MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2017

SUBJECT:	PHYSICS
PAPER NUMBER:	I
DATE:	4th September 2017
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.

1. a. The pressure P and the density ρ of a gas are related by the expression $P^{\frac{1}{2}} = c\sqrt{\frac{\rho}{\gamma}}$ where γ and c are constants.
   (i) Using the fundamental definitions, derive the base units of the density ρ and show that the base units of the pressure P are kg $\mathrm{m^{-1}s^{-2}}$. (2, 2)
   (ii) If γ has no unit, determine the unit of c and suggest a quantity that may be represented by c. (2)

   b. On her way back home from a bank, an elderly woman sat down to rest on a bench and placed her bag with money beside her. A robber came along, spotted her bag, and began to pull on the handle with a force of 64 N at an angle of 25° with respect to vertical. The elderly woman was not going to let go easily, so she pulled on the handle with a force F. The weight of the bag is 15 N. For a brief period of time, the bag did not move.
   i. Draw a free body diagram showing the forces acting on the bag when it was not moving.(4)
   ii. Determine the angle to the vertical at which she was pulling at the bag, when the bag was not moving. (4)

(Total: 14 marks)

2. A boy kicks a stone at an angle of 25.0° above the horizontal from the edge of the rooftop of a building. The stone hits the ground at a point that is 105 m away from the base of the building 4.20 s later. Ignore air resistance.
   a. Sketch graphs that show how the following quantities change as a function of time:
   i. horizontal distance, x; (2)
   ii. vertical distance, y; (2)
   iii. horizontal velocity, v_x; (2)
   iv. vertical velocity, v_y. (2)
   These need to be qualitatively correct. You should not put numbers on the axes.

   b. Find the initial velocity u of the stone. (2)

   c. Find the maximum height H reached by the stone. (5)

(Total: 15 marks)

3. a. A ball is dropped to the floor from a height h. When it strikes the ground, it briefly undergoes a change of shape before rebounding to a maximum height less than h.
   i. List in order the different energy transformations taking place. (3)
   ii. Explain why it does not rebound to the original height from which it was dropped. (2)

   b. Joseph is tossing an orange of mass 0.30 kg into the air. He throws the orange straight up and then catches it, at the same point in space. Ignore air resistance.
   i. What is the change in the gravitational potential energy of the orange at the end of its trajectory? Explain your answer. (2)
   ii. Joseph tosses the orange again straight up, starting 1.00 m above the ground. He fails to catch it. What is the change in the gravitational potential energy of the orange during this trajectory? (1)

(Total: 8 marks)

4. a. Explain what is meant by angular speed. (2)

   b. Derive an expression for the force required to make a particle of mass m move in a circle of radius r with uniform angular speed. (3)

   c. Christine is playing with her dolls and decides to give one of them a ride on an old record player turntable. The mass of the doll is 0.2 kg and the turntable is set to rotate at 33.3 revolutions per minute.
   i. Calculate its angular speed in radians per second. (3)
   ii. The doll is placed 13 cm from the centre of the spinning turntable platform. Determine the magnitude of the linear velocity of the doll. (2)
   iii. The force of friction that keeps the doll from slipping is 0.6 N. Calculate the maximum angular speed that the turntable can rotate at before the doll (still positioned 13 cm from the centre) starts to slip outwards. (2)

(Total: 12 marks)

5. a. Explain what is the 'centre of gravity' of a body. (2)

   b. Three forces in one plane act on a rigid body. State the conditions for static equilibrium. (4)

   c. A paint bucket of mass 20 kg sits on top of a ladder. A rope exerts horizontal forces on the ladder at each of its ends. The ladder stands on a smooth frictionless surface and it is the rope alone that keeps the ladder from sliding apart (see Figure 1). Ignoring the weight of the ladder and using the values shown in the diagram, calculate:
   i. the reaction that the ground exerts on one foot of the ladder; (2)
   ii. the tension in the rope by considering the equilibrium of one half of the ladder. (6)

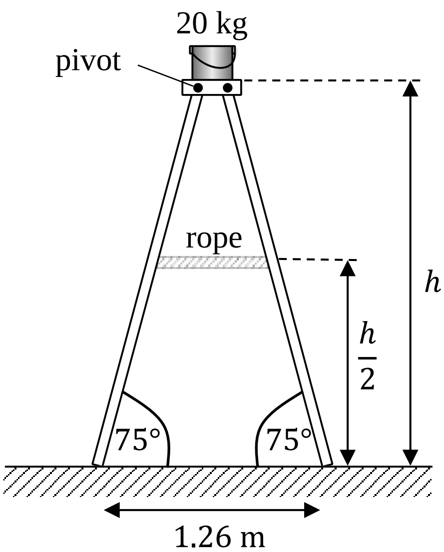

Figure 1

(Total: 14 marks)

6. a. Explain what are charge carriers and define electric current. (2, 2)

b. $I = nAvq$ is a relation that defines current flow through a conductor in terms of charge carriers.

i. State the meaning of each symbol of the equation. (4)

ii. Use the equation to explain why charges in a semiconductor travel much more quickly than in a metallic conductor of the same dimensions and with the same current in it. (2)

c. Figure 2 shows a strip of doped silicon $260\ \mu\text{m}$ wide that contains 8.8×10^{22} conduction electrons per cubic meter and an insignificant number of holes. When the strip carries a current of $130\ \mu\text{A}$, the drift speed of the electrons is $44\ \text{cm s}^{-1}$. Calculate the thickness, t, of the strip. (3)

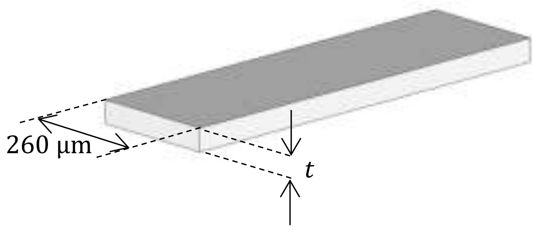

Figure 2

(Total: 13 marks)

7. a. The outer sticker on an AA sized battery (as shown in Figure 3) usually shows the typical terminal potential difference of the battery. The e.m.f of the battery and its internal resistance are not shown on the sticker. Briefly explain the terms e.m.f, internal resistance and terminal potential and how they are related to each other. (3)

Figure 3

b. Figure 4 shows a battery with e.m.f ε, internal resistance r and variable load resistance R.

i. Sketch a labelled graph that shows how terminal potential difference changes with external load resistance R. (3)

ii. Hence, use your graph to explain why a voltmeter should have a very high resistance if it is to be used to measure accurately the e.m.f of a battery. (2)

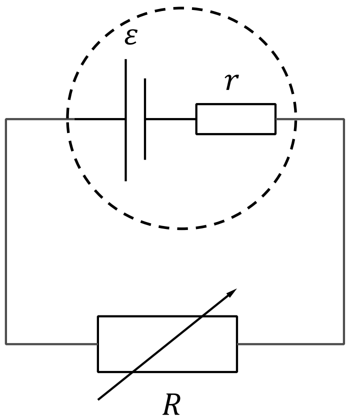

Figure 4

c. The battery in part (b) has an e.m.f. $1.5\ \text{V}$ and internal resistance $0.12\ \Omega$. It is connected to a purely resistive load of $2.0\ \Omega$. Find:

i. the terminal potential difference of the cell; (2)

ii. the efficiency of the circuit in this configuration. (2)

(Total: 12 marks)

Please turn the page

8. a. Explain the term 'nuclear binding energy'. (2)

b. Sketch a graph that shows the variation of binding energy per nucleon with mass number for naturally occurring isotopes. (4)

c. With the aid of the graph drawn in part (b), account for the possibility of energy release by nuclear fission and nuclear fusion. (2)

d. An isotope of nitrogen is $^{15}_{7}\text{N}$. The mass of the $^{15}_{7}\text{N}$ nucleus is 14.996269 u.

i. Calculate the mass difference in atomic mass units between the mass of $^{15}_{7}\text{N}$ and the total mass of its constituent particles. (2)

ii. Calculate the binding energy per nucleon of $^{15}_{7}\text{N}$ in MeV. (2)

(Total: 12 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.

9. a. A programmer designs a short video clip on two spaceships, a silver and a black spaceship. In one video scene, the two spaceships enter the screen from the left and are moving towards the right with constant accelerations. The silver spaceship starts with an initial velocity of $2.00\ \text{km s}^{-1}$ and has an acceleration of $0.40\ \text{km s}^{-2}$. The black spaceship starts with a velocity of $6.00\ \text{km s}^{-1}$and has an acceleration of $-0.40\ \text{km s}^{-2}$.

i. Determine the time at which the silver spaceship just overtakes the black spaceship. (6)

ii. On the same time axis, sketch graphs that show how the velocities of the two spaceships change with time. (4)

b. The acceleration due to gravity can be directly measured using normal lab apparatus. Describe an experiment that is used to determine the acceleration due to gravity. Your description should include:

i. a list of equipment and materials to be used;

ii. a labelled diagram of the setup;

iii. a description of the procedure to follow and the measurements that need to be taken;

iv. a table of results;

v. a sketch of the graph expected to be obtained from the results;

vi. an indication of how to determine the acceleration due to gravity. (15)

(Total: 25 marks)

10.a. State the principle of conservation of momentum. (3)

b. A student is optically tracking a deep space probe using a large telescope. He decides to use simple physics to get information about its movement. At regular 24-hour time intervals, he jots down the distance moved by the probe on a motion diagram, like the one in Figure 5.

i. Describe the motion of the deep space probe between the first reading (reading A) and the fourth reading (reading D). Explain your answer. (2)

ii. Explain how he can use the diagram to calculate the acceleration of the probe and hence calculate the acceleration of the probe. (3, 4)

iii. Explain why this method of obtaining data is likely to be highly inaccurate. (2)

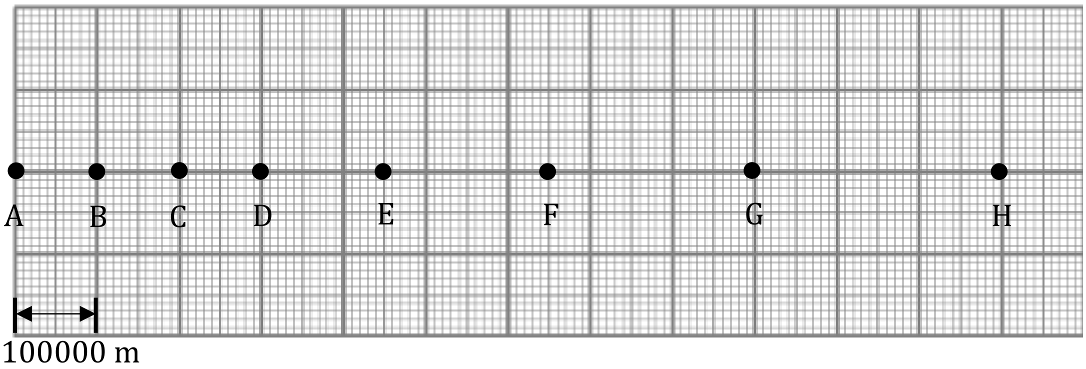

Figure 5

c. A deep space probe, like the one in Figure 6, carries a module that can be ejected from it by a small explosion. The space probe of total mass 500 kg is travelling in deep space at 160 m s^{-1} when it detonates the explosion to release the module of mass 150 kg. Immediately after the explosion, the probe, now of mass 350 kg, continues to travel in the original straight line but at a speed of 240 m s^{-1}.

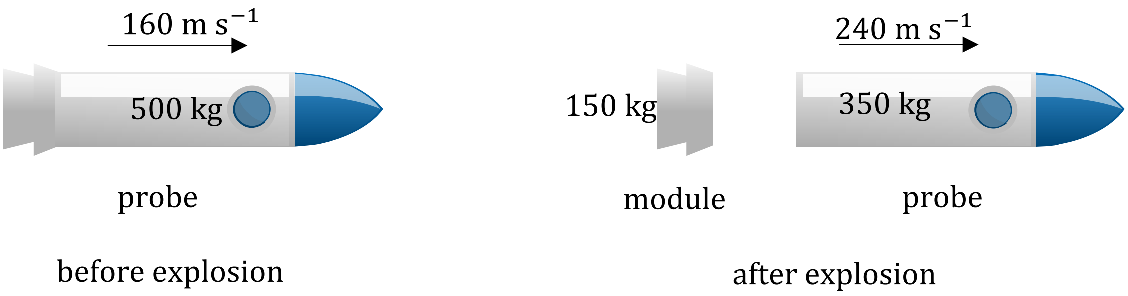

Figure 6

i. Discuss how the principles of conservation of momentum and conservation of energy apply in this instance. (4)

ii. Calculate the magnitude of the velocity of the capsule immediately after the explosion and state its direction of movement. (3)

iii. Determine the total amount of energy given to the probe and capsule by the explosion. (4)

(Total: 25 marks)

11.a. Explain the term 'moment of inertia' when referring to a rigid body rotating about a fixed axis. (3)

b. A fidget spinner of known moment of inertia, I, is free to rotate about a vertical axle, as shown in Figure 7. The spinner is given a light tangential hit such that it starts spinning and then left to rotate freely until it stops. Describe a method of finding the opposing frictional couple, assuming it to be constant. Your description should include:

i. a description of the procedure to follow that includes a list of the measurements that need to be taken; (3)

ii. the calculations necessary to determine the frictional couple. (5)

Figure 7

c. A space station shaped like a giant wheel, similar to the one in Figure 8, has a radius of 100 m and a moment of inertia of 5.00×10^8 kgm^2. A crew of 150, lives on the rim and the station is rotating. When 100 people move to the centre of the station for a union meeting, the angular speed changes. Assume the average mass of a crew member is 65.0 kg.

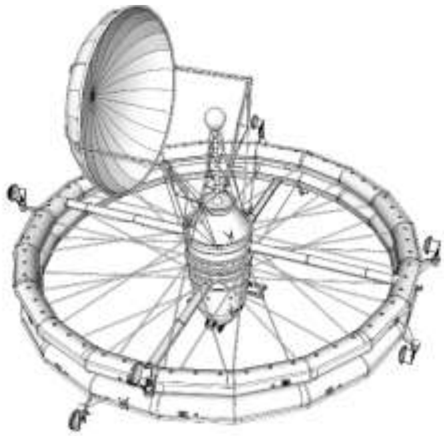

Figure 8

i. Determine the average centripetal force that one crew member experiences. (3)

ii. Calculate the angular speed of the space station before the crew move in for the meeting. (2)

iii. Calculate the new moment of inertia of the space station when the 100 crew members move to the centre of the space station for the meeting. (5)

iv. Determine the new angular speed of the space station. State any principle that you made use of in arriving at your answer. (4)

(Total: 25 marks)

12.a. Define tensile stress, tensile strain and Young modulus. (2, 2, 2)

b. Explain why the quantities, listed in part (a), are more useful than force and extension for a description of the elastic properties of matter. (3)

c. Figure 9 shows the variation of F, the load applied to two wires X and Y, and their extension e. The wires are made of iron and have the same initial length.

i. Which wire has the smaller cross-section? Explain. (3)

ii. Explain how the graph for X can be used to obtain a value for the Young modulus of iron. List the additional measurements that are needed. (6)

iii. Name the physical quantity that can be determined from the area under graph Y. (1)

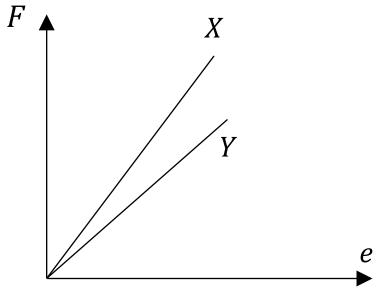

Figure 9

d. A cylindrical brass rod of length 70 cm is positioned vertically on one of its ends. A mass of 15 kg is placed on the top end. The radius of the rod is 1.5 cm and the Young modulus of brass is 3.5×10^{10} Pa. Determine:

i. the contraction of the rod under load; (3)

ii. the energy stored in it. (3)

(Total: 25 marks)

13.a. Describe a model for conduction in a metal. Your description should include:

i. reference to the behaviour of charge carriers in a metal with and without the influence of a potential difference applied across the metal, and; (4)

ii. a labelled diagram of a metal bar across which a potential difference is applied, showing the direction of the electric field, charge carrier flow and current flow. (2)

b. Why does the electrical conductivity of an intrinsic semiconductor increase as the temperature rises? (2)

c. Introducing certain impurities into semiconducting material also increases its electrical conductivity. Describe briefly either an n-type or a p-type semiconductor and explain why this increase in conductivity occurs. (3)

d. Write down Kirchhoff's laws for circuits and point out that each is essentially a statement of a conservation law. (4, 4)

e. Use Kirchhoff's laws to determine the currents in branches AB, FC and ED of the circuit shown in Figure 10. (6)

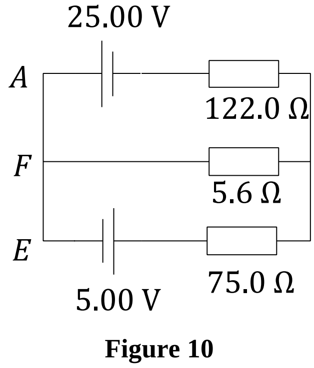

Figure 10

(Total: 25 marks)

14.a. Explain why you can look up values for the resistivity of a substance (at a given temperature), but not the resistance. (2)

b. The temperature coefficient of resistance of a material is the fractional change in the resistance of the material at $0\ °C$ per kelvin change in temperature. Describe an experiment that is used to determine the temperature coefficient of resistance of a copper wire. Your description should include:

i. a list of equipment and materials to be used;
ii. a labelled diagram of the set-up;
iii. a description of the procedure to follow and the measurements that need to be taken;
iv. a table of results;
v. a sketch of the graph expected to be obtained from the results;
vi. an indication of how to determine the temperature coefficient of resistance. (12)

c. A bread toaster has a heating element that is made of nichrome. When the nichrome element is red hot, its temperature is around $1200\ °C$ and its resistance is $12.0\ \Omega$.

i. Calculate the resistance of the nichrome element when it is at a room temperature of $20\ °C$ given that its temperature coefficient of resistance is $0.4 \times 10^{-3}\ °C^{-1}$. (4)
ii. State **TWO** assumptions that are necessary to be able to work out part (i). (2)

d. The slider of a variable resistor of resistance $250\ \Omega$ is set at its mid-point as shown in Figure 11.

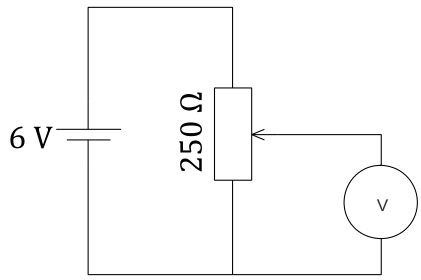

Figure 11

i. Find the potential difference recorded by a digital voltmeter of infinite resistance connected as the voltmeter V in the circuit. (2)
ii. The digital voltmeter is replaced by a moving coil voltmeter of resistance $500\ \Omega$. Calculate the new readings when using this meter. (3)

(Total: 25 marks)

15.a. Describe an experiment in which the wave characteristics of electrons are observed. (4)

b. When an electron is accelerated to a higher speed, what happens to its de Broglie wavelength? (2)

c. An electron of mass m is moving with a velocity v in a medium.

i. Show that the relation between the momentum p of the electron and its kinetic energy KE is given by $p = \sqrt{(2m \times KE)}$. (4)
ii. Calculate the de Broglie wavelength of electrons with kinetic energy of 1.0 keV. (4)

d. The Paschen series in the hydrogen emission spectrum is formed by electron transitions from energy levels that are greater than 3 to energy level 3, as shown in Figure 12.

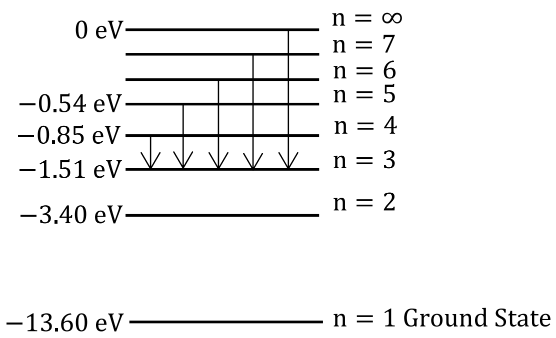

Figure 12

i. Calculate the longest wavelength of radiation that can be emitted from the Paschen series. (2)

ii. Determine in which part or parts of the electromagnetic spectrum the Paschen series is found, given that the wavelength of red light is 650 nm and wavelength of violet light is 400 nm. (2)

e. Neutrons and protons are not fundamental particles as they are made up of quarks. The table shows the charge and mass of the quarks that make up neutrons and protons.

Name	Up	Down
Charge	$+\frac{2}{3}e$	$-\frac{1}{3}e$
Mass	$\frac{1}{3}m_p$	$\frac{1}{3}m_p$

i. Name **THREE** different fundamental particles and state what is a fundamental particle. (4)

ii. Show that a hadron composed of one up quark and two down quarks has the correct basic properties to be a neutron. (3)

(Total: 25 marks)

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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 EIGHT questions in this section. This section carries 50% of the total marks for this paper.

1. a. Explain the statement: *The specific latent heat of vaporization of water is 2.26 × 10^7 J kg^{-1}.* (2)

   b. A student suggests that an electric kettle may be used to obtain an approximate value for the specific latent heat of vaporization of water.
   i. Make a list of the measurements that must be made to measure this quantity. (6)
   ii. Write down the equation used to calculate the final result. Give the meaning of the symbols in the equation. (6)
   iii. Mention **ONE** important source of uncertainty in the experiment. (2)

(Total: 16 marks)

2. The First Law of Thermodynamics states that for an *isolated* thermodynamic system:

$$\Delta U = \Delta Q + \Delta W$$

   a. Write down the meaning of each term in the equation. (3)

   b. Give **ONE** example of a thermodynamic change in an ideal gas when under each of the following conditions:
   i. $\Delta W = 0$;
   ii. $\Delta U = 0$;
   iii. $\Delta Q = 0$. (3)

   c. Ice at 0 ^{o}C is converted to boiling water at 100 ^{o}C. Explain how the First Law applies to each stage of this process. (6)

(Total: 12 marks)

3. A balloon contains helium at a temperature of 300 K.

   a. Calculate the average molecular kinetic energy of helium atoms. (3)

   b. If helium inside the balloon is replaced by hydrogen, what will be the average molecular energy of hydrogen molecules at 300 K? What change, if any, will there be in the average molecular speed? Explain your answer. (5)

   c. Explain, using the kinetic theory, why the pressure of the gas inside the balloon decreases as its temperature falls. Assume that the volume of the balloon remains constant. (4)

   d. What will be the effect on the pressure if the volume of the balloon decreases as the temperature falls? Explain your answer. (3)

(Total: 15 marks)

4. Figure 1 illustrates the principle of a heat engine.

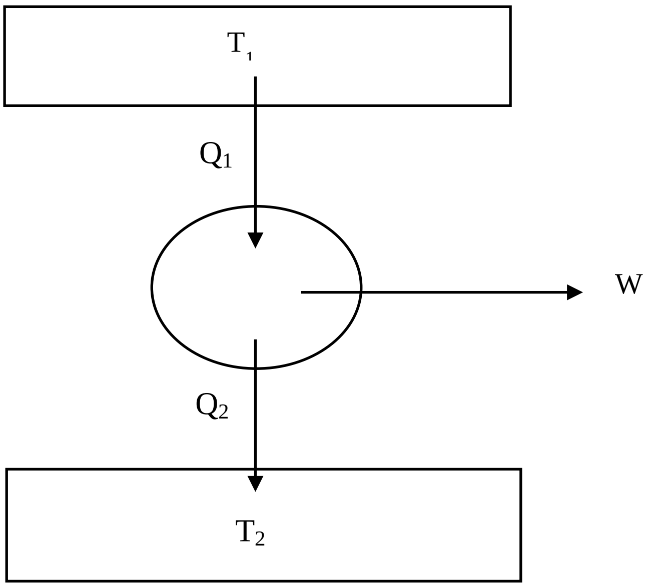

Figure 1

   a. What is a heat engine? (3)

   b. What does each of the symbols T_1 , T_2, W, Q_1, and Q_2 in Figure 1 represent? How are W, Q_1, and Q_2 related? (7)

   c. The maximum thermal efficiency of a certain ideal heat engine is 40% when the working substance enters at 250 ^oC. What is the temperature in Kelvin at which the working substance leaves the engine? (4)

(Total: 14 marks)

5. A ray of light AP is incident on a rectangular glass block of refractive index 1.5 at the point P, as shown in Figure 2.

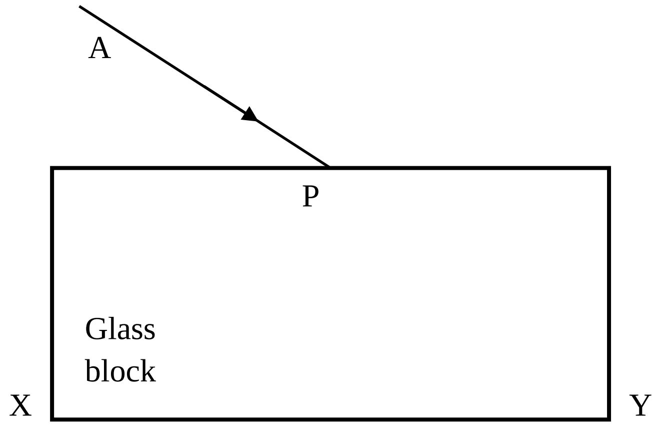

Figure 2

   a. Copy the diagram and draw the light path through the block and out of the side XY. Why is the emergent beam parallel to the incident beam? Mark the relevant angles on the diagram. (5)

   b. Which angles should be measured to find the refractive index of the block? (2)

   c. Calculate the angle of incidence on side XY which produces an emergent ray travelling in air along XY. (4)

(Total: 11 marks)

6. A and B are two fixed point charges of +4.0 nC and -6.0 nC respectively. The distance between A and B is 4.0 cm, as shown in Figure 3.

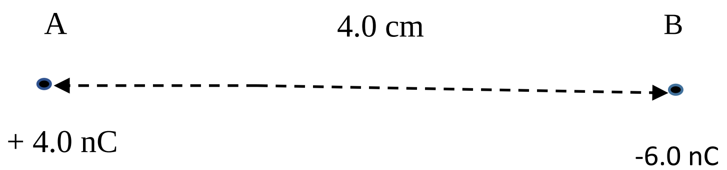

Figure 3

   a. Explain why there is *no* neutral point between A and B on the line joining the two charges? (2)

   b. Show that a neutral point is located at 18 cm away from charge A along the line joining the two charges. (4)

Question continues on next page

Charge B is now removed and a charge of 1 nC is moved from position Y to position X along the path, shown in Figure 4.

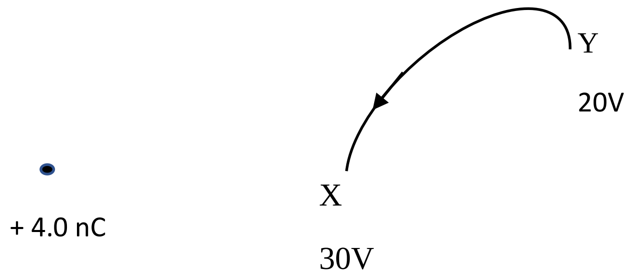

Figure 4

c. If the electrostatic potentials at X and Y are 30 V and 20 V respectively, calculate the work that must be done in moving the charge? How would this work change if,

i. X was closer to 4nC charge;

ii. path from Y to X was a straight line. (6)

(Total: 12 marks)

7. a. A permanent horseshoe magnet M is placed so that it produces a vertical magnetic field across a stretched wire AB as shown in the Figure 5. The wire is connected to the output of a signal generator.

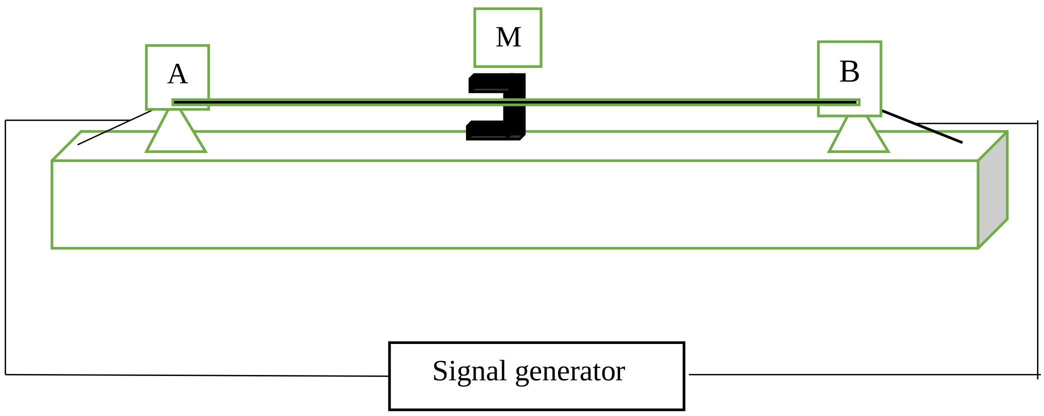

Figure 5

As the frequency of the alternating current flowing through the wire is increased from zero, the wire vibrates with increasing amplitude. The amplitude decreases when the frequency is increased beyond a certain value f_o.

i. Explain why does the wire vibrate? (3)

ii. If the magnetic flux is vertical, in which plane does the wire vibrate? (2)

iii. State the phenomenon demonstrated by this experiment. (2)

b. If the speed, v, of transverse waves in a wire of length L is given by the equation $= \sqrt{\frac{T}{m}}$, where T is the tension in the wire, and m is its mass per unit length, obtain an expression for the fundamental frequency of vibration of the wire in terms of m, T and L. (4)

(Total: 11 marks)

8. A narrow beam of electrons travelling in a horizontal plane enters a uniform magnetic field of flux density, B, as shown in Figure 6.

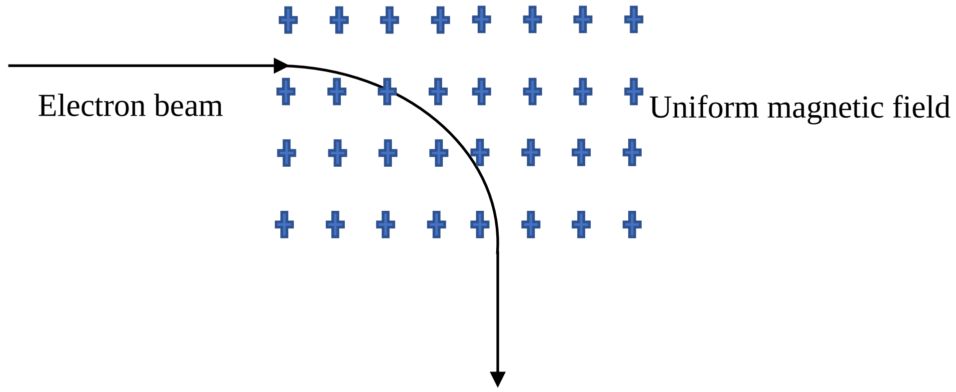

Figure 6

a. Write down an equation for the force on the electron due to the magnetic field, and hence show that the radius *r* of the circular orbit of an electron travelling with speed *v* is given by:

$$r = \frac{mv}{Be}$$ (4)

b. When electrons are accelerated through a potential difference of 1000 V their speed *v*, is given by:

$$v = \sqrt{\frac{2000e}{m}}$$

where $\left(\frac{e}{m}\right)$ is the charge to mass ratio of the electron. If these electrons then enter a uniform magnetic field of flux density 0.0030 T, their path is a circle of radius 35 mm. Calculate the charge to mass ratio of the electron. (5)

(Total: 9 marks)

Please turn the page

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.

9. Figure 7 shows an apparatus which may be used to measure the thermal conductivity, *k*, of glass in the form of a tube.

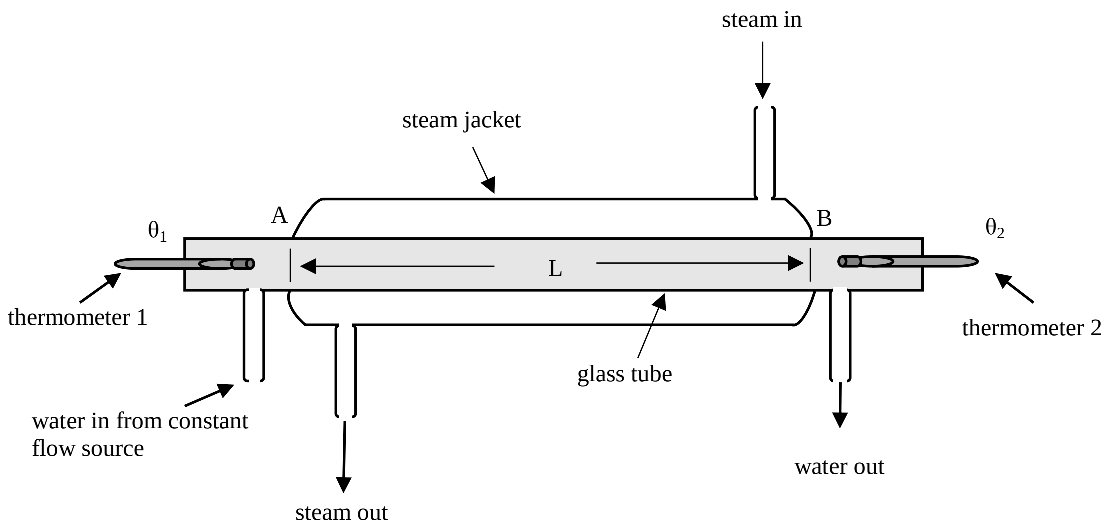

Figure 7

Water flows at a constant rate through the tube AB of length *L*, while steam at 100 ^oC flows through the jacket surrounding the tube. The specific heat of water is 4200 $Jkg^{-1}K^{-1}$ and *L* is 0.75m. The temperatures of the incoming and outgoing water are θ_1 and θ_2, recorded using thermometers 1 and 2. The temperatures and rate of flow of water, *m*, are measured when conditions are steady. The thermal conductivity of the glass of the tube AB is then calculated using the equation

$$k = \frac{Q \ln\frac{r_2}{r_1}}{2\pi L\left(100 - \frac{\theta_2 - \theta_1}{2}\right)}$$

where *Q* is the rate of flow of heat through the walls of the tube, and r_1, r_2 are the inner and outer radii of the tube.

a. State the observations that should be made to find out if steady conditions have been reached.(2)

b. The approximate values of r_1 and r_2 are 0.8 cm and 1 cm, respectively. Describe how you would measure these radii to obtain more accurate values. Assume that a separate piece of glass tubing with identical radii is provided. (4)

c. In one experiment, the mass of water flowing through the tube in 5 minutes was found to be 3.42 kg. What is the rate of flow of heat *Q* through the wall of the tube if the incoming and outgoing temperatures of water are 20.0 ^oC and 50.0 ^oC respectively? (6)

d. Hence determine the thermal conductivity of the glass tube. (2)

The experiment may be repeated by changing the rate of flow of water through the tube.

e. State which quantities in the equation will change when the rate of flow of water is changed. (3)

f. Use the equation for *k* to show how the thermal conductivity of the glass tube may be obtained from a graph. (8)

(Total: 25 marks)

10.a. i Sketch a graph to show how the extension, *x*, of a spiral spring depends on the force, *F*, acting upon it, assuming Hooke's law is obeyed. (3)

ii. Use the graph to obtain an expression for the energy stored in the spring when the extension is *x* and the force is *F*. (3)

iii. Write down an expression for the energy stored in terms of *k* and *x*. Hence, sketch a graph to show how the energy stored in the spring depends on its extension. (5)

b. i. What is meant by the capacitance, *C*, of a capacitor? (3)

ii. Sketch a graph to show how the charge, *Q*, on a capacitor depends on the voltage, *V*, across its terminals. (3)

iii. Use the graph to obtain an expression for the energy stored in the capacitor in terms of *Q* and *V*. (3)

iv. Write down an expression for the energy stored in the capacitor in terms of *C* and V. Hence sketch a graph to show how the energy stored in a capacitor depends on the voltage across it. (5)

(Total: 25 marks)

11.a. When a body, of mass *m*, performs simple harmonic motion, its period, *T*, is given by,

$$T = 2\pi\sqrt{\frac{x}{a}}$$

where *a* is its acceleration towards the centre of oscillation when its displacement from this centre is *x*. Use this equation to show that the period *T* is given by,

$$T = 2\pi\sqrt{\frac{m}{F/x}}$$

where *F* is the restoring force acting on the body. (3)

Question continues on next page

b. Figure 8 shows U-tubes containing water of density ρ having a cross-sectional area A. In Figure 8b, the water in the U-tube has been displaced when compared to the U-tube shown in Figure 8a so that its surface can oscillate about its rest position.

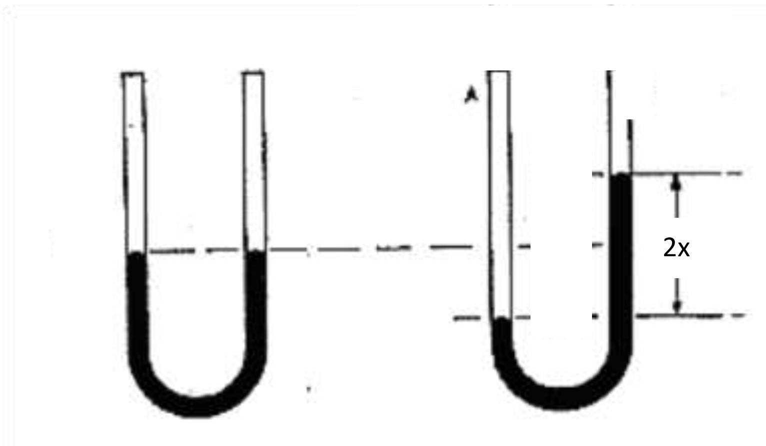

Figure 8a Figure 8b

Figure 8

i. Obtain an equation for the weight of a column of water of cross sectional area a and height $2x$. (3)

ii. What is the mass of water in the tube if the length of the water column is L? Hence, using the result of question a, show that the period of oscillation of the water column is given by

$$T = 2\pi\sqrt{\frac{L}{2g}}$$ (6)

c. The equation in part (b) relates the period T to the length of the water column L.

i. Describe how a student may use the water column in the tube to determine the acceleration due to gravity. Your answer should include a description of the experimental procedure and how the final result may be obtained from a graph. (9)

ii. Explain why the student would prefer to work with a long tube rather than a short tube. (2)

iii. Describe **ONE** important difficulty which a student may encounter while performing the experiment. (2)

(Total: 25 marks)

12.a. A satellite of mass m travels in a circular orbit at a height h above the Earth. The Earth's radius R is 6.40×10^6 m and its mass M is 6×10^{24} kg.

i. Draw a free body force diagram for the satellite and give an expression for any force which appears in your diagram. (5)

ii. Show that the period, T, of the satellite is given by:

$$T^2 = \frac{4\pi^2(R+h)^3}{GM}$$

(8)

iii. Calculate the minimum period that a satellite orbiting the Earth may have. (4)

b. Explain what happens to the (i) potential energy; (ii) kinetic energy and (iii) total energy of a satellite when it moves from a high to a low Earth orbit. Also, write down an expression used to calculate each of these quantities. (8)

(Total: 25 marks)

13. P and S are two coils facing each other at a distance of a few centimetres. V is a centre zero voltmeter connected across coil S (see Figure 9).

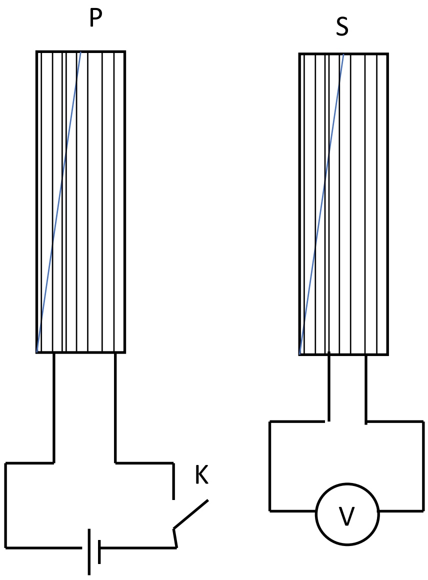

Figure 9

a. Describe what happens when the switch K is closed, and when it is opened. (10)

b. A small coil of 100 turns is wound around the middle of a long solenoid of cross sectional area 12.0×10^{-4} m^2, length 0.300 m, and 1000 turns. A current of 2 A flows through the solenoid.

   i. Calculate the magnetic flux through the solenoid. (4)

   ii. If the current falls to zero in 5 s at a constant rate, what will be the induced current in the coil if its resistance is 10.0 Ω? (3)

c. In the circuit shown in Figure 10, a 12 V battery is connected in series with a 12 V filament lamp, a switch S and a neon bulb. An iron cored inductor of low resistance is connected across the neon bulb. Current flows through the neon bulb only when the voltage across it exceeds 50V.

   Explain why,

   i. when the switch S is closed, the filament lamp takes a few seconds to light up to its normal brightness; (4)

   ii. when the switch is opened, the neon bulb emits a short flash of light. (4)

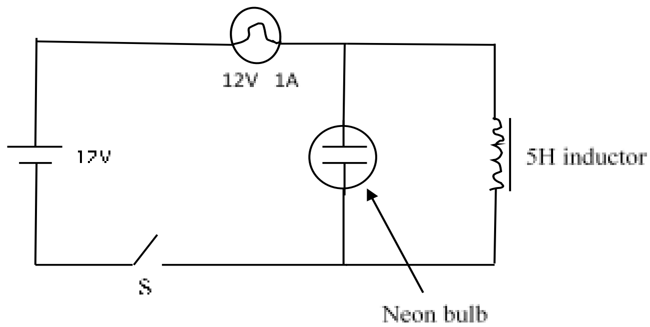

Figure 10

(Total: 25 marks)

14. Monochromatic light falls normally onto a diffraction grating with 1.38×10^5 lines per metre. The diffracted light then falls onto a white screen 2.50 m away from the grating. Figure 11 shows the diffraction maxima on one side of the zero order maximum observed on the screen.

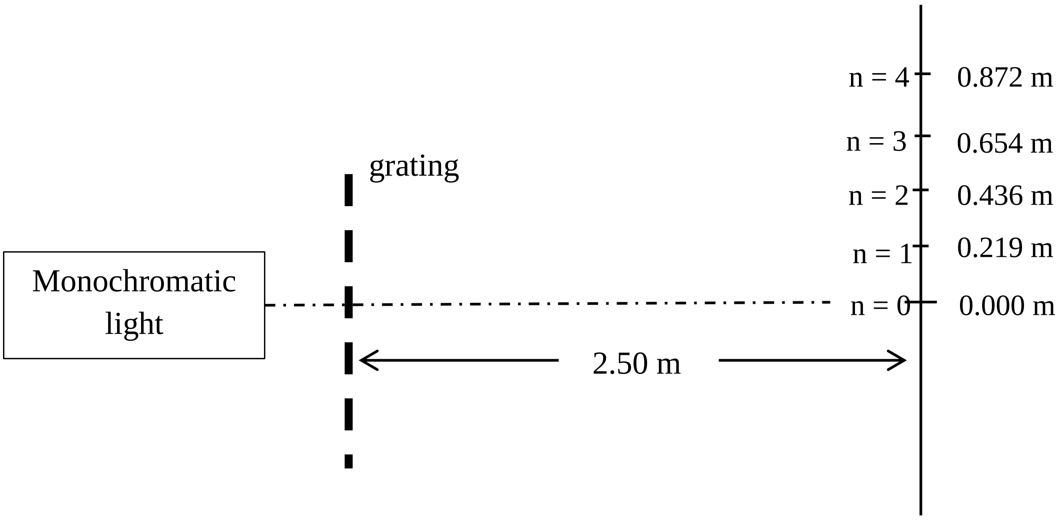

Figure 11

a. Explain how the pattern observed on the screen is formed. (4)

b. Describe how, in an actual experiment, the data shown in Figure 11 may be used to determine the wavelength of the light used. (5)

c. By using the data of the diffraction spectrum shown in Figure 11, calculate the wavelength. (8)

d. Describe and explain the effect, if any, on the appearance of the diffraction pattern when:
   i. a grating with a larger number of lines per metre is used; (4)
   ii. the distance from the grating to the screen is increased. (4)

(Total: 25 marks)

15. A loudspeaker M is connected to a variable frequency signal generator to emit sound waves of a single frequency towards two microphones, L_1 and L_2, placed along a metre rule in front of the loudspeaker, as shown in Figure 12. The signals from the two microphones are connected to a double beam oscilloscope.

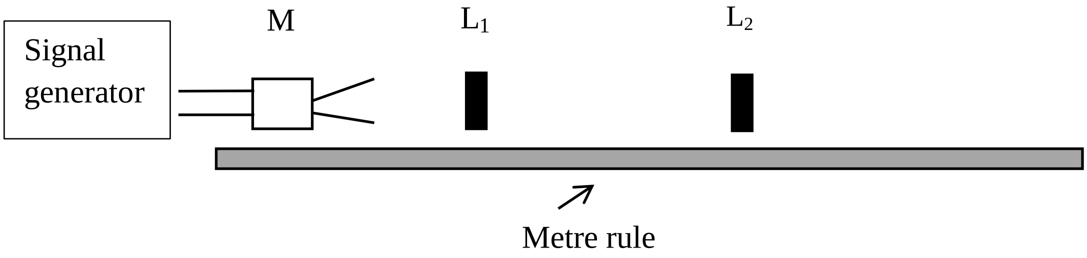

Figure 12

a. Describe how a sound wave travels away from the loudspeaker. (5)

b. Draw a series of approximately equally spaced short vertical lines to represent the air layers in front of the speaker when the speaker is switched off. Draw a new series of lines which shows how the layers are displaced at some instant after the speaker is switched on. (3)

c. With the help of your diagram in part (b), sketch, on the same axes, graphs of:
   i. displacement – distance;
   ii. pressure change – distance for the sound wave.
   Use the label "C" to mark the compressions and the label "R" to mark the rarefactions on your graphs. (4, 4)

d. The signals from the two microphones are usually out of phase.
   i. Explain what is meant by out of phase. (2)
   ii. When are the two signals in phase? (2)

e. During an experiment, when the frequency of the sound wave was set at 2.50 kHz, it was found that the two signals on the oscilloscope were in phase when the two microphones were 0.396 m apart. If it is known that the velocity of sound in air is approximately 300 ms^{-1}, what is the speed of sound as calculated from this experiment? (5)

(Total: 25 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2017

SUBJECT:	PHYSICS
PAPER NUMBER:	III – *Practical*
DATE:	30th August 2017
TIME:	2 hours 5 mintues

Experiment: Experiments with Capacitors

Apparatus: circuit board, a number of electrolytic capacitors, one resistor, a multi-meter, a 9 V battery

Important Note:

- Make sure that the multi-meter is in the correct measuring range before switching on.

Diagram:

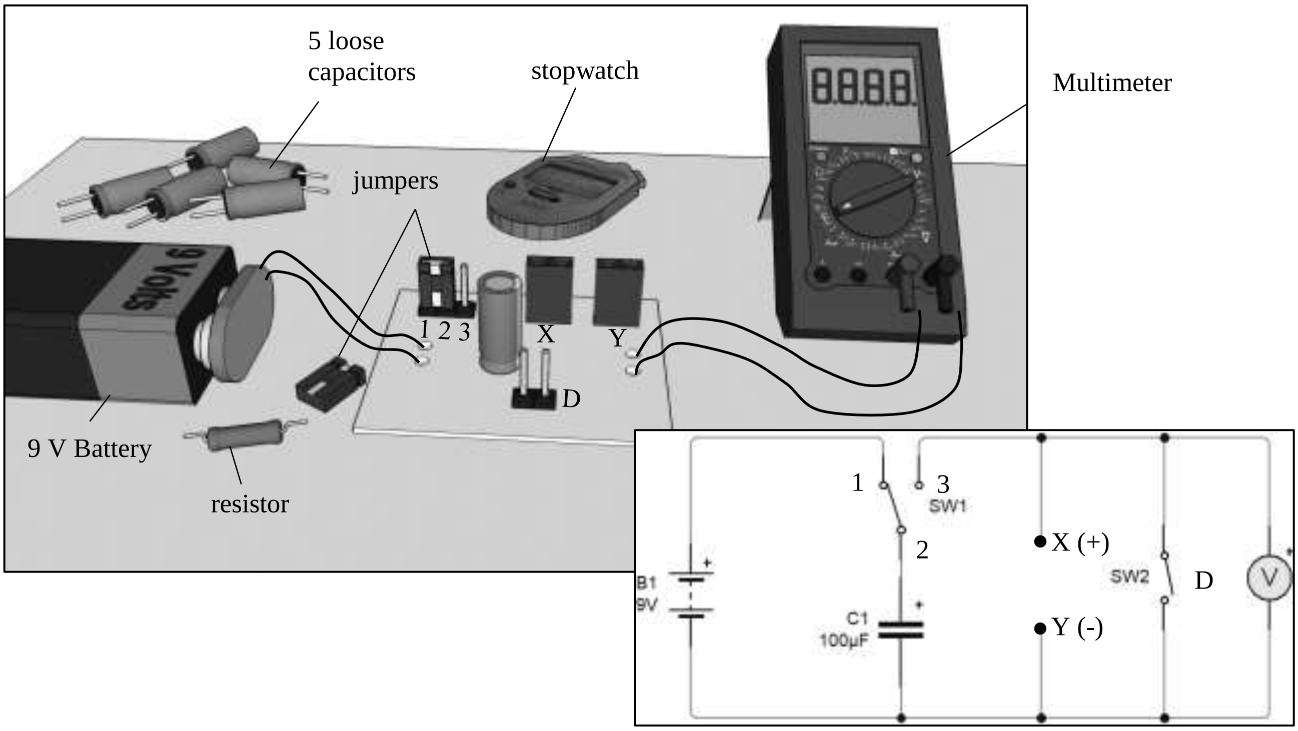

Figure 1: The experimental setup

Part A:

1. In this first part of the experiment, you will investigate the discharging of a capacitor.
2. Set up the digital meter to read DC voltage and connect it to the pair of wires that are terminated in plugs. Make sure that you set it up to the correct range. Connect the 9 V battery to its clip.
3. Connect the provided resistor between the terminals marked **X** and **Y**. Polarity does not matter.

4. The charging process of the 100 μF capacitor $\boldsymbol{C_1}$, (that is soldered to the board), is initiated by connecting the jumper across pins 1 and 2 as shown in the diagram, (Note: leaving these two pins connected for a brief period ensures that the capacitor gets fully charged). To start the discharging process, disconnect the jumper from pins 1 and 2 and connect it across pins 2 and 3.

Pins 1-2 connected	**Pins 2-3 connected**
Charging	Discharging

5. Charge the capacitor $\boldsymbol{C_1}$ as instructed in part 4 and then start the discharging process as also instructed in part 4. As soon as you start the discharging of the capacitor, record the voltage V as it changes every 10 seconds in Table 1. There is no need to record the initial voltage.

Table 1

Time t /s	Voltage V /V	$\ln V$
±	±	
10		
20		
30		
40		
50		
60		
70		
80		
90		

(9)

6. Complete Table 1 by working out the values in the third column. (9)
7. The equation that relates the voltage on the capacitor with time is given by:

$$V = V_0 e^{-\frac{t}{RC_1}}$$

where V_0 is the initial voltage on the capacitor, R is the value of the discharging resitor and C_1 is the capacitance of the capacitor.

8. Rearrange the equation in part 7 in the form $y = mx + c$.

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____(8)

9. Plot a graph of $\ln V$ on the y-axis against t on the x-axis. (15)

10. Use the graph to determine the initial voltage V_0 on the capacitor and the value of the resistor R.

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____(10)

Part B:

11. In this part of the experiment, you will investigate energy losses in the movement of charge from a charged capacitor to an uncharged one through the resistance of the connecting wires.
12. It is given that the fraction of energy dissipated in the resistance of connecting wires depends only on the ratio of final to initial capacitance and that the values of the original charge and the resistance play no role.
13. Read steps 14 to 17 carefully before you start taking any readings.
14. Remove from the circuit the resistor that you connected in part 3. In its place, between the terminals marked **X** and **Y** connect, **one at a time**, the **loosely provided electrolytic capacitors, $\boldsymbol{C_2}$,** of different capacitances ($100\ \mu\text{F}, 220\ \mu\text{F}, 330\ \mu\text{F}, 470\ \mu\text{F}$ and $680\ \mu\text{F}$).
15. The **positive** terminal of the electrolytic capacitors $\boldsymbol{C_2}$ should be connected to **X** and the **negative** terminal to **Y**, as shown in Figure 2. **Start by connecting the $\mathbf{100\ \mu F}$ capacitor between X and Y.**
16. This capacitor, $\boldsymbol{C_2}$, needs to be fully discharged **before** you can proceed and **every time you change the capacitor**. If the voltmeter reads approximately 0 V, then the capacitor is discharged. If not, connect the second jumper that you are provided with across the two pins labelled **D**. You should note that with the jumper connected, the voltage on the voltmeter reads $0\ \text{V}$. **Remove the jumper from the pins labelled D after full discharge.**

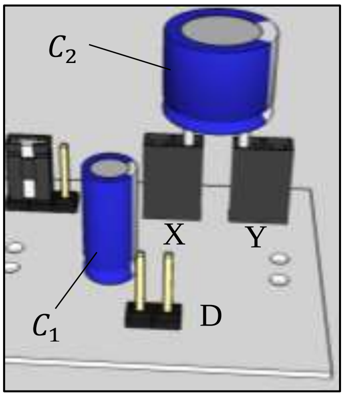

Figure 2

17. The $100\ \mu\text{F}$ capacitor $\boldsymbol{C_1}$ that is soldered to the board is charged by connecting pins 1 and 2 together using the jumper (similar to the instruction in part 4). Connecting pins 2 and 3 together, will transfer the charge from this capacitor to the uncharged capacitor (that you connected in the previous step) between **X** and **Y**.
18. With the $100\ \mu\text{F}$ capacitor $\boldsymbol{C_2}$ between **X** and **Y,** charge the capacitor that is soldered to the board by connecting pins 1 and 2 together.

19. Move the jumper between pins 2 and 3 and record the voltage read by the voltmeter in the column for V in Table 2.
20. Repeat steps 18 and 19, for the 220 μF capacitor $\boldsymbol{C_2}$ and the other remaining three capacitors.

Table 2

C_1/μF	C_2/μF	V_{batt}/V	V /V	E_{before}/ J $\left[\frac{1}{2}C_1V_{batt}^2\right]$	E_{after} /J $\left[\frac{1}{2}(C_1+C_2)V^2\right]$
100	100	9.2			
100	220	9.2			
100	330	9.2			
100	470	9.2			
100	680	9.2			

(5)

21. Complete Table 2 by filling in the column E_{before}, the energy stored in the capacitor C_1 before charge was transferred to the uncharged capacitor and the column E_{after} the energy stored in both capacitors after the charge is transferred. (10)
22. Given that the fraction of energy dissipated in the resistance of connecting wires depends only on the ratio of the two capacitances, complete Table 3 by working out the dissipated energy ΔE and the ratio of the capacitances P.

Table 3

$P = \frac{C_1+C_2}{C_1}$	$\Delta E = \lvert E_{after} - E_{before}\rvert$

(10)

23. Plot a graph of ΔE /J on the y-axis against P values on the x-axis. (15)
24. The equation that relates the dissipated energy with the ratio of the capacitances is given by:

$$\Delta E = \frac{k(C_1+C_2)}{C_1}$$

where k is a proportionality constant.

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25. Use the graph to determine the proportionality constant k.

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____(5)

26. State **TWO** sources of error and **TWO** corresponding precautions undertaken during the experiment.

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____(4)

(Total: 100 marks)

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