MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD
UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2016

SUBJECT:	PHYSICS
PAPER NUMBER:	I
DATE:	2nd September 2016
TIME:	9.00 a.m. to 12.05 p.m.

A list of useful formulae and equations is provided.

This paper carries 40% of the marks for the examination.
It is expected that answers be accompanied by the proper units.

Section A
Attempt all eight questions in this section. This section carries 50% of the total marks for this paper.

Question 1

Figure 1 shows the velocity- time graph of a moving object. Its initial velocity at A equals u, while its velocity at B at time t, equals v.

a. Write in terms of the symbols given, the acceleration a of the object as it moves from A to B. **[1 mark]**

b.
(i) Calculate, in terms of symbols, the area between line AB and the time axis. **[2 marks]**
(ii) In your result, substitute for v with the answer obtained in part (a). **[4 marks]**
(iii) Comparing your answer with the equations of linear motion, state what the area in part (i) represents. **[2 marks]**

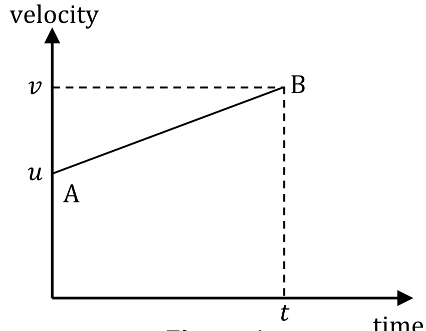

Figure 1

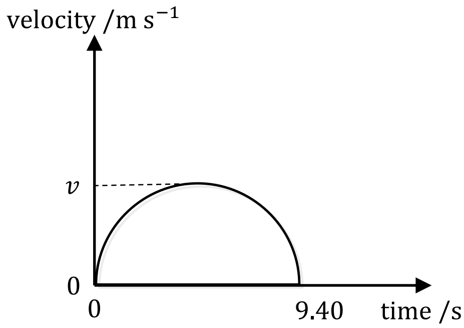

Figure 2

c. The velocity-time graph shown in Figure 2, takes the form of a semicircle. Calculate the distance travelled by the moving object in 9.40 seconds. **[2 marks]**

Question 2

A video shows a young man positioned at the edge of a rooftop, throwing a basketball, at an angle 35.0 ° above the horizontal with the intent to net the ball in a basketball net fixed on the ground below. The ball hits the ground 4.50 seconds later, 120 m away from the base of the building. Ignore air resistance.

a. Find the initial velocity of the ball. **[3 marks]**

b. Find the initial height $h_{building}$ from which the ball was thrown. **[2 marks]**

c. The maximum height h_{Max} above ground that the ball reaches is given by

$$h_{Max} = \frac{u_y^2}{k} + h_{building}$$

where u_y is the initial vertical velocity with which the ball was projected.

(i) If the equation is homogenously correct, derive the units of k. **[2 marks]**

(ii) Show that $k = 2g$ and hence determine the maximum height reached by the ball. **[4 marks]**

d. Sketch a graph that shows how the vertical velocity of the ball changes with time from when it is projected until it hits the ground. **[2 marks]**

Question 3

A stuntman of mass 55 kg goes through a loop-the-loop of radius 7 m while skating on a frictionless ramp. At point A, he just makes contact with the track. Point C is the centre of the circular loop.

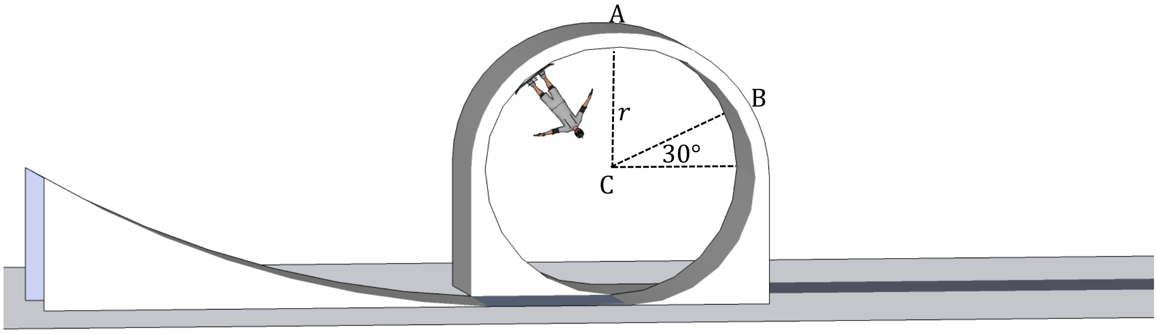

Figure 3

a. Calculate his velocity at point A. **[3 marks]**

b. Find his total energy at the same point. **[3 marks]**

c. Sketch a free body diagram showing the forces acting on the stuntman when he reaches point B. Point B subtends an angle of 30° with the horizontal. **[3 marks]**

d. Calculate his kinetic energy at point B, if his total energy is constant. **[3 marks]**

Question 4

A model aeroplane of mass 0.56 kg, flies in a horizontal circular path of radius 60 m at a height of 24 m above the ground. The lift on the aeroplane is the reaction of the air that is diverted downwards by the action of its wings. This is equivalent to the force created by the air pressure difference between the upper and lower sides of the wings. To keep moving in a circular path, it has to bank at an angle θ of 15° as shown in the diagram of Figure 4.

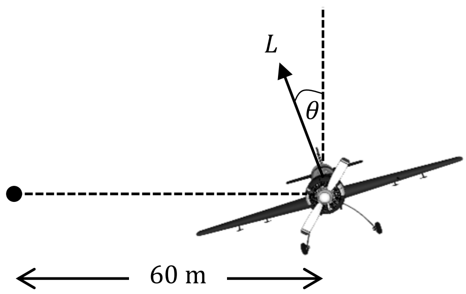

Figure 4

a. Sketch a diagram showing all the forces acting on the aeroplane. **[2 marks]**

b. Calculate its angular speed ω. **[3 marks]**

c. Find the time taken by the aeroplane to complete one circle. **[2 marks]**

d. Find the difference in pressure between the upper and lower surface of the wings, if each has an area of $1.58\ \mathrm{m}^2$. **[3 marks]**

e. During its flight, the model aeroplane develops a fault and glides downwards along the same circular path. Assuming a constant vertical descent velocity of $0.2\ \mathrm{m\ s^{-1}}$, how many complete circles does it make before it crashes? **[2 marks]**

Question 5

a.
 (i) State the conditions which an object must obey when in a state of static equilibrium. **[2 marks]**
 (ii) If only three coplanar, non-parallel forces act on an object in equilibrium, why do the lines of action of the three forces have to pass through a single point? **[2 marks]**

b. A uniform ladder AB of mass 18 kg, rests against a smooth vertical wall and on rough horizontal ground. Its top B rests 5.5 m above the ground, while its foot A rests 1.8 m from the wall.
 (i) On a diagram, draw all the forces acting on the ladder, showing clearly the line of action of the reaction at the ground. **[4 marks]**
 (ii) A cat of mass 2 kg climbs the ladder up to a height of 2 m vertically above the ground. Readjusting the forces in your diagram, calculate the magnitude and direction of the reaction at the foot of the ladder. **[6 marks]**

Question 6

a. Describe how the energy levels of silicon atoms give rise to the formation of bands when this substance is in the form of a crystalline solid. **[2 marks]**

b. What is the difference, where applicable, in position and width of the valence band, the conduction band and the forbidden band in an insulator, in a semiconductor and in a metallic conductor? **[6 marks]**

c. State the difference in electron population in the above bands in an insulator, a semiconductor and a metallic conductor. **[3 marks]**

d. How does a rise in temperature affect the above populations? **[1 mark]**

e. What is the difference between an intrinsic and an extrinsic semiconductor? **[2 marks]**

Question 7

a. Define temperature coefficient of resistance. **[2 marks]**

b. An analogue milliammeter has a coil resistance of 20 Ω and a full scale deflection (f.s.d.) of 5 mA. It is to be converted into an ammeter with f.s.d. of 5 A.
 (i) Draw a circuit showing how a resistor R can be connected to the millammeter so as to affect this change. **[2 marks]**
 (ii) Calculate the value of this resistor, correct to 4 significant figures. **[3 marks]**

c. This resistor R consists of a resistance wire having a temperature coefficient of resistance of $0.00040°C^{-1}$. The resistance wire has a correct value for the ammeter conversion when at a temperature of 0°C.
   (i) If the temperature rises from 0°C to 20°C, what would the conversion resistance value become? **[2 marks]**
   (ii) Assuming that the resistance of the milliammeter coil does not change with temperature, what current would the ammeter actually be reading at f.s.d.? **[4 marks]**

Question 8

Figure 5 shows the energy levels in electron volts (eV) of an isolated hydrogen atom.

a. With reference to these energy levels, explain what is meant by:
   (i) ground level; **[1 mark]**
   (ii) ionisation level. **[1 mark]**

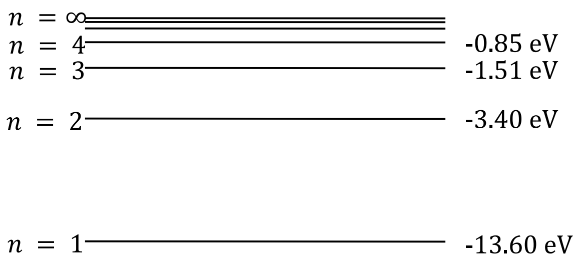

Figure 5

b. An electron which lies in level $n = 3$ moves to level $n = 1$.
   (i) Does this electron receive or emit energy? Explain why. **[2 marks]**
   (ii) Work out in Joules, the change in energy during this transition. **[2 marks]**
   (iii) Calculate the wavelength of the light emitted or absorbed during this change. **[2 marks]**

c. Some solitary electrons belonging to a group of hydrogen atoms existing as a rarified gas, lie in level $n = 4$. Explain why a series of six lines in a spectrum can be produced when energy is absorbed or emitted by these hydrogen atoms. **[3 marks]**

<u>Section B</u>

Attempt any <u>four</u> questions from this section. Each question carries 25 marks. This section carries 50% of the total marks for this paper.

Question 9

a.
   (i) State Newton's third law of motion. **[2 marks]**
   (ii) Give TWO examples of third law pairs of forces. **[4 marks]**

b.
   (i) State the law of conservation of linear momentum. **[3 marks]**
   (ii) Using Newton's laws of motion, deduce the law of conservation of linear momentum. **[5 marks]**

c. A platform suspended from a rope passing over a pulley, is used by a man to paint the front of his house. The mass of the painter is 80 kg, while that of the platform is 25 kg. When the painter pulls on the rope producing a tension T, his reaction on the floor of the platform is R, while the acceleration upwards of the man and the platform is 0.8 m s^{-2}.

(i) Sketch TWO free body force diagrams, one for the painter and another for the platform, to show the forces acting on each. **[4 marks]**

(ii) Find the value of the tension T, in the rope. **[5 marks]**

(iii) Calculate the reaction R of the platform on the man. **[2 marks]**

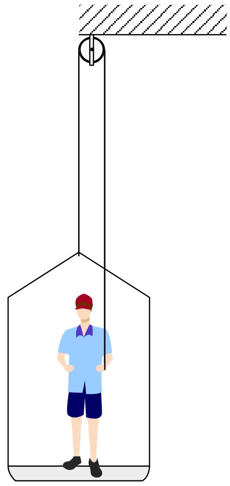

Figure 6

Question 10

a. A car of mass m goes round a circular track of radius r. The resultant reactions of the wheels with the ground are R_1 and R_2, while the frictional forces at the wheels are F_1 and F_2. The distance between the wheels is $2a$, while the height of the centre of gravity above the ground is h.

(i) Derive equations linking the reactions with the weight and the frictional forces with the centripetal force. **[4 marks]**

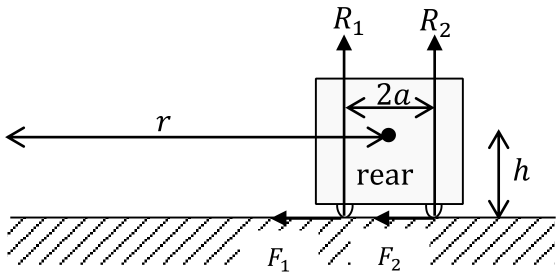

Figure 7

(ii) Taking moments about the centre of gravity, obtain a relation linking the frictional forces with the reactions. **[3 marks]**

(iii) Derive an expression for R_1 in terms of the speed of the car, and hence derive the condition if the car is not to overturn outwards. **[5 marks]**

b. A smooth object A of mass 0.25 g, moves in a horizontal circle of radius r, on the inside of a smooth hemispherical bowl of radius R, equal to 30 cm. The angle θ between the radius R of the bowl and the radius r of the circular path, is 15°.

(i) Draw a free body diagram of the forces acting on object A. **[2 marks]**

(ii) Calculate the value of the reaction of the bowl surface on the object. **[3 marks]**

(iii) Find the radius of the horizontal circle performed by the object. **[2 marks]**

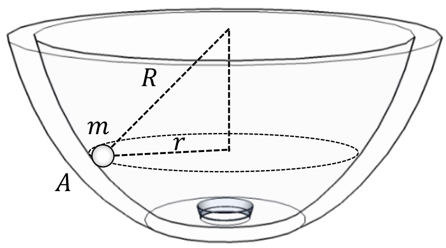

Figure 8

(iv) Calculate the tangential velocity of the object. **[3 marks]**

(v) Find the value of the centripetal force. **[3 marks]**

Question 11

a.

(i) Define angular momentum. **[2 marks]**

(ii) State the law of conservation of angular momentum. **[3 marks]**

(iii) Explain how a diver can make use of this law, to perform more somersaults while diving. **[4 marks]**

b. A flywheel and axle mounted on frictionless bearings, have a moment of inertia of 5×10^{-4} kg m^2. They are set rotating from rest by applying a constant force F of 1.70 N to a string wound on the axle. The axle has a diameter of 1 cm.
   (i) Find the angular acceleration of the system. **[3 marks]**
   (ii) Calculate the linear acceleration of the string. **[2 marks]**
   (iii) If after some time its angular velocity is found to be 82.5 rad s^{-1}, work out the length of string that has been unwound from the axle. **[4 marks]**
   (iv) After unwinding this length of string, the tension is removed. What is the value of the opposing couple that should be applied to stop the rotation after 1.5 turns. **[3 marks]**
   (v) Instead of applying a tension to the string, a mass m was suspended from it, to produce the same rotation. Draw a free body force diagram of the suspended mass, showing also any acceleration produced. Calculate the value of this mass to 3 decimal places. **[4 marks]**

Question 12

a.
   (i) State Hooke's law for a long thin wire. **[1 mark]**
   (ii) Define Young's modulus of elasticity. **[1 mark]**
   (iii) Explain how Young's modulus of elasticity can be obtained from Hooke's law. **[2 marks]**

b. Sketch a graph of force F against extension ΔL for a thin wire, naming and explaining all the stages the wire goes through, until it breaks. **[3 marks]**

c. A student obtains readings for a set of forces F, producing different extensions ΔL, in a long thin wire, loading it until it is permanently damaged. Hoping to obtain a straight line graph, he plots $\log F$ against $\log \Delta L$.
   (i) Explain why he obtains a near straight line, but not quite. **[1 mark]**
   (ii) How can he still obtain a value for Young's modulus from his graph? **[2 marks]**

d. State ONE precaution for each of the following sources of error:
   (i) decrease extension errors as much as possible; **[2 marks]**
   (ii) avoid errors due to almost invisible kinks in the wire; **[2 marks]**
   (iii) eliminate errors due to changes in temperature; **[2 marks]**
   (iv) eliminate errors due to the yielding of the support from which the wire is suspended. **[2 marks]**

e. A rubber catapult of length 29.3 cm with a Young's modulus of 9.2×10^8 Pa, is used to project vertically upwards a stone of mass 240 g. The cross-sectional area of the cord of the catapult is 1.75×10^{-5} m^2. The catapult extension is directly proportional to its tension, and the stone projected from it reaches a height of 24.6 m.
   (i) What is the stone's initial kinetic energy? **[2 marks]**
   (ii) Calculate its initial velocity. **[2 marks]**
   (iii) What is the extension of the catapult cord if 20% of its energy is lost as heat? **[3 marks]**

Question 13

a. Four identical filament lamps are connected in two different circuits as shown in the diagrams of Figure 9. The circuits use identical batteries.
   (i) Rank the brightness of the bulbs. **[3 marks]**

(ii) What happens to the brightness of bulb B if bulb A is replaced by a wire? **[2 marks]**

(iii) What happens to the brightness of bulb C if bulb D is removed from the circuit? **[2 marks]**

(iv) Why is it more likely for any one of the filament lamps to burn out just after they are switched on and not when they have been on for a while? **[2 marks]**

b. A p.d. is applied across a wire of cross-sectional area A and number of free electrons per unit volume n, each carrying a charge e. When the p.d. is applied, the electrons move with a velocity v. Show that the charge Q, crossing a plane perpendicular to the wire in time Δt, is given by $Q = nAve\Delta t$ **[4 marks]**

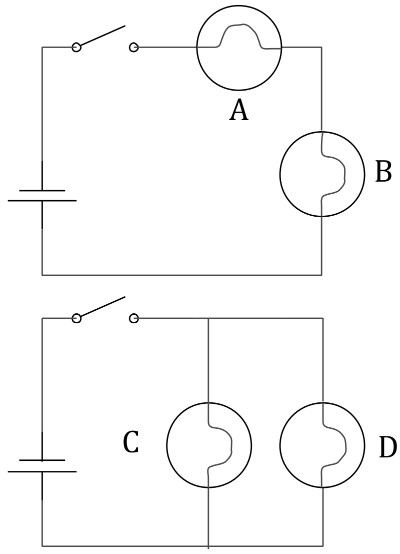

Figure 9

c. A battery is connected across a uniform resistance wire AB, which is 1 m long. The e.m.f. of the battery is only known approximately.

(i) How can the potential drop per cm of wire AB, be found accurately? Your answer should include a list of any additional apparatus needed, a circuit diagram and a description of the procedure to follow. **[5 marks]**

After completing the experiment it is found that the p.d. drop per cm of wire AB is 0.022 V cm^{-1}.

A cell of e.m.f. 1.10 V and internal resistance 1.38 Ω, is connected in series with a resistance R of 15 Ω. The p.d. across the external resistance R is balanced across part of the wire AB.

(ii) Draw a circuit showing how it is set up to be balanced, taking care to connect the correct polarities. **[4 marks]**

(iii) Across what length of wire AB is it balanced? **[3 marks]**

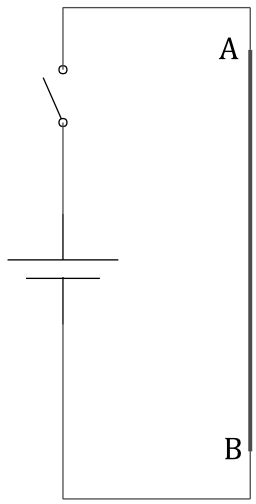

Figure 10

Question 14

a.

(i) State Kirchhoff's laws of electric currents. **[4 marks]**

(ii) Show how each of Kirchhoff's laws implies a conservation law. **[6 marks]**

b. Cells A and B are connected in parallel as shown in the accompanying circuit. Cell P has an e.m.f. of 2 V and an internal resistance of 0.5 Ω , while cell Q has an emf of 1.4 V and an internal resistance of 1.2 Ω. Their terminals are connected in series with resistor R_1 of 2 Ω and two parallel resistors R_2 of 4 Ω and R_3 of 8 Ω as shown in the diagram.

(i) Redraw the circuit, replacing resistors R_2 and R_3 with a single equivalent resistor, giving its value. **[3 marks]**

(ii) Calculate the currents flowing through R_1, R_2 and R_3. **[9 marks]**

(iii) Calculate the powers dissipated in each of these resistors. **[3 marks]**

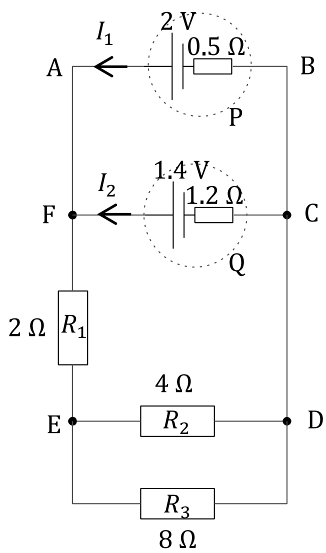

Figure 11

Question 15

a.

(i) Explain what is meant by *nucleon number, atomic number*, *isotopes* and *half-life*. **[4 marks]**

(ii) Explain how to change from unified mass constant u to kilograms, giving a scientific reason for each step in the explanation. **[2 marks]**

b.

(i) What is meant by half-value thickness of a material, when a homogeneous beam of gamma rays is transmitted through it? **[2 marks]**

(ii) Starting with the relationship between the γ-count rate and the linear absorption coefficient μ for a material, obtain a relationship between the half-value thickness of the material through which the γ rays are being transmitted, and the linear absorption coefficient μ. **[4 marks]**

c. Describe an experiment used to find the half-life of radon gas. A labelled diagram of the apparatus, an explanation of the method used and the theory of how the half-life is found, are expected. **[9 marks]**

d. The half-life period of Radium-B is 27 minutes.

(i) What is the value of the disintegration constant of this element? **[2 marks]**

(ii) How long will it take for $\frac{9}{10}$ of the original number of atoms to decay? **[2 marks]**

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Section A

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Question 1

A 100 g copper block at 100°C is immersed in 200 cm^3 of water at 20°C. A student explains what happens, in terms of energy, in these words:
The heat inside the block is greater than that inside the water so that the extra internal energy flows from the block to the water until the internal energy of the block and the water are the same.

a. Correct this statement using the terms *temperature* and *heat*. **[3 marks]**

b. The specific heat capacity of water is about 10 times that of copper. What is the final temperature of the water and block? **[5 marks]**

c. In practice, the final temperature will be different from that calculated. Explain why. **[2 marks]**

Question 2

A mass M of gas (assumed to behave like an ideal gas) at a temperature T is enclosed in a thin metal cylinder fitted with a light, frictionless piston. The gas is compressed by pushing the piston very slowly inwards, such that the compression is an isothermal process.

a. Sketch a pressure-volume diagram for the compression. Label your graph (A). **[2 marks]**

b. Write down the equation relating pressure P and volume V for the compression. **[1 mark]**

c. On the same $P-V$ axes, sketch graphs to show how the volume varies with pressure when:
   (i) the compression takes place at temperature $2T$; Label your graph (B). **[2 marks]**
   (ii) the mass of gas at temperature T in the cylinder is reduced to $\frac{M}{2}$; Label your graph (C). **[2 marks]**

d. Explain carefully why no $P-V$ diagram can be drawn for the gas if the compression takes place very rapidly. **[3 marks]**

e. During the compression, whether slow or rapid, work is done on the gas. Explain in both cases what happens to the energy so expended. **[4 marks]**

Question 3

In the circuit shown below, the capacitors are fully charged sometime after closing switch S.

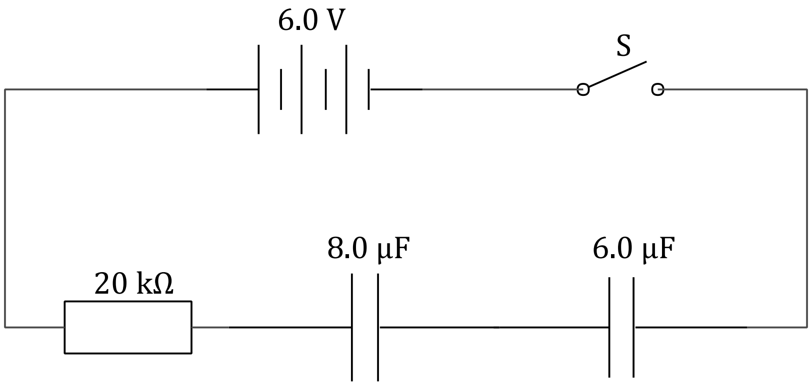

Figure 1

a. How can you deduce that the capacitors carry equal charges when fully charged? **[3 marks]**

b. What is the charge on each capacitor when fully charged? **[3 marks]**

c. What is the work done by the battery while charging the capacitors? **[2 marks]**

d. What is the energy stored in each capacitor when fully charged? **[4 marks]**

e. Why is the total energy stored in the capacitors less than the work done by the battery in charging the capacitors? **[1 mark]**

Question 4

a. What conditions must be met for a ray of light to be totally internally reflected at the boundary between two transparent media? **[2 marks]**

b. OP is a ray of light made up of red and blue light. The angle of incidence at point *P* on the water-air boundary is 48.0°. The refractive indices of water for red and blue light are 1.340 and 1.352 respectively.

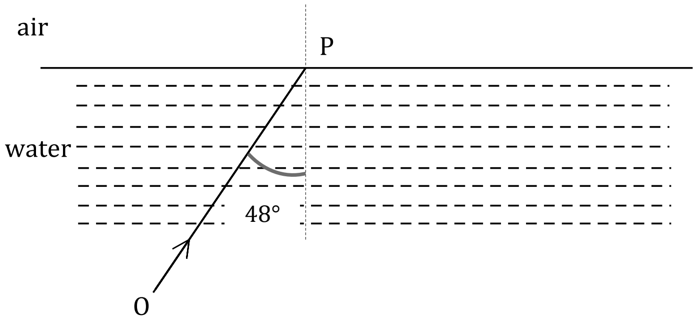

Figure 2

(i) Show the necessary calculations to find out what happens to the light at *P*. **[8 marks]**

(ii) Which of velocity, frequency and wavelength of light change/s as it travels from water to air? **[3 marks]**

Question 5

In an investigation of the properties of *transverse, stationary* waves, one end of a rubber cord is attached to a vibrator, the frequency of which can be varied. The other end of the rubber cord is attached to a rigid support.

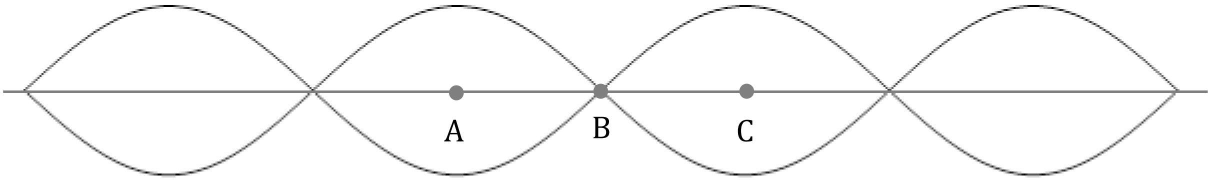

Figure 3

The diagram shows the cord vibrating in one of its harmonics.

a. Explain the terms *transverse* and *stationary.* **[2 marks]**

b. Describe how the stationary wave is formed in the rubber cord. **[5 marks]**

c. Describe the motion of the cord at each of the points A, B, and C emphasizing any differences. **[5 marks]**

Question 6

A signal generator is connected across a capacitor C and an inductor L as shown in Figure 4. The voltage output of the generator is kept constant, but the frequency is increased from a low value.

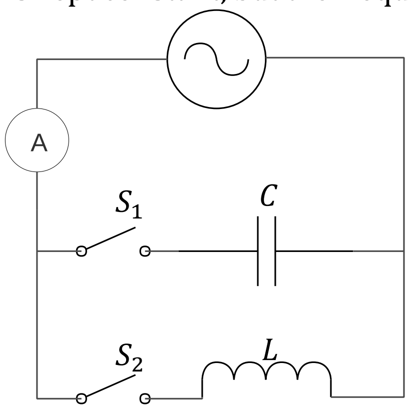

Figure 4

a. When the switch S_1 is closed the ammeter registers a current. Does current flow between the plates of the capacitor? **[1 mark]**

b. What changes take place inside the capacitor as the alternating current flows in the circuit? **[3 marks]**

c. Write down an equation for:
   (i) the capacitive reactance of the capacitor;
   (ii) the inductive reactance of the inductor;
   (iii) the current through C when only switch S_1 is closed;
   (iv) the current through L when only switch S_2 is closed. **[4 marks]**

d. Sketch graphs on the same axes to show how you would expect the voltages V_C and V_L to change as the frequency is increased when S_1 and S_2 are closed one at a time. **[4 marks]**

Question 7

A child's swing consists of a seat of mass 2.00 kg suspended by four ropes from two fixed supports. The ropes have negligible mass. When the empty seat is pulled back slightly from its rest position and released, it oscillates with simple harmonic motion.

a. What conditions must be obeyed in order for a body to perform simple harmonic motion? **[2 marks]**

b. The acceleration-time graph for the seat is shown in Figure 5.

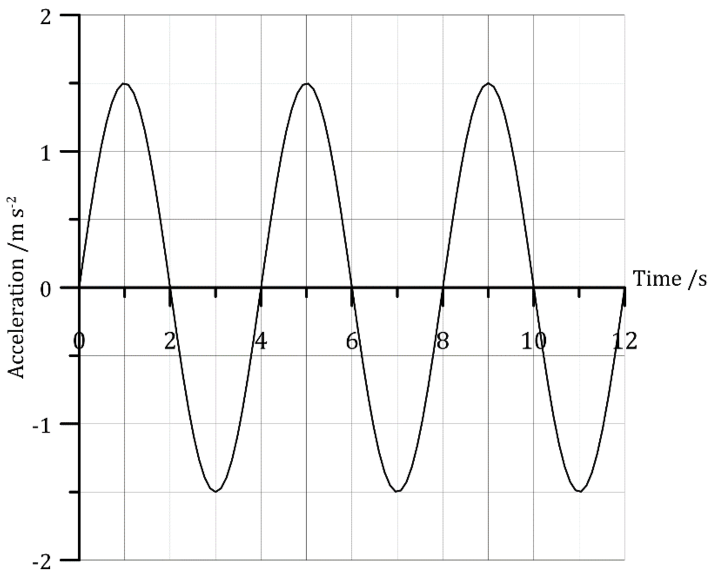

Figure 5

Use the graph to obtain

(i) the period; **[1 mark]**

(ii) the amplitude; **[3 marks]**

(iii) the maximum velocity; **[2 marks]**

(iv) the maximum restoring force; **[2 marks]**

(v) the energy of the seat assuming there are no energy losses. **[2 marks]**

Question 8

In 1929, Edwin Hubble discovered that the velocity, v, of nearby galaxies is proportional to their distance, D, from us. He estimated the constant of proportionality, H_0, between v and D to be $16 \times 10^{-18}\ \mathrm{s}^{-1}$. A modern value for H_0 is $2.17 \times 10^{-18}\ \mathrm{s}^{-1}$.

a.

(i) Which of v and D produced the greater uncertainty in Hubble's measurements? **[1 mark]**

(ii) Write down an equation relating v and D, and hence show that the age of the Universe is given by $\frac{1}{H_o}$. **[3 marks]**

(iii) What is the main assumption underlying your equation? **[2 marks]**

(iv) What is the age of the Universe, in billions of years, (A) according to Hubble and (B) according to the modern value of H_0? **[4 marks]**

b. The expansion of the Universe is one piece of evidence for the Big Bang theory. What is the other main source of backing for this theory? Explain how this experimental evidence backs the Big Bang theory. **[4 marks]**

Section B

Attempt any four questions from this section. Each question carries 25 marks. This section carries 50% of the total marks for this paper.

Question 9

The diagram in Figure 6 shows an apparatus used to determine the thermal conductivity of a plastic in the form of a sheet (C and C′) about 2 mm thick.

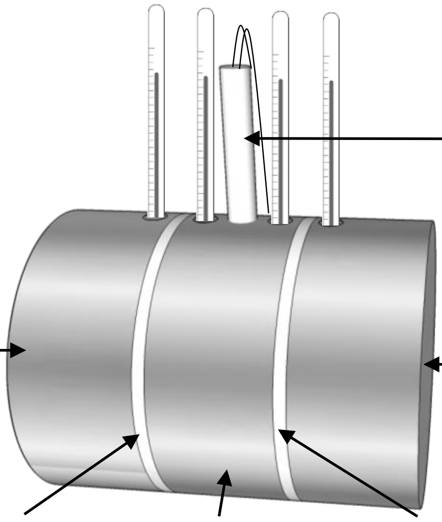

Figure 6

A, B and B′ are cylindrical copper blocks about 10 cm in diameter and about 2 cm thick. An electrical heater of known power P is embedded in block A. Blocks B and B' have the same dimensions. T_1, T_2, T_3, T_4 are thermometers which measure the temperatures of the two faces of each of the plastic sheets.

a. Describe how you would expect the readings of one pair of thermometers such as T_1 and T_2 to change with time after the heater is switched on. **[3 marks]**

b. Sketch graphs of temperature against time for both thermometers as part of your answer. **[2 marks]**

c. Write down an equation for the rate of flow of heat through the sheet C when steady conditions are reached. **[1 mark]**

d. Give the meaning and units of each of the symbols in your equation. Give the physical meaning of the negative sign which should appear in your equation. **[8 marks]**

e. A student took the following readings after steady conditions were reached:
Power of heater $P = 100$ W;
Temperature shown by $T_1 = 52.3$°C;
Temperature shown by $T_2 = 74.0$°C;
Temperature shown by $T_3 = 73.2$°C ;
Temperature shown by $T_4 = 54.5$°C ;
Thickness of each plastic sheet = 2.5 mm;
Diameter of each plastic sheet= 10.5 cm.

(i) Calculate an average value for the thermal conductivity of the plastic sheet. **[6 marks]**

(ii) Why do the thermometers T_1 and T_4, T_2 and T_3 show slightly different temperatures? **[4 marks]**

(iii) The plastic sheets are smeared with a light oil before being placed in position between the copper blocks. Why? **[1 mark]**

Question 10

a. The pressure, P, of a *mole* of *ideal* gas is given by the equation

$$P = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$$

where N is the Avogadro Number, V is the volume of one mole of the gas, m is the mass of each molecule, and $\langle c^2\rangle$ is the *mean square speed* of the gas.

(i) What is the meaning of the terms: *mole, ideal gas,* and *mean square speed?* **[4 marks]**

(ii) Show that the internal energy of a mole of an ideal gas is given by

$$U = \frac{3}{2}PV$$

[3 marks]

(iii) Hence, use the ideal gas equation to prove that the internal energy of an ideal gas is proportional to the temperature. **[2 marks]**

(iv) Explain why the internal energy of *real* gases is not proportional to the temperature. **[2 marks]**

b. The diagram in Figure 7 shows a container composed of two compartments of equal volume. One of the compartments contains one mole of hydrogen at 300 K while the other is filled with one mole of helium at 500 K. Assume that both gases are ideal gases.

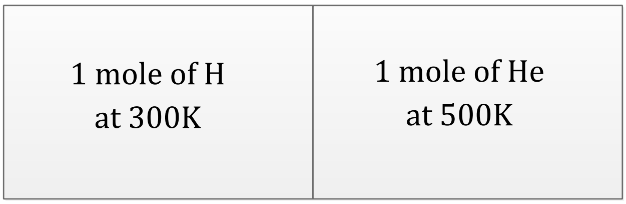

Figure 7

(i) Calculate the mean kinetic energy of the molecules of each gas. **[6 marks]**

(ii) Calculate the r.m.s. speed of the molecules of each gas; **[6 marks]**

(iii) If the partition separating the two gases is removed so that the two gases mix, explain what happens to the mean kinetic energy of each gas after equilibrium has been reached. **[2 marks]**

(Mass of a hydrogen molecule $= 3.35 \times 10^{-27}$kg, Mass of helium atom $= 6.70 \times 10^{-27}$kg)

Question 11

a. A satellite of mass m is orbiting the Earth in a circular orbit of radius R.

(i) Write down an equation for the gravitational force acting on the satellite, taking the mass of the Earth to be M. **[1 mark]**

(ii) What are the assumptions that enabled you to write down your equation? **[2 marks]**

(iii) Obtain an expression for the tangential velocity, v_{orb}, of the satellite. **[2 marks]**

b. Sketch a graph to show how the gravitational force, F, acting on the satellite changes with distance, r, from the Earth's centre. Start your graph at $r = R_E$ where R_E is the radius of the Earth. **[3 marks]**

c. The area enclosed by your graph in part (b), the distance axis, and the lines $r = R_E$ and $r = \infty$ is given by $W = -\frac{GMm}{R_E}$.

(i) What does this area represent? **[2 marks]**
(ii) Why does W have a negative value? **[2 marks]**
(iii) Write down an equation for the gravitational potential at the Earth's surface. **[1 mark]**
(iv) Derive an equation for the escape velocity, v_{esc}, of the satellite assuming it starts its journey on the Earth's surface. **[4 marks]**
(v) The escape velocity is greater than the orbital velocity. What is the significance of this fact? **[2 marks]**
(vi) Calculate the escape velocity of the Moon given that distance of the Moon from Earth is 3.80×10^8 m. **[6 marks]**

Question 12

a. Two long, parallel, vertical, straight, conductors, X and Y, carrying currents of 10 A and 20 A downwards, are passed through a horizontal board. The wires are separated by a distance of 20.0 cm.

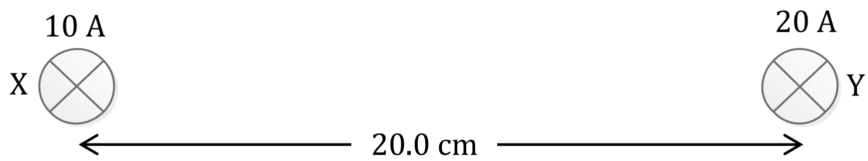

Figure 8

In all questions below neglect the effect of the Earth's magnetic field.

(i) Copy the diagram and use it to describe the behaviour of a compass needle as it is moved gradually along the line joining the conductors. **[4 marks]**
(ii) In what ways is a magnetic flux line different from an electric flux line? **[2 marks]**
(iii) The magnetic flux density B at a point in the magnetic field distant r metres away from a long straight conductor carrying a current I A is given by the equation

$$B = \frac{\mu_o}{2\pi r} I$$

Calculate the distance from wire X of the neutral point formed between the conductors. **[4 marks]**
(iv) Calculate the force per metre acting on the conductor X due to the current in Y. **[4 marks]**
(v) What is the corresponding force on one metre of Y? **[2 marks]**
(vi) Give the direction of each of the forces. **[2 marks]**

b. A child sleeps at a distance of 30 cm from the household wiring which carries 3.6 kW of power at 240 V r.m.s.

(i) What is the maximum flux density at the position of the child? **[5 marks]**
(ii) Why may the magnetic field due to the household wiring affect the health of the child more than the Earth's magnetic field? **[2 marks]**

Please turn the page.

Question 13

a. State Faraday's and Lenz's laws of electromagnetic induction. **[4 marks]**

b. A short bar magnet NS moves downwards with constant velocity along the axis of a thick copper ring as shown in Figure 9.

(i) Explain why a current is induced in the ring as the magnet passes through it. **[3 marks]**

(ii) Sketch a graph to show how the induced current in the ring changes as the magnet moves from a point well above the ring to a point well below it. (Assume that a clockwise current as seen from above the ring is counted as positive.) **[6 marks]**

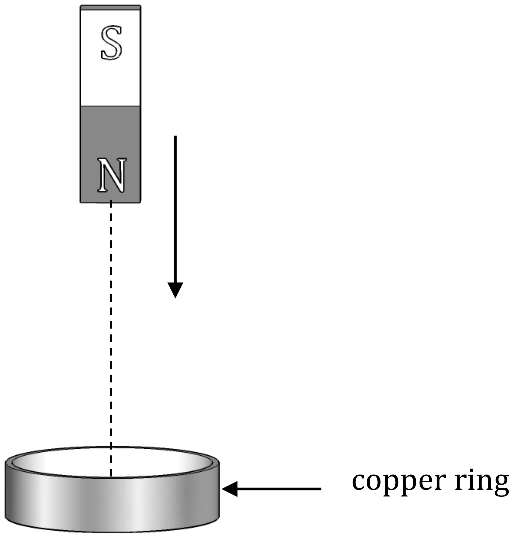

Figure 9

c. An iron-cored coil of low resistance wire is connected across a 12 V battery. A high resistance 24 V filament lamp is then connected across the iron-cored coil as shown in the circuit diagram of Figure 10.

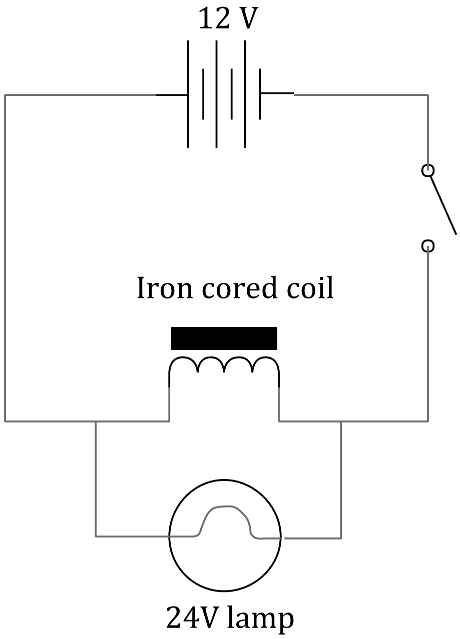

Figure 10

(i) Explain why the current in the coil does not instantaneously reach a steady value when the switch is closed. **[2 marks]**

(ii) If the self-inductance of the coil is 2.0 H, what is the initial rate of increase of current in the coil? **[2 marks]**

(iii) Why is the initial rate of increase of current independent of the resistance of the coil? **[2 marks]**

(iv) Describe and explain what will be observed if, after a steady current is reached, the switch is suddenly opened. **[5 marks]**

(v) Why is an iron-cored coil used in this experiment? **[1 mark]**

Question 14

a. A helium-neon laser produces a beam of coherent red light. What are the main differences between *ordinary light* and *coherent light*? **[4 marks]**

b. A student directs this laser beam onto a double slit arrangement as shown in Figure 11.

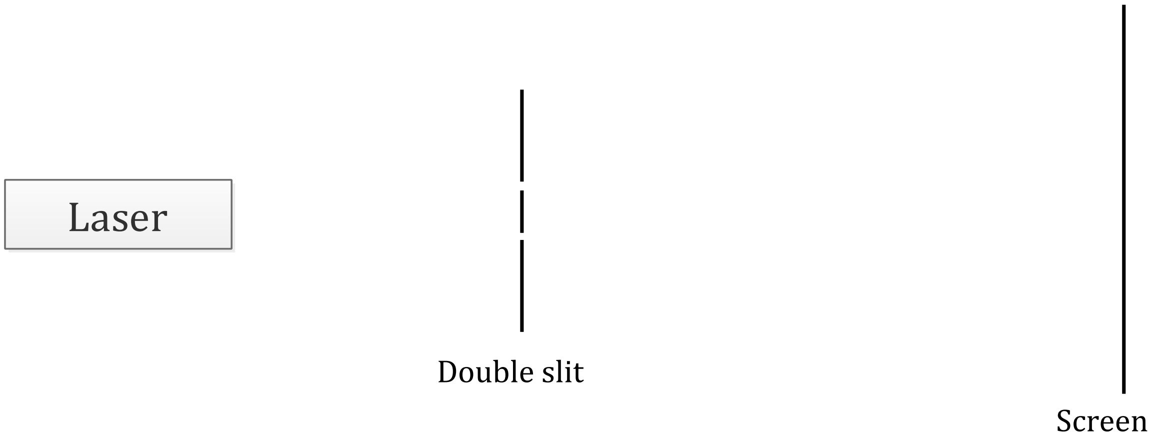

Figure 11

(i) A pattern of bright red fringes is observed on the screen. Explain, in terms of waves, why bright fringes are produced. **[4 marks]**

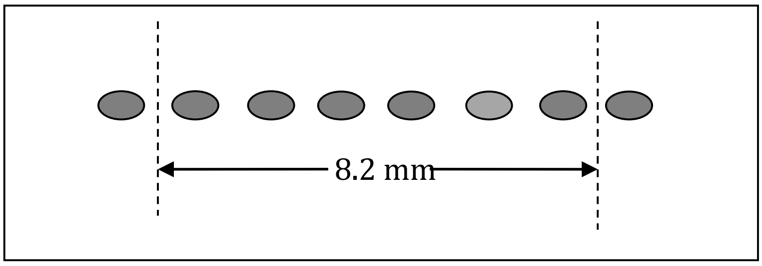

Figure 12

(ii) The diagram in Figure 12 shows the value measured by the student of the distance between a series of fringes. He also measures the distance between the double slit and the screen as 0.750 m. Calculate the distance between the slits if the wavelength of the light used is 633 nm. **[4 marks]**

(iii) The student wishes to determine the distance between the slits more precisely. Which of the student's measurements should be taken more precisely in order to achieve this? Explain your answer. **[3 marks]**

(iv) The helium-neon laser is replaced by a laser which emits green light. There are no further changes in the apparatus. Explain the effect which this change has on the fringes observed on the screen. **[2 marks]**

c. The laser is now replaced by a single slit and a bright filament lamp so that white light from the slit falls on the double slit.

(i) Why is it very difficult to obtain a fringe pattern on a screen when using such a source? **[2 marks]**

(ii) How is it possible to observe white light fringes in the laboratory? **[2 marks]**

(iii) Explain why only a *small number of coloured* fringes are observed on the screen. **[4 marks]**

Question 15

a. Describe how you would use a spectrometer and a diffraction grating to measure the wavelength of monochromatic light. Your description should include:
   (i) a labelled diagram of the set-up; **[2 marks]**
   (ii) a description of the procedure to follow and the measurements that need to be taken (Assume that the grating and the spectrometer have already been properly adjusted.); **[4 marks]**
   (iii) the calculations necessary to find the wavelength of monochromatic light. **[6 marks]**

b. What is the main advantage of having a grating with a large number of lines per metre? **[2 marks]**

c. In one such experiment, the monochromatic source was replaced by a white light source.
   (i) Describe the changes observed in the field of view of the spectrometer. **[4 marks]**
   (ii) What changes would be observed if now the grating was replaced by a glass prism? **[2 marks]**

d. In an experiment with a grating with 600 rulings per mm, it is found that at a diffracting angle of 54.8° a blue line and a red line coincide. If the blue wavelength is 454 nm, find the order numbers for both colours and also the red wavelength. **[5 marks]**

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD
UNIVERSITY OF MALTA, MSIDA

MATRICULATION CERTIFICATE EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2016

SUBJECT:	PHYSICS
PAPER NUMBER:	III - *Practical*
DATE:	29th August 2016
TIME:	2 hours 5 minutes

Experiment: Experiments with thermistors

Apparatus: stand and clamp, beaker, spirit lamp, liquid-in-glass thermometer, thermistor, multi-meter and stopwatch.

Important Note:

- This experiment involves high temperature flames and highly flammable substances. For this reason and at all times particular attention is needed to carry out the experiment.
- Failure to follow these instructions may incur damage to the apparatus and loss of time.

Diagram:

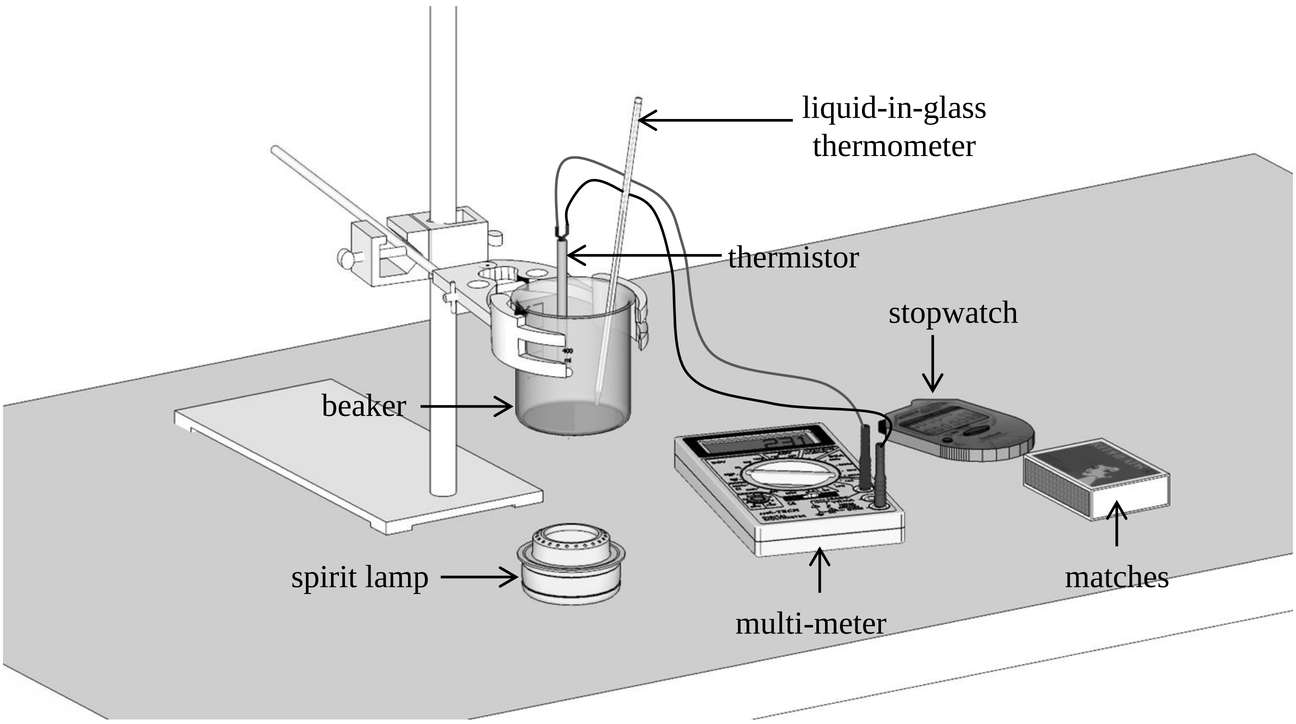

Figure 1 The experimental setup

Method – Part A:

1. The apparatus is set up for you. Make sure that you have all the apparatus that is shown in the diagram of Figure 1 and that the spirit lamp is positioned underneath the beaker.

2. The thermistor provided is a *negative temperature coefficient* thermistor. Explain what is meant by *negative temperature coefficient thermistor.*

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____ **[2 marks]**

3. A beaker with approximately 200 ml of water is clamped to the stand above the spirit lamp. Make sure that this beaker is fixed securely to the clamp. Do not tighten the clamp unless it is really necessary. Tightening the clamp too much may break the beaker.
4. A liquid-in-glass thermometer is already placed in the beaker.
5. Make sure that the thermistor is placed inside the beaker with water but it is not touching the bottom of the beaker.
6. The leads of the thermistor are connected to the multi-meter. [One of the leads should be connected to the common socket on the multi-meter and the other lead to the socket where the multi-meter can read resistance.]
7. The thermistor has a resistance R_0 equal to 10 kΩ (10 000 Ω) at a temperature T_0 of 298.15 K. Set the multi-meter to read resistance in the appropriate range.
8. Record the temperature of the water in the beaker and the corresponding resistance of the thermistor in the first row of Table 1. **[2 marks]**
9. Light the spirit lamp with the matches provided paying particular attention not to get burnt. **Carefully move the spirit lamp until it is underneath the beaker**.
10. Record in Table 1, the value of resistance R of thermistor as it varies with temperature θ read from the thermometer.
11. Repeat step 10 for at least 5 other different temperature values that span at least a 30°C temperature range. **[10 marks]**
12. **Do not turn off** the spirit lamp. You will need the water to reach a steady maximum temperature for the second part of the experiment.
13. **Take out the thermistor from the beaker when you are done taking readings.**

Table 1

θ /°C	T /K	$\frac{1}{T}$ /K^{-1}	R /Ω	$\ln R$

14. Complete Table 1 by working out the absolute temperature T /K, $\frac{1}{T}$ /K^{-1} and $\ln R$.

[12 marks]

15. The relationship between the resistance R and the absolute temperature T is given by:

$$R = R_0 e^{-\beta\left(\frac{1}{T_0}-\frac{1}{T}\right)}$$

where β is a constant, R_0 is the resistance of the thermistor at temperature T_0.

16. Rearrange the equation in part (15) to show that $\ln R = \frac{\beta}{T} + K$, where $K = \ln R_0 - \frac{\beta}{T_0}$.

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____ **[5 marks]**

17. Plot a graph of $\ln R$ against $\frac{1}{T}$ and use it to determine the constant β.

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____ **[12 marks]**

DO NOT WRITE ABOVE THIS LINE

Method – Part B:

18. The thermistor should now have cooled and reached room temperature.
19. Record the resistance R_a of the thermistor at room temperature.

    $R_a =$ _______________Ω **[1 mark]**
20. The water in the beaker has now reached or nearly reached its boiling point.
21. Place the thermistor back into the beaker with water and wait till the readings on the multi-meter cease to change very rapidly. At this point, the thermistor should be in thermal equilibrium with the water inside the beaker.
22. You will now take the thermistor out of the beaker and record its resistance as it changes with time while the thermistor cools down in air. [If you do not manage to start the stopwatch exactly as you take out the thermistor from the beaker, you can restart this part of the experiment by placing the thermistor back in the boiling water, resetting the stopwatch and starting over.] You can take the first reading of resistance R at $t = 0$ s while the thermistor is still in the boiling water.
23. Record the resistance readings every 15 seconds over a period of 2 minutes. **[9 marks]**

Table 2

t /s	R /Ω	T /K	$\Delta T = T - T_a$ /K	$\ln\left(\frac{\Delta T}{T_i}\right)$
0				
15				
30				
45				
60				
75				
90				
105				
120				

24. The equation in part (16) can be rearranged to give the absolute temperature of the thermistor for a given resistance value.

$$T = \frac{\beta}{\ln R - K}$$

25. Use the equation in part (24) to work out the absolute temperatures in the column for T /K of Table 2. **[9 marks]**

26. Use again the equation in part (24) to work out the absolute temperature of the room T_a /K using the resistance value R_a that you recorded in part (19).

$T_a =$ _______________ K **[1 mark]**

27. The temperature difference ΔT, in Table 2, is the difference between the absolute temperature T of the thermistor and the room temperature T_a. Work out the values for $\Delta T\ /K$ in the appropriate column of Table 2. **[9 marks]**

28. Let T_i denote the temperature difference between the temperature of the thermistor when it was in the boiling water and the room temperature. T_i is therefore equal to ΔT when $t = 0$ s. Copy this value from Table 2 and write it down below.

$T_i =$ _______________ K **[1 mark]**

29. Complete Table 2 by working out the values for $\ln\left(\frac{\Delta T}{T_i}\right)$. **[9 marks]**

30. Newton's law of cooling states that the rate of change of temperature of a body while cooling is directly proportional to the temperature difference between the temperature of the body and its surroundings. In this context, this is given by:

$$\Delta T = T_i e^{-kt}$$

where k is a proportionality constant.

31. Rearrange the equation in part (30) in the form $y = mx + c$.

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____ **[4 marks]**

32. Plot a graph of $\ln\left(\frac{\Delta T}{T_i}\right)$ against time t and use your graph to determine a value for k.

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____ **[12 marks]**

33. State ONE source of error and ONE corresponding precaution taken during the experiment.

[2 marks]