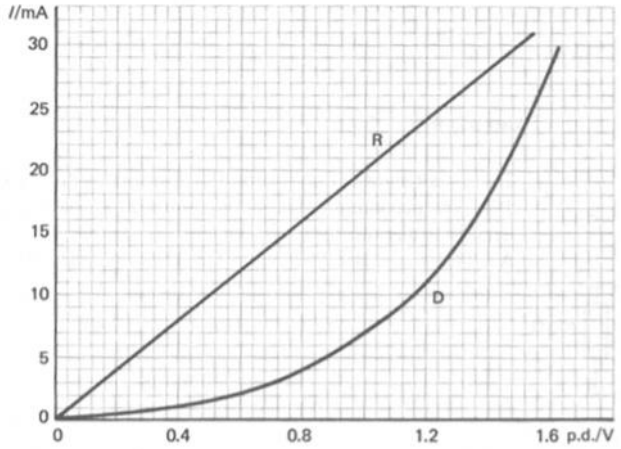


Figure 11

   i. Compare how the resistance of the resistor and the diode vary as the potential difference across them increases. Give reasons for your answer.

   ii. Use the graph to find the current through a cell of 1.5 V, when R and D are connected to it in parallel (Assume the cell has zero internal resistance and a current flows through D).

   iii. What is the potential difference needed for a current of 15 mA to pass through R and D when these are connected in series?

[3, 3, 3 marks]

c. The 4 V cell in the circuits shown in Figure 12 has zero internal resistance.

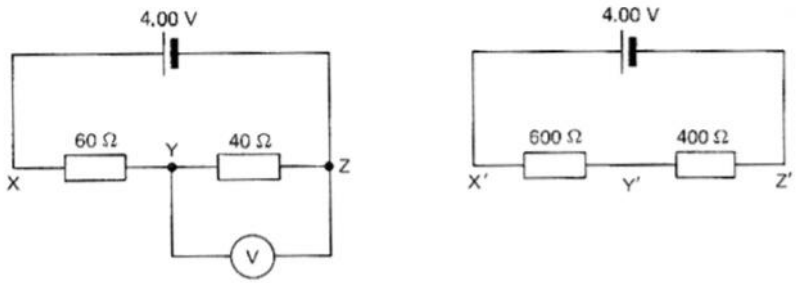


Figure 12

An accurately calibrated voltmeter connected across YZ records 1.5 V.

   i. Calculate the resistance of the voltmeter.
   ii. If the voltmeter is now connected across Y'Z' would it still read 1.5 V? Give a reason for your answer.

[3, 2 marks]