L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2018 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	I
DATE:	28th April 2018
TIME:	9:00 a.m. to 12:05 p.m.

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. A violin string produces a tone with a frequency f. The string has a mass m and length L. The relationship between the frequency of the vibrating string, its mass, its length and its tension T is given by:

$$f = \sqrt{\frac{T}{mL}}$$

i. Show that the equation is homogeneously correct in terms of base units. (3)

ii. The screw on the upper part of the violin is turned such that the tension in the string is increased by 5%. Calculate the percentage increase in the frequency produced by the string. (5)

b. Figure 1 shows the curved path taken by a truck travelling at constant speed. Five possible vectors A, B, C, D and E are also shown. Vector E represents the zero vector. Which vector best represents:

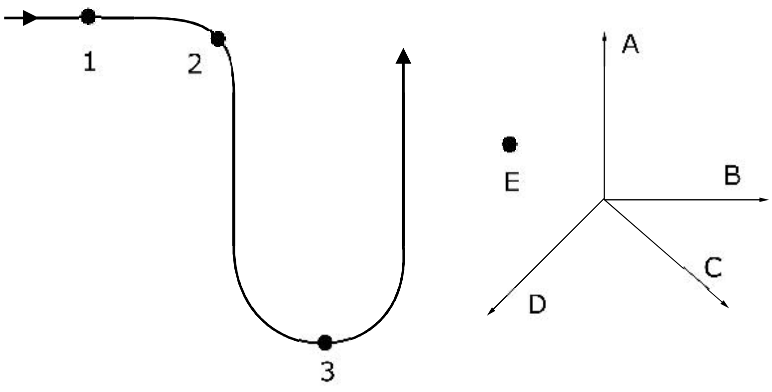

Figure 1

i. the car's velocity at position 1? (1)

ii. the car's acceleration at position 1? (1)

iii. the car's velocity at position 2? (1)

iv. the car's acceleration at position 3? (1)

(Total: 12 marks)

2. Two friends are sitting in a stationary small rowing boat fishing for squids. Squids are the fastest swimmers among invertebrates. A cavity within the squid is filled with water. A powerful muscle, squeezes the cavity and expels the water through a narrow opening at high speed.

   a. With reference to the principle of conservation of momentum, explain how the squid propels itself forward. (3)

   b. Describe **ONE** other practical example of a moving object that makes use of this same mechanism to propel itself forward. (2)

   c. At time t = 3.0 s the person sitting at the front of the boat throws a bag to his friend sitting at the rear end of the boat with the latter catching the bag 0.2 s later.

      i. What is the total momentum of the system consisting of the boat and both men? Explain your answer. (2)

      ii. Taking positive velocity as being in the direction of the rowing boat moving forward, determine which plot in Figure 2 represents the velocity of the rowing boat as it changes with time. Neglect any drag force on the boat from the water. Explain your choice. (5)

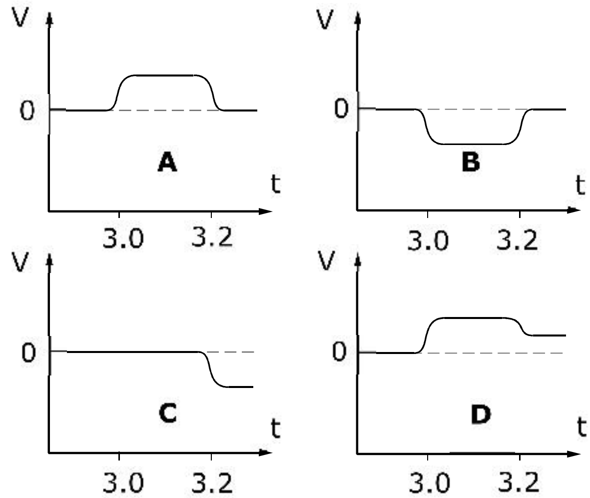

Figure 2

(Total: 12 marks)

3. An ice-cube of mass m = 10 g and side length 2L = 0.01 m is released from rest at point A, which is on the inside of a hemispherical glass bowl of radius R = 0.30 m as shown in Figure 3. At position C, the ice-cube comes momentarily to rest.

   a. State the energy conversions taking place as the ice cube moves through positions A, B and C. (3)

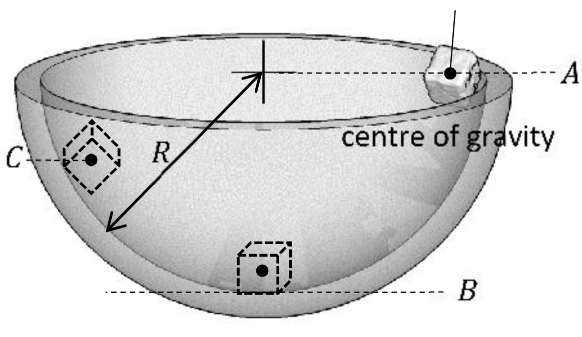

Figure 3

   b. Show that the gravitational potential energy of the ice-cube at A relative to B is given by, mg(R – L). (2)

   c. If there were no mechanical energy losses, derive an expression in terms of g, R and L for the speed of the ice-cube at B. (4)

   d. Given that the speed of the ice-cube at B is $1.5\ \mathrm{m\,s^{-1}}$, calculate the mechanical energy lost as the ice-cube moves from A to B. (3)

(Total: 12 marks)

4. A high-speed ultracentrifuge is used to separate a mixture in two test-tubes as shown in Figure 4. The centrifuge produces an extraordinarily large centripetal acceleration of 250000 g, where g is the free-fall acceleration due to gravity. When rotating the samples are 18 cm apart. Calculate:
   a. the apparent weight of a sample of mass 0.0030 kg; (2)

   b. the linear speed of a sample in the test tube; (3)

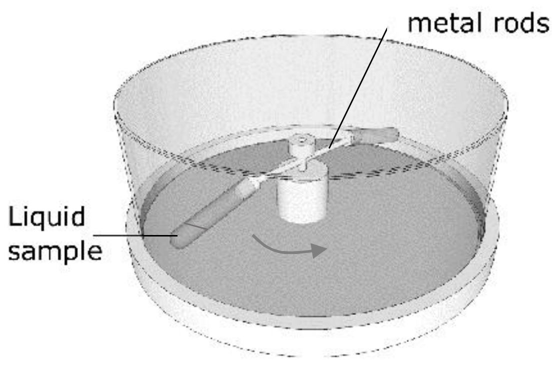

Figure 4

   c. the stress in the metal rods if each has a cross-sectional diameter of 0.75 cm; (4)

   d. the angular velocity; (3)

   e. the frequency in revolutions per minute. (2)

(Total: 14 marks)

5. An aluminium ladder of mass 20 kg is used in an archive book library to move from shelf to shelf. It has two identical uniform legs pivoted by the hinge at the top. A light chain keeps the legs from separating. The legs can freely roll on wheels as shown in Figure 5.
   a. On a copy of the diagram, draw the forces acting on the ladder. (4)

   b. Calculate the reaction force of the ground on each of the legs. (2)

   c. Calculate the tension in the chain. (4)

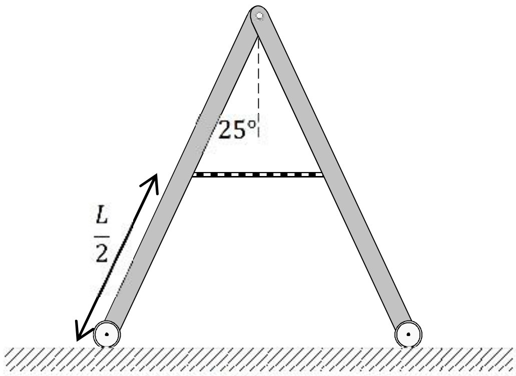

Figure 5

(Total: 10 marks)

Questions continue on next page

6. a. Define electrical resistivity and conductivity. (2)

b. Derive an equation for the combined resistance of two resistors connected in parallel. (4)

c. A student wants to determine the value of the resistance R using a circuit as shown in Figure 6. He uses a battery of e.m.f 4.0 V and internal resistance r together with a galvanometer of resistance 10 Ω that deflects full scale for a current of 100 mA. With switch S open, he observes that when he connects the galvanometer across the terminals of the cell, the galvanometer over deflects.

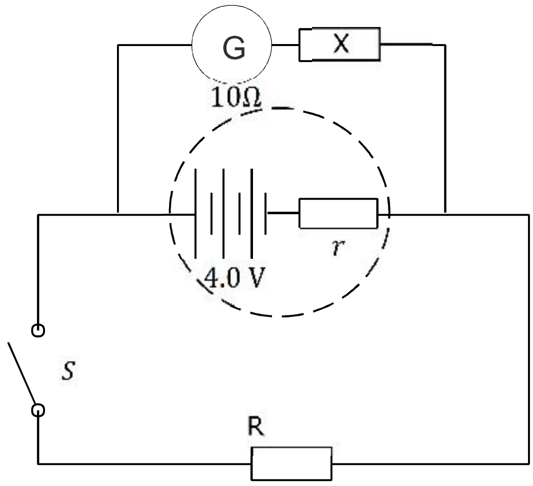

Figure 6

i. A resistor X is connected to the galvanometer so that it can be used as a voltmeter without over deflecting. Explain in which way resistor X is connected to the galvanometer and calculate a value of this resistor X that prevents the galvanometer from ever over deflecting in this circuit. (1, 4)

ii. With switch S still open, the galvanometer and resistor X are connected across the terminals of the battery and the reading on the galvanometer reads 96 mA. Determine the internal resistance r of the battery. (3)

iii. When switch S is closed, the reading on the galvanometer decreases to 85 mA. Calculate the terminal potential of the battery and the resistance of resistor R. (4)

(Total: 18 marks)

7. During the construction of a railway, rail tracks are laid down during cold weather. When the steel rails are laid in cold weather they are stretched and fixed into place in a process called pre-straining. An engineer decides to pre-strain by 3.0×10^{-4} a section of rail of unstretched length of $45\ \mathrm{m}$. The following data is typical for a length of steel rail:

Young modulus of steel	$2 \times 10^{11}\ \mathrm{Pa}$
Cross-Sectional area of steel rail	$7.5 \times 10^{-3}\ \mathrm{m}^2$

a. State Hooke's law when applied to a wire under stress. (2)

b. Explain why laying of steel rail tracks usually takes place in cold weather. (1)

c. Calculate the tensile force required to produce the pre-strain in the rail required by the engineer. (4)

d. Calculate the elastic strain energy stored per unit volume of steel rail when pre-strained. (3)

(Total: 10 marks)

8. a. Figure 7 shows the apparatus used to demonstrate the photoelectric effect. Identify and name the parts A, B, C and D of the equipment. (4)

b. Briefly describe how the apparatus shown is used to demonstrate the photoelectric effect. (3)

c. Part A of the apparatus is made of platinum with a work function of 6.35 eV.

i. Convert the value of the work function from electron volts to joules. (1)

ii. Find the threshold frequency for platinum. (3)

iii. What maximum wavelength of light incident on platinum releases photoelectrons from the platinum's surface? (1)

(Total: 12 marks)

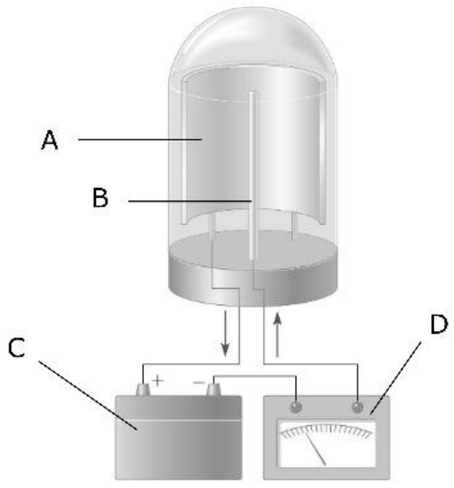

Figure 7

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. In a physics laboratory, a glider is released from rest on a frictionless air track which is inclined at an angle θ. Figure 8 shows snapshots of the glider taken every 0.25 seconds as it travels 0.90m.

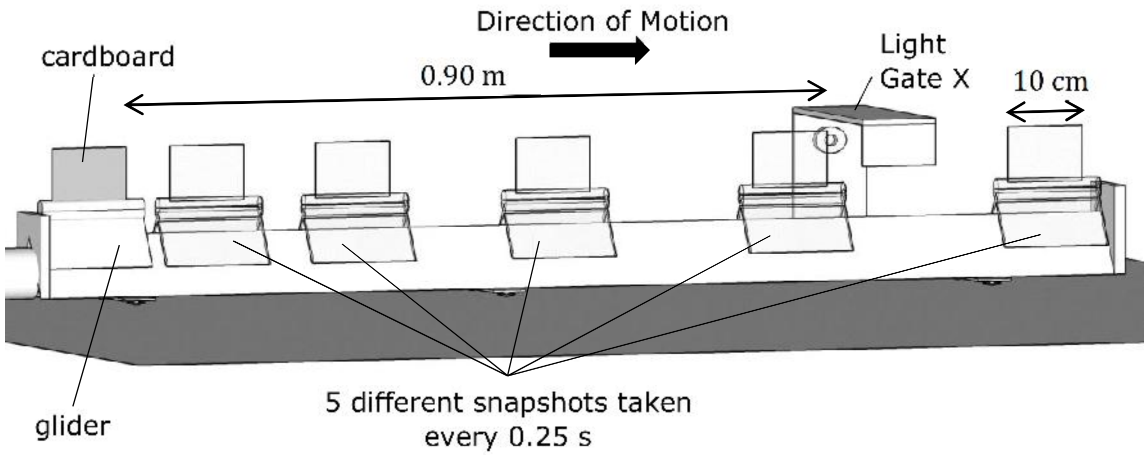

Figure 8

i. Describe the motion of the glider and give reasons for your answer. (1)

ii. A timer connected to the light gate at point X reads 0.1 s. Calculate the velocity with which the glider passes the light gate X. (1)

iii. Calculate the acceleration, if any, of the glider. (2)

iv. Calculate the time it takes the glider to reach light gate X. (2)

v. Determine the angle of inclination of the air track. (3)

vi. Sketch a graph of the distance moved by the glider against time. (3)

Question continues on next page

b. The diagram in Figure 9 shows a wastebasket placed behind a chair. Three different directions are indicated for the velocity of a ball thrown by the kneeling woman.

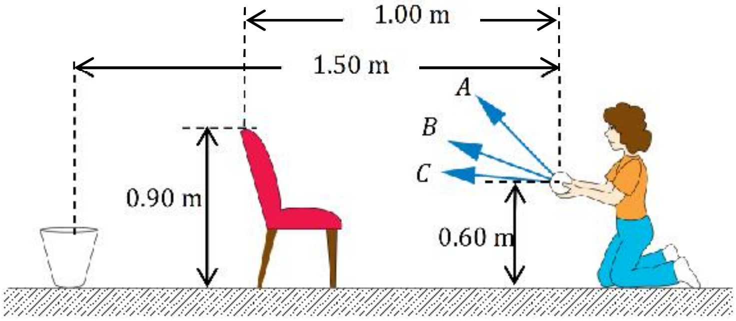

Figure 9

i. Which of the three directions (A, B or C) are most likely to result in the ball landing in the basket? Explain. (4)

ii. The girl chooses to throw the ball in the direction B which is inclined at 30° to the horizontal. Calculate the minimum velocity with which she must throw the ball if the ball is to miss hitting the chair. (5)

iii. Make the necessary calculations to determine if the ball ends up in the wastebasket when projected with the minimum velocity in the B direction. (4)

(Total: 25 marks)

10. Figure 10 shows an exaggerated yo-yo made from two metal solid disks. The mass M of each disk is 1.5 kg and each has a radius R of 10.0 cm. A solid cylinder joins the two disks together. The cylinder has a mass m of 0.75 kg and a radius of 4.0 cm. A light string is wrapped around the inner cylinder and the yo-yo is allowed to drop from rest. Take the centre of the cylinder as the axis of the system, with positive torques directed to the left along this axis.

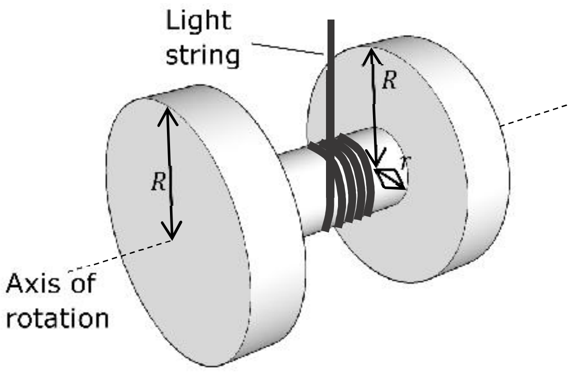

Figure 10

a. Explain the term moment of inertia. (1)

b. Given that the moment of inertia I of both a solid disk and a cylinder is given by $\frac{1}{2} \times mass \times radius^2$, write down an expression for the moment of inertia of the yo-yo in terms of M, m, R and r. (3)

c. Is the weight of the yo-yo exerting any torque on the yo-yo with respect to the axis of rotation? Explain your answer. (2)

d. Taking the downward direction as the negative coordinate direction, indicate whether the following are positive or negative and explain your answer in each case:
   i. torque exerted by the tension in the light string; (1)
   ii. the angular acceleration; (1)
   iii. the translational acceleration. (1)

e. Write an expression for the angular acceleration α in terms of the translational acceleration a and radius r. Take into consideration any positive or negative signs you indicated in part (d). (2)

f. Write Newton's second law for the system in terms of m, M, a, T and g. (2)

g. Write Newton's second law for rotation in terms of I, a, T and r. (3)

h. Show that the translational acceleration a is given by the expression,

$$a = -\frac{(2M+m)g}{2M + M\left(\frac{R}{r}\right)^2 + \frac{3m}{2}}$$

and calculate a value for translational acceleration of the yo-yo. (4, 2)

i. Calculate a value for the tension in the string. (2)

j. Calculate the time it takes the system to drop 1.00 m from rest. (1)

(Total: 25 marks)

11. a. An object in mechanical equilibrium must satisfy two conditions. State these **TWO** conditions. (4)

b. The bicep muscle is responsible for lifting the forearm and anything that is held in hand. Two tendons connect the muscle to the upper arm and the forearm. Using the data given in Figure 11, find the magnitude of the force F_b that the bicep muscle exerts to keep the forearm horizontal and at 90° to the upperarm. (6)

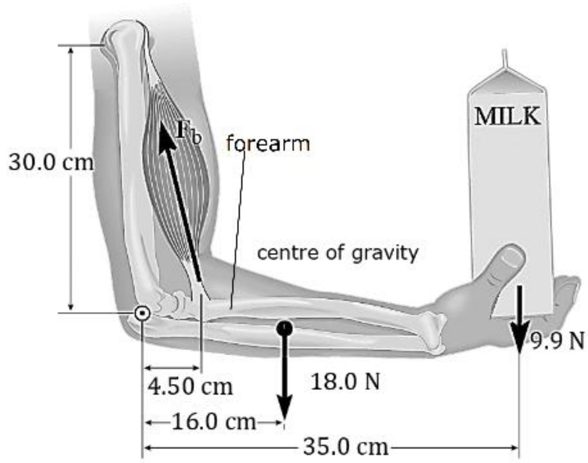

Figure 11

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c. A uniform horizontal steel beam of mass 600 kg is lifted by a crane whose jib is 16.0 m long and moves about a pivot as shown in Figure 12. The hoisting cable with tension T_1 slides smoothly over the top of the jib and attaches to the electric winch inside the cabin. Another cable with tension T_2 is fixed between the top of the jib and the top of the cabin, as shown. The weight of the jib is 18000 N.
   i. Determine the tension T_1. (2)
   ii. Calculate the tension T_2. (4)
   iii. Find the magnitude and direction with respect to the horizontal of the reaction force at the pivot. (9)

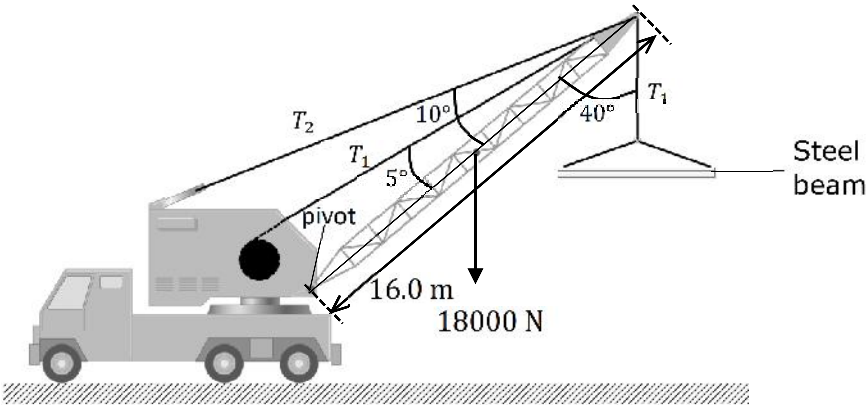

Figure 12

(Total: 25 marks)

12. An adventurous mountain bike rider of mass 85.0 kg is on a journey through a forest.
   a. At one point he gets off his bike and tries to cross a river by swinging from one side to the other of the river by making use of a vine 10 m long that is hanging from a tree. He doesn't know that the vine has a breaking strength of 1000 N.
      i. Draw a free body diagram showing the forces acting on the man at the bottom of the swing. (2)
      ii. If the position from which he starts the swing is 2.5 m above the lowest point reached along swing, determine the angle that the vine makes with the vertical. (3)
      iii. Calculate the acceleration the man experiences in the direction of the swing as he starts to swing. (3)
      iv. Determine the maximum speed reached by the man. (3)
      v. Determine if he makes it across the river without falling in. (4)

   b. His bike develops a flat tyre. He positions his bike as shown in Figure 13. He applies a tangential force to the wheel to spin it and observes that droplets of water fly off in a direction that is tangent to the rim of the wheel. A droplet breaks loose from the tyre at Point A on one turn and rises vertically to 64.0 cm above A. A second droplet breaks loose at the same point on the next turn and rises 55.0 cm above point A. The radius of the wheel is 0.35 m.

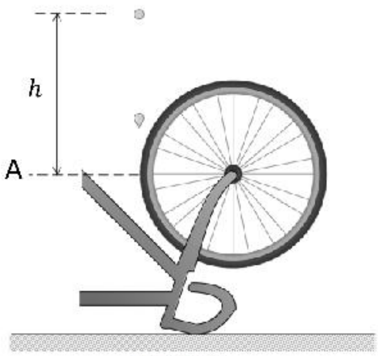

Figure 13

      i. Why does the first drop rise higher than the second drop? (2)
      ii. Calculate the velocities with which the drops break loose from the tyre. (4)
      iii. Neglecting air resistance and if the acceleration is constant, determine the wheel's angular acceleration. (4)

(Total: 25 marks)

13. Thomas is jumping on his pogo stick, as shown in Figure 14. The stick stores energy in a spring that has a spring constant of 2.5×10^4 N m. In position P, the spring is compressed at its maximum and Thomas is momentarily at rest. At position Q the spring is relaxed and Thomas is moving upwards while at position R Thomas is again momentarily at rest at the top of the jump. Take the mass of the pogo stick and Thomas combined to be 30 kg and take both potential energies to be zero at position Q.

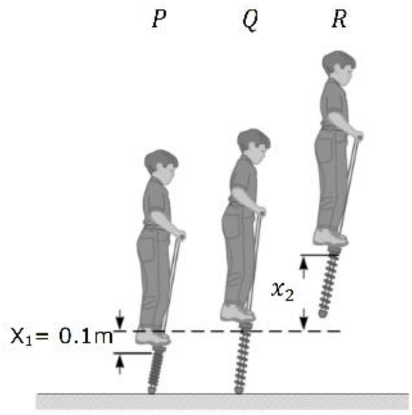

Figure 14

a. State the energy conversion as Thomas goes through positions P, Q and R. (3)

b. Calculate the total energy of the system. (5)

c. Determine x_2. (3)

d. Calculate the speed of Thomas at position Q. (3)

e. Show that the spring is compressed by 0.012 m when the acceleration is zero. (5)

f. By writing an expression for the total energy, calculate the boy's velocity at the position described in part (e). (6)

(Total: 25 marks)

14. a. i. Briefly describe how a temperature rise affects the electrical conductivity and the number of electrons and holes in an intrinsic semiconductor. (2)

ii. Introducing certain impurities into a semiconducting material increases its electrical conductivity. Describe briefly how an intrinsic semiconductor is changed into a p-type semiconductor and explain how the conductivity of the semiconductor is affected. (3)

b. A student sets up the circuit as in Figure 15.

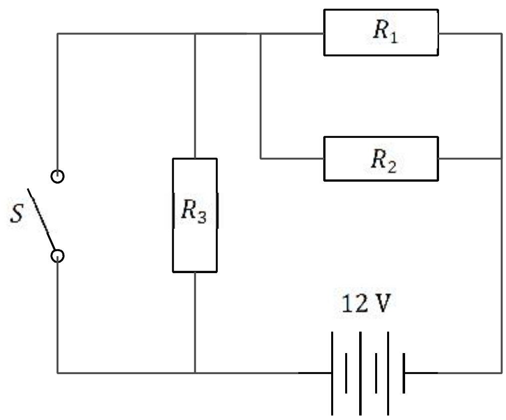

Figure 15

i. With switch S open, explain what happens to the potential difference across R_3 if the resistance R_1 decreases. (2)

ii. With switch S still open, and the resistance R_1 decreases, explain what happens to the voltage across R_2. (2)

iii. Switch S is closed. Does the current through R_1 increase or decrease? Explain your answer. (2)

iv. If R_1, R_2 and R_3 are changed so that they have identical resistance values of 6 Ω and switch S is set to an open state, calculate the total rate of change of electrical energy into heat energy by the three resistors. (2)

c. State Kirchoff's circuit laws. (4)

Question continues on next page

d. For the circuit shown in Figure 16, determine the currents I_1, I_2 and I_3. (8)

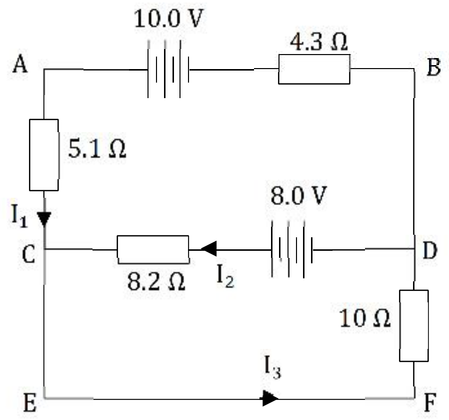

Figure 16

(Total: 25 marks)

15. a. State the name of **TWO** forces acting between nucleons in a nucleus and describe their relative importance in keeping the nucleus together. (4)

b. As in the Rutherford's alpha scattering experiment, an α particle with a kinetic energy of 1.0 MeV is projected straight towards a gold nucleus $^{197}_{79}\mathrm{Au}$ in a gold foil.

i. Explain why it would be correct to assume that the gold nucleus remains stationary in the potential 'collision' with the α particle. (2)

ii. Assuming that the gold nucleus remains stationary, determine the distance of closest approach between the centres of the α particle and gold nucleus. (3)

iii. Given that the approximate size of a nucleon is $1.3 \times 10^{-15}\mathrm{m}$, determine if the two nuclei get close enough to 'touch'. (3)

iv. Calculate the minimum initial kinetic energy needed for an α particle to make contact with the gold nucleus. (5)

c. A certain radioactive nuclide has a half-life of 200.0 s. A sample containing just this one radioactive nuclide has an initial activity of 80000.0 s^{-1}.

i. Calculate the activity $600.0\,\mathrm{s}$ later. (1)

ii. What is the probability per second that any one of the nuclei decays? (2)

d. i. Briefly explain what is meant by fundamental particles and state the name of the family of particles to which they belong. (2)

ii. Name the **THREE** fundamental particles and their corresponding neutrinos. (3)

(Total: 25 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

L-Università ta' Malta

ADVANCED MATRICULATION LEVEL
2018 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	II
DATE:	28th April 2018
TIME:	4:00 p.m. to 7:05 p.m.

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. Write down the equation associated with the first law of thermodynamics, clearly defining each term. (4)

   b. Indicate the conservation law on which it is based. (1)

   c. Write down expressions for the first law of thermodynamics as it applies to the following processes:
   i. a change at constant volume; (2)
   ii. an adiabatic change; (2)
   iii. a cyclic process. (2)

   d. A piston compresses an ideal gas initially at 17 °C and pressure 1.0×10^5 Pa until its volume is halved. Determine the final pressure of the ideal gas when the process is:
   i. isothermal; (2)
   ii. adiabatic. (2)
   [Assume an adiabatic constant $\gamma=1.4$]

   (Total: 15 marks)

2. a. The theory of ideal gases describes the macroscopic behavior of large numbers of ideal gas molecules. What are the **FOUR** main assumptions associated with this theory? (4)

   b. Using the ideal gas equation, derive the relationship between the mean molecular kinetic energy and the temperature of an ideal gas. Define all symbols used. (4)

   c. Assuming that hydrogen molecules satisfy the ideal gas conditions, determine the root mean square speed of hydrogen particles at a temperature of 26.85°C. (4)
   [Hydrogen Molar Mass: 1.01×10^{-3} kgmol^{-1}] **(Total: 12 marks)**

3. a. State Newton's universal law of gravitation. What makes it universal? (3)

   b. A satellite moves in a circular orbit about a planet. By relating Newton's universal law of gravitation with the centripetal force of a particle in circular motion, determine a relation between the period of the satellite, T, and its radial position, R, defining any other symbols used. (4)

   c. A satellite is put in orbit about Earth, making 10 orbits a day. At what radial position would the satellite need to be if it is to maintain this orbit without external assistance? (3)

   (Total: 10 marks)

4. a. Explain the term capacitance. (2)

b. Which graph would yield the energy of a capacitor? Explain. (3)

c. A dielectric is inserted into an isolated capacitor. Explain what happens to the following quantities, and why:
   i. charge stored in the capacitor; (2)
   ii. capacitance of the capacitor; (3)
   iii. energy stored in the capacitor. (3)

d. A parallel-plate capacitor has a capacitance of 1.40 μF. A material with relative permittivity of 2.1 is inserted as a dielectric material. Determine the new capacitance of the parallel-plate capacitor. (2)

(Total: 15 marks)

5. a. Define magnetic flux density (B). (3)

b. Define the SI unit used for B. State any assumptions considered in the definition. (5)

c. A positively charged particle moves with a velocity v inside a uniform magnetic field as shown in Figure 1. The particle experiences an upward force F. Find the direction of the magnetic field acting on the particle. State which rule was used to determine the direction. (2)

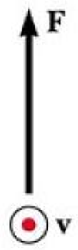

Figure 1

d. A straight wire of length 1.1 m carrying a current of 13 A is placed in a uniform magnetic field of field strength 0.1 T. The current direction makes an angle of 45° with the magnetic field. Find the magnitude and direction of the force on the length of wire. State which rule was used to determine the direction of the force. (5)

(Total: 15 marks)

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

b. A circular loop of conducting wire is initially held in a uniform magnetic field, with the plane of the loop perpendicular to the field lines, as shown in Figure 2. The loop is then allowed to move freely inside the magnetic field. Describe **TWO** kinds of motion which do **not** generate an induced current in the loop. (4)

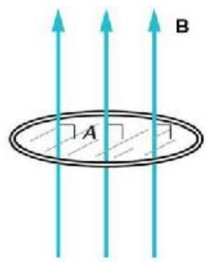

Figure 2

c. The same circular loop made of 15 turns and having a radius of 10 cm is now inclined, such that the angle between the magnetic field and the loop is 30°. The magnetic field strength is then increased steadily from 1 T to 5 T in a time interval of 10 s. Calculate the back emf generated around the loop. (5)

(Total: 12 marks)

7. The oscillations of a simple pendulum are shown in the velocity-time graph illustrated in Figure 3. The pendulum is initially released from rest and allowed to oscillate.

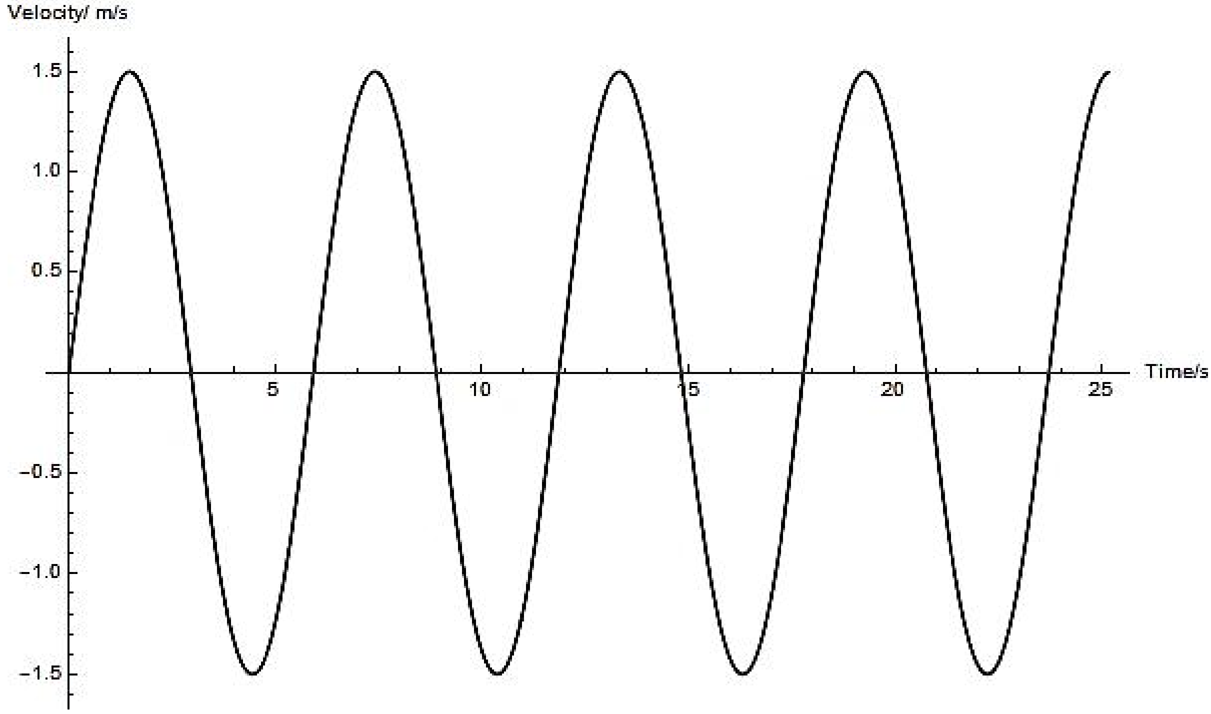

Figure 3

a. What condition must be satisfied for simple harmonic motion (SHM) to occur? (2)

b. From the velocity-time graph shown in Figure 3 (energy losses are being neglected),
   i. write down the period of oscillation of the pendulum; (1)
   ii. write down the amplitude of the pendulum's motion; (2)
   iii. calculate the maximum acceleration of the pendulum's motion; (2)
   iv. if the pendulum has a mass of 10 g, find the total energy of the system; (2)
   v. describe what happens to the energy of the pendulum as it swings over one period. (3)

(Total: 12 marks)

8. a. Explain the principle of superposition of waves. (2)

b. List **TWO** properties associated with stationary waves that contrast with progressive waves. (2)

c. A guitar string is 80 cm long and has a mass per unit length of 4×10^{-4} kgm^{-1}. It is held stretched with a tension of 110 N.
   i. What happens to the fundamental frequency and higher harmonics when the string is loosened? (3)
   ii. Determine the frequency of the second harmonic. (2)

(Total: 9 marks)

Questions continue on next 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. a. What thermodynamic condition must be satisfied for the temperature of a system to be recorded accurately? Give a brief explanation of how this may be achieved when performing a temperature measurement. (3)

   b. The temperature of two systems was recorded and it was shown to be exactly the same for both. Explain the difference between temperature and heat in this context. (3)

   c. i. Explain what is meant by the triple point of water. (5)
      ii. Mention **TWO** advantages of using the triple point of water, as opposed to the ice point as a fixed point for a temperature scale. (2)

   d. i. Describe how the constant-volume gas thermometer is used to make temperature measurements. (3)
      ii. Explain how this thermometer can be used to establish an ideal gas temperature scale. (3)
      iii. Two constant-volume gas thermometers are constructed, one with nitrogen (N_2) while the other with hydrogen (H_2). Both contain enough gas to sustain a pressure of 80 kPa at the triple point of water. What is the difference between the pressures in the two thermometers if they are immersed in boiling water?
      [N_2 thermometer reading when immersed in boiling water 373.35K]
      [H_2 thermometer reading when immersed in boiling water 373.15K] (4)

   e. A platinum resistance thermometer measures a resistance of 95.3 Ω at the triple point of water, and 150.1 Ω at the steam point of water. Determine the resistor's value at the freezing point of water. (2)

(Total: 25 marks)

10. a. Define the terms specific heat capacity and specific latent heat of vaporisation. (4)

   b. Explain the following situations using the concepts defined in part (a):
      i. Cold water is kept in a metal container. The water stays cooler if the cloth surrounding the container is kept moist. (2)
      ii. As water evaporates, its temperature decreases. (2)

   c. i. Describe how the specific latent heat of vaporisation of water may be determined experimentally. Include a labelled diagram of the apparatus, a list of measurements to be taken, the method used, and a sketch of the graph that you would plot. (10)
      ii. List **TWO** precautions which should be taken during the experiment above. (2)

   d. An old-style copper kettle of mass 3.5 kg contains 3 kg of water. If the water and kettle are in thermal equilibrium at 15 ^{o}C, how much heat is required to raise the temperature of the water-kettle couple to 101 ^{o}C? It may be assumed that the kettle does not allow any water and vapor to escape.
      [Specific heat capacity of copper: 385.0$Jkg^{-1}K^{-1}$]
      [Specific heat capacity of water: 4181.3 $Jkg^{-1}K^{-1}$]
      [Specific heat capacity of steam: 2080 $Jkg^{-1}K^{-1}$]
      [Specific latent heat of vaporisation of water: 2264.7 x 10^3 $Jkg^{-1}K^{-1}$] (5)

(Total: 25 marks)

11. a. i. Define the thermal conductivity of a material. (4)

ii. Explain why it is not possible for a material to have a negative thermal conductivity. (2)

b. The base of a frying pan is composed of a single 5 mm thick layer of material A. The frying pan designers would like to increase the rate of heat transfer through the bottom of the pan. A potential design is put forward where the bottom of the pan consists of a 1 mm layer of material B which is sandwiched between two 2mm layers of material A. Assuming perfect contact between the layers and that the thermal conductivity of material B is higher than that of material A. Sketch the temperature gradient for both designs and explain which design conducts heat more efficiently. (4)

c. A glass window of thickness 5 mm forms part of a room that has dimensions 1 m by 1.5 m. The temperature of the room is 28 ^{o}C while the air outside is -5 ^{o}C.

i. Determine the amount of heat that would have flowed out of the window area over the course of an hour. (4)

In order to better insulate the room thermally, a 3 mm layer of a second material is put in perfect thermal contact with the glass layer of the window. The rate of heat loss through the window reduces to half that of the initial value.

ii. Find the intermediate temperature at the contact point of the two layers. (4)

iii. Use the result in part (ii) to find the thermal conductivity of the new layer. (3)

iv. What assumption did you have to make in your calculations? (1)

v. If both layers of the window had to be replaced with a single layer of material of thickness 8 mm, what would its thermal conductivity have to be in order to retain the same rate of heat flow? (3)

[Thermal conductivity of glass: $k_{\text{glass}} = 0.98\,\text{Wm}^{-1}K^{-1}$]

(Total: 25 marks)

12. a. Define the term electric field strength. (2)

b. i. Explain the nature of equipotentials and their relation to electric field lines in the context of an electric field. (2)

Draw the field lines and equipotentials for the following scenarios:
(In both cases the pair of charges are a small distance away from each other.)

ii. two positive charges; (2)

iii. a positive and negative charge. (2)

Question continues on next page

c. Consider two parallel plates of length L, 1 m, as shown in Figure 4, where the plates produce a uniform electric field of E_0 = 50 Vm^{-1}. Two particles of charge C_1 = +3 μC and C_2 = -1 μC enter the field from the two opposite sides of the parallel plate system as shown. The mass of C_1 is 5×10^{-4} kg and of C_2 is 1×10^{-4} kg. The initial vertical position is the same for both particles and corresponds to an elevation of 15 cm above the lower plate. The particles enter the uniform field with a horizontal speed of 0.12 ms^{-1}. The plate separation is 25 cm.

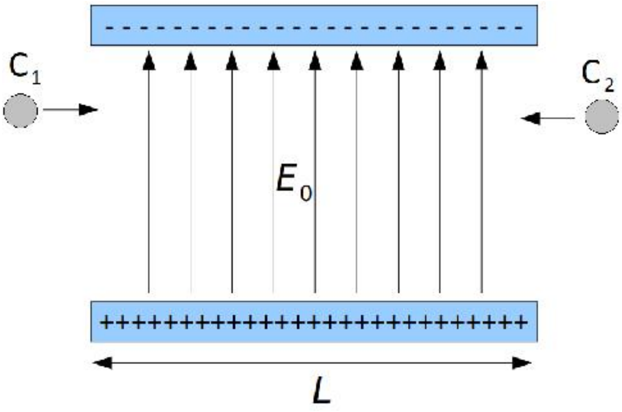

Figure 4

i. Draw a diagram to describe the trajectory of each particle inside the uniform field. (2)

ii. What is the horizontal speed of each particle at a time t, after it enters the uniform field? Explain your answer. (2)

iii. Determine the vertical acceleration of each particle in the field. (4)

iv. Determine the speed at which C_2 collides with its respective plate. (3)

v. With what kinetic energy should C_2 enter the plates if it is to just pass through the system without hitting the lower plate? (6)

(Total: 25 marks)

13. a. Domestic users in Malta are supplied with mains electricity at a root mean square voltage of 230 V.

i. State what is meant by root mean square voltage. (2)

ii. Calculate the peak value of the supply voltage. (2)

iii. Calculate the average power dissipated in a lamp connected to the mains supply when the maximum current is 0.45 A. (3)

b. Figure 5 shows the trace obtained on the screen of an oscilloscope. The time base of the oscilloscope is set at 20 ms per division and the voltage sensitivity at 10 V per division. For the ac source, calculate:

i. the rms voltage; (2)

ii. the frequency. (2)

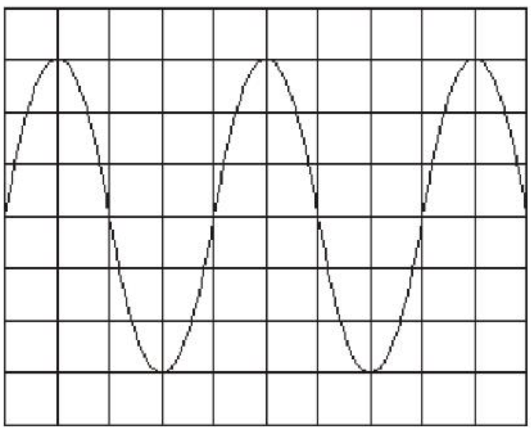
Figure 5

c. Suppose a sinusoidal voltage source is connected in series with an inductor having negligible resistance, as shown in Figure 6.

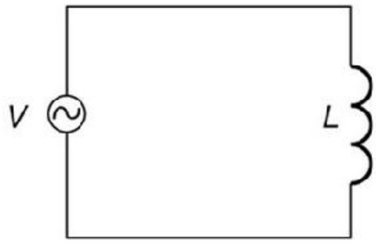

Figure 6

i. Sketch (on the same axes) a graph of current and voltage across the inductor as function of time. (3)
ii. Write down expressions for rms current I and rms voltage V through the inductor L. (2)
iii. Calculate the inductive reactance of a 3 mH inductor when 60 Hz and 10 kHz AC voltages are applied. (3)
iv. What is the rms current at each frequency if the applied rms voltage is 120 V? (3)
v. Explain how large inductors can be used in series with home computers to reduce high-frequency sound output. (3)

(Total: 25 marks)

14. a. Explain what is meant by the focal point of a lens. (2)

b. Draw ray diagrams for the following lenses for rays coming from infinity:
i. converging lens;
ii. diverging lens.
Indicate the focal point for both diagrams. (6)

c. Describe, using ray diagrams, how a virtual image may be formed by a converging lens. How is this different from a real image originating from the same lens? (4)

d. A window can be considered as a lens with an infinite focal length. Hence derive a relationship between the image and object distances. (3)

e. A virtual image is formed 8 cm from a lens with focal length 10 cm. Determine the object distance. (4)

f. Describe an experiment to determine the focal length of a lens giving a brief description of the method, a labelled diagram of the apparatus used, and the graph you would plot to obtain your result. (6)

(Total: 25 marks)

15 a. Describe the phenomenon of red-shift. (2)

b. What does the red-shift of spectral lines from distant galaxies indicate? Explain. (4)

c. State Hubble's law. Sketch the graph associated with this law. (6)

d. The spiral galaxy NGC 2342 has a radial velocity of $5\,279\ \mathrm{km\,s^{-1}}$, and is at a distance of $2.283 \times 10^{24}\ \mathrm{m}$ from the Sun. What is the value of the Hubble constant? (2)

e. If R represents the radial size of the Universe and T_0 its age, how is the Hubble constant H related to the age of the Universe T_0? (3)

Question continues on next page

f. Determine the age of the universe in years. (You may assume that a year is consists of 365 days). (3)

g. Briefly discuss the big bang theory. State **TWO** points of evidence in support of the theory. (5)

(Total: 25 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

L-Università ta' Malta

ADVANCED MATRICULATION LEVEL
2018 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	III – *Practical*
DATE:	1st June 2018
TIME:	2 hours 5 minutes

Experiment: Rigidity Modulus of Copper

Apparatus: stand and clamp, 30 cm ruler, metre ruler, small steel spring, copper wire, shaft, nuts, hanger and weights, stopwatch and steel washers.

Diagram:

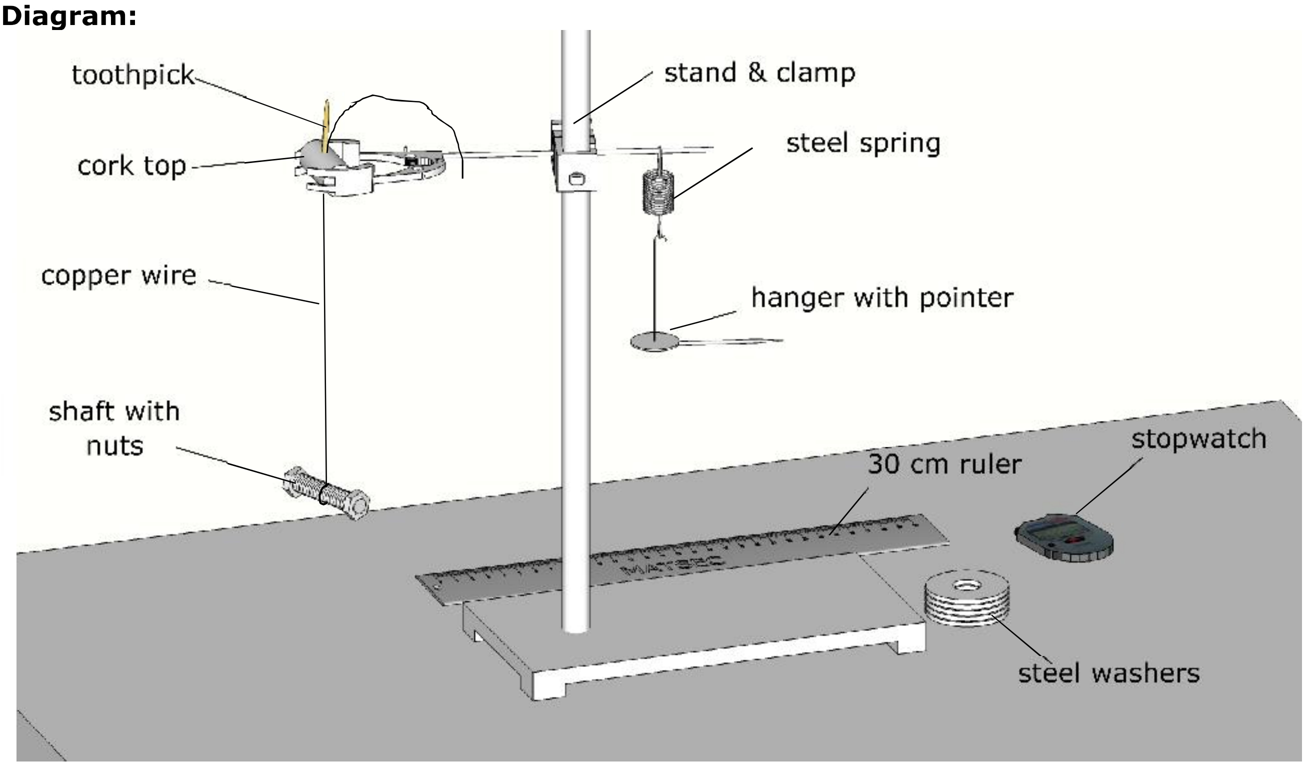

Figure 1: The experimental setup

Part A:

1. The apparatus is set up for you. Make sure that you have all the apparatus that is shown in Figure 1.
2. The steel spring provided obeys Hooke's law. This fact will be applied to determine the unknown mass of the steel washers.

Questions continue on next page

3. State Hooke's Law.

(2)

4. Load one steel washer on the hanger and attach the hanger to the steel spring.
5. With the ruler positioned such that the 0 cm mark is on top, record the position of the pointer along the 30 cm ruler when one steel washer is loaded. Record this in row $n = 1$ of Table 1. (2)
6. Add the remaining steel washers to the hanger and each time record the position of the pointer along the ruler. (9)

Table 1

Number of Steel Washers n	Position of Pointer s /m
	$\pm$
1	
2	
3	
4	
5	

7. If s is the position of the pointer after adding n steel washers of mass m on the hanger, s_0 is the position of the pointer with no masses, k is the spring constant and m_H is the mass of the hanger, show that:

$$n = \left(\frac{k}{mg}\right)s - \left(\frac{ks_0 + m_H g}{mg}\right)$$

(5)

---

8. Plot a graph of n on the y-axis against s on the x-axis. (10)

9. Given that $k = 11.2011\ \mathrm{N\ m^{-1}}$, determine the mass m of a single steel washer.

____

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(4)

10. The nuts screwed on the shaft have exactly $^{1}/_{5}$ th the mass of the steel washers. Calculate the mass m_N of a single nut. This value will be used in Part B.

____

____

____

____

(1)

Please turn the page

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Part B:

11. In this part of the experiment, a shaft with a variable moment of inertia suspended from the end of a strand of copper wire will be used to determine the rigidity modulus η of copper.
12. The length L of copper wire, measured from the bottom of the cork to the upper part of the shaft, can be changed by removing the toothpick from the cork top, adjusting the length and putting back the toothpick to hold the copper wire firmly in place.
13. The moment of inertia of the shaft about the vertical axis through its centre and perpendicular to the length of the shaft can be changed by screwing or unscrewing the nuts as shown in Figure 3 (a) and (b).

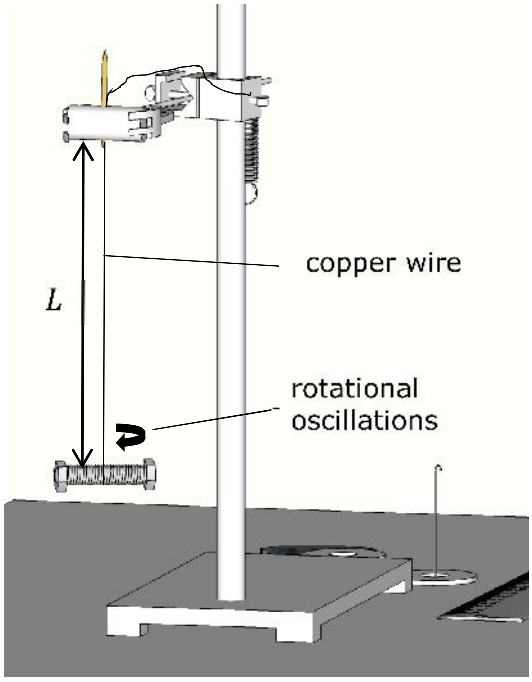

Figure 2

14. Which of the diagrams of Figure 3 [(a) or (b)] shows a setup with the largest moment of inertia of the shaft? Explain.

____

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____

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(3)

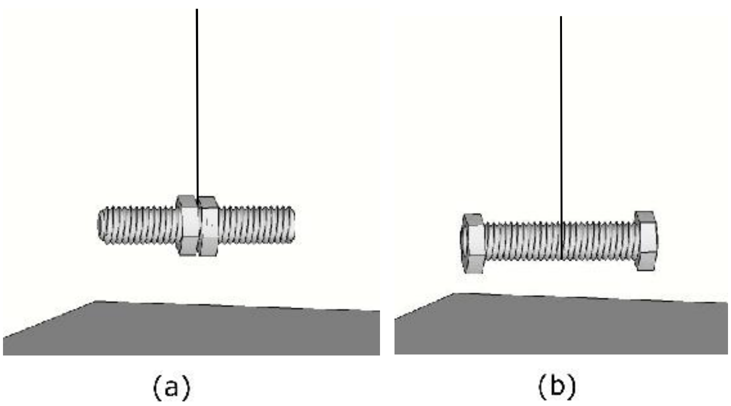

Figure 3

15. The rotational oscillations will take place in the direction shown in Figure 2. It is best to set the shaft oscillating by pushing gently on one end and releasing it.
16. Let T_1 be the time taken for the shaft to perform 10 oscillations with the nuts as shown in Figure 3 (a) and T_2 be the time taken for the shaft to perform 10 oscillations with the nuts as shown in Figure 3 (b). Do **not** tighten the nuts too much on the wire as it may break.
17. Set the length L of the copper wire to 0.25 m.
18. Set the nuts as shown in Figure 3 (a) and record the time T_1 for 10 oscillations in Table 2.

(2)

19. Set the nuts as shown in Figure 3 (b) and record the time T_2 for 10 oscillations in Table 2.

(2)

20. Repeat steps 17 to 19 for the lengths of wire L shown in Table 2. (16)

Table 2

L /m	T_1 /s	T_2 /s	$t_1 = \left(\frac{T_1}{10}\right)$ /s	$t_2 = \left(\frac{T_2}{10}\right)$ /s	t_1^2 /s^2	t_2^2 /s^2	$(t_2^2 - t_1^2)$ /s^2
$\pm$ 0.002 mm	$\pm$	$\pm$					
0.25							
0.30							
0.35							
0.40							
0.45							

21. t_1 and t_2 are the periodic times for oscillations with timings corresponding to T_1 and T_2 respectively. Complete Table 2 by working out the missing values. (12)

22. Use the ruler to measure the length p in metres of the shaft. Repeat this measurement three times across three different points and calculate the average length. Record all measurements in Table 3. If the nuts are removed from the shaft, screw them back on when ready. (4)

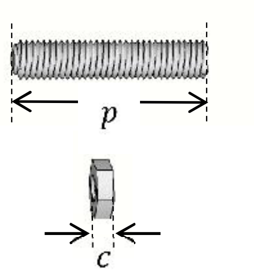

Figure 4

23. Use the ruler to measure the thickness c of one nut in metres at three different points and calculate the average. Record all measurements in Table 3. (4)

Table 3

		Reading 1	*Reading* 2	*Reading* 3	*Average*
p /m	$\pm$ m				
c /m	$\pm$ m				

24. Use the value of the mass m_N of a single nut from Step 10, the average value for p and the average value for c from Step 23 to calculate the values X, Y and K to complete Table 4. K is the difference in the moment of inertia between the setups of Figure 3 (a) and (b). (4)

Table 4

$X = p - \left(\frac{c}{2}\right)$ /m	$Y = \left(\frac{c}{2}\right)$ /m	$K = \frac{m_N(X^2 - Y^2)}{2}$ / kg m^2

25. It is given that the periodic times t_1 and t_2 are related to the length of the copper wire by the expression:

$$(t_2^2 - t_1^2) = \frac{8\pi KL}{\eta a^4}$$

where a is the radius of the copper wire and η is the rigidity modulus of copper.

26. Show that the unit of η is the Pascal (Pa).

(3)

27. Plot a graph of $(t_2^2 - t_1^2)$ on the y-axis against L on the x-axis. (10)

28. Given that the radius a of the copper wire is $0.00011\ \mathrm{m}$, calculate the rigidity modulus η of copper.

(5)

29. State **ONE** source of error and **ONE** corresponding precaution undertaken during the experiment of Part B.

(2)