MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2019 SECOND SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	I
DATE:	2nd September 2019
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 to be $9.81\ \mathrm{m\,s^{-2}}$ 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. For a monatomic gas at a temperature T, its internal energy U is given by $U = \frac{3}{2}nRT$, where n is the number of moles and R is the ideal gas constant.

i. An equation is proposed to describe a physical system. State **TWO** ways in which such an equation may be incorrect. (1, 1)

ii. Determine the units of R in terms of base units. (4)

b. A golfer uses three hits to get the golf ball into the hole. The first hit displaces the ball $3.5\ \mathrm{m}$ North-West, the second hit moves the ball $1\ \mathrm{m}$ further North and the last hit takes the ball $0.44\ \mathrm{m}$ South-East.

i. Draw a diagram that shows the path taken by the golf ball. Clearly indicate the original starting position and final position of the ball in the hole. (2)

ii. Determine the distance and direction of the hole from the original position of the ball when it was first hit. (4)

(Total: 12 marks)

2. A driver is driving a car at a constant speed on a highway when a car accident happens just in front of him. Before the driver applies the brake, the car travels a further distance (thinking distance) due to the driver's reaction time. The distance travelled until the car comes to rest is called braking distance. For a car travelling at $14\ \mathrm{m\,s^{-1}}$, the average thinking distance and braking distance are $17\ \mathrm{m}$ and $50\ \mathrm{m}$ respectively.

a. Determine the deceleration of the car during braking. (2)

b. Determine the total time taken from when the driver sees the accident until the car stops. (3)

c. Sketch a velocity-time graph over this time period. (3)

d. Calculate the braking force applied during braking if the mass of the car is $1100\ \mathrm{kg}$. (2)

e. If the braking force calculated in part (d) is kept constant and more passengers are seated in the car, how will this affect the braking distance covered by the car? Explain your answer. (2)

(Total: 12 marks)

3. A $15\,\mathrm{kg}$ block is attached to a spring with spring constant of $200\,\mathrm{N\,m^{-1}}$. The block lies on a frictionless inclined plane. Initially, the system is kept at rest with the spring stretched by $10\,\mathrm{cm}$, as shown in Figure 1.

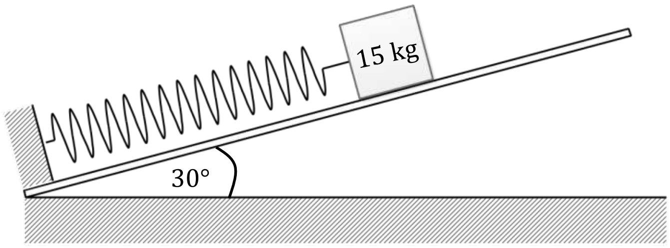

Figure 1

   a. State the energy changes that start to take place when the block is released. (3)

   b. The system is released. Determine the total energy lost by the system at the moment when the block is moving through the point where the spring becomes unstretched. (4)

   c. Calculate the velocity of the block at this point. (2)

   d. How would the velocity calculated in part (c) change if the inclined plane were **not** frictionless? Explain your answer. (3)

(Total: 12 marks)

4.
   a. Show that the acceleration of a body moving in a circular path of radius r with uniform speed v is $\frac{v^2}{r}$. Use diagrams to clearly indicate how you arrived at your answer. (6)

   b. A small object of mass m is attached to one end of a light inelastic string of length L. The other end of the string is fixed. The string holding the object is held taut and horizontal before the object is released. Find, in terms of m and L, the values of the following quantities when the object reaches the lowest part in its path:
      i. the kinetic energy; (1)
      ii. the linear speed; (1)
      iii. the angular speed; (1)
      iv. the magnitude of the centripetal acceleration, and; (1)
      v. the magnitude of the tension in the string. (2)

(Total: 12 marks)

5. A $5\,\mathrm{kg}$ uniform beam of length $2\,\mathrm{m}$ has an inextensible light string attached at each end and a load of $10\,\mathrm{kg}$ attached at some unknown position. The other end of each string is attached to some vertical surface. The whole system is in equilibrium with the beam being horizontal. Figure 2 illustrates the system in its equilibrium state.

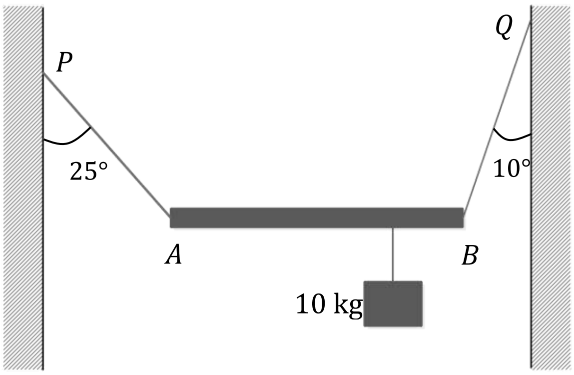

Figure 2

   a. State the **TWO** necessary conditions for this system to be in equilibrium. (4)

   b. Obtain the values of the tension in each string. (4)

   c. Determine the position of the $10\,\mathrm{kg}$ load. (4)

d. If the 10 kg load had to be placed directly at the centre of mass of the uniform beam and the system is in equilibrium with the rod staying horizontal, what can you say about the angles that the strings make with the vertical wall? Explain your answer. (2)

(Total: 14 marks)

6. A long circular cable of length L is composed of smaller circular wires made of two different materials A and B each having a resistivity ρ_A and ρ_B respectively. The cross-section of the cable is shown in Figure 3. Each small wire has an equal cross-sectional area, S.

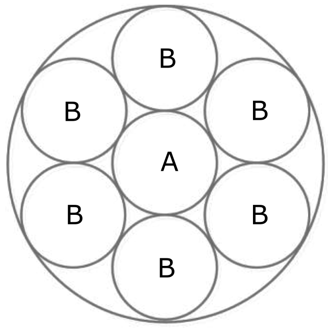

Figure 3

a. Define the resistivity of a material. (2)

b. Show that the resistances R_A and R_B of the individual wires making up the cable are related by $R_{\mathrm{A}} = \frac{R_{\mathrm{B}}\rho_{\mathrm{A}}}{\rho_{\mathrm{B}}}$ (3)

c. Given that the wires are connected in parallel, show that the total resistance R_{total} of the cable wire is $R_{total} = \frac{R_A R_B}{R_B + 6R_A}$. (3)

d. Hence show that $R_{total} = \frac{\rho_A \rho_B}{\rho_B + 6\rho_A} \times \frac{L}{S}$. (4)

(Total: 12 marks)

7. An explanation of the photoelectric effect would be that the electromagnetic wave falling on the metal supplies the energy needed by the electrons to break free from the metal. However, this explanation left many details of the photoelectric effect unexplained.

a. Describe **FOUR** observations that emerged from the photoelectric effect experiment that could not be explained by classical physics. (8)

b. Light in the ultraviolet region of the electromagnetic spectrum illuminates a tungsten surface and electrons are ejected. The wavelength of ultraviolet light is 220 nm and a stopping potential of 1.1 V is needed to just prevent any of the ejected electrons to reach the opposite electrode. Calculate the work function for tungsten in MeV. (4)

(Total: 12 marks)

8. A material of cross-sectional area A and length L conducts a current I through it.

a. Derive the expression $I = nAve$, where n is the number of charge carriers per unit volume of the material, v is the drift velocity of the charge carriers and e is the electronic charge. (4)

b. Derive an expression for the time taken by a charge carrier to travel along the whole length of the wire. (1)

c. It is observed that the drift velocity of electrons is small. Explain how the effects of a current through a circuit are instantaneous despite this small velocity value. (3)

d. Two wires X and Y are made of the same material and are connected in series to a cell. The cross-sectional area of wire X is twice that of Y, whilst the length of wire Y is three times that of X.

i. Compare the current passing through each of the wires. (2)

ii. Show that the time for an electron to travel along the whole wire Y, t_Y, is given by $t_Y = \frac{3}{2}t_X$, where t_X is the time taken for the electron to travel along the whole wire X. (4)

(Total: 14 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 passenger lift is at rest on the sixth floor. At time $t = 0\,s$, a passenger pushes a button to go to another floor. The graph in Figure 4 shows how the acceleration a of the passenger lift changes with time, t, as it goes to a higher floor. Let v_y be the velocity of the lift and y be the displacement of the lift from the sixth floor.

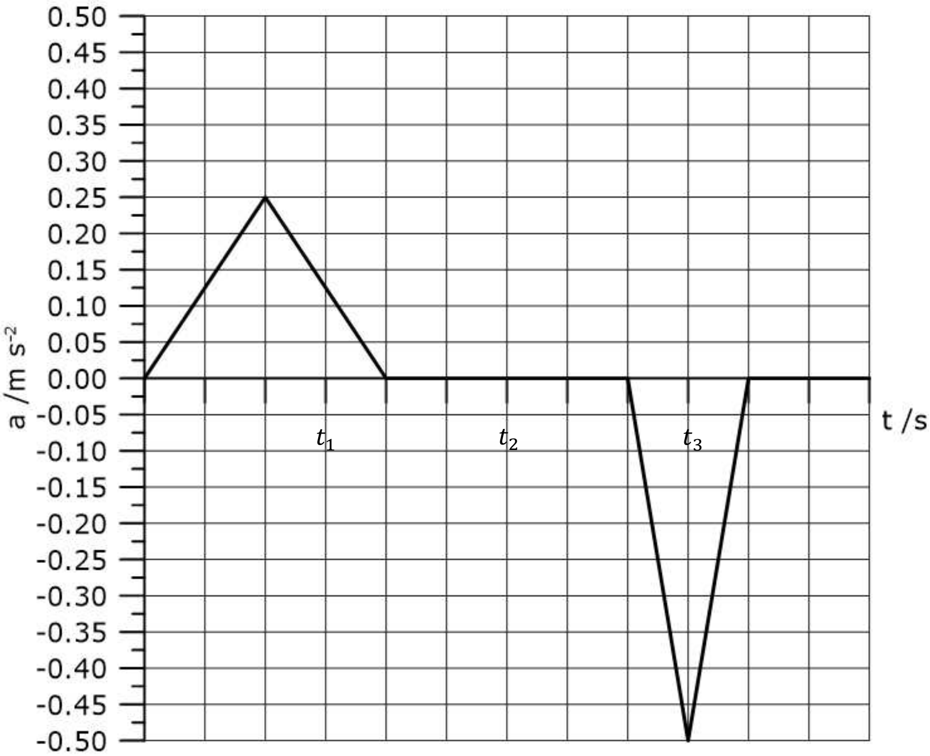

Figure 4

i. Describe the motion of the lift as it goes to a higher floor. (3)

ii. Sketch a graph of the velocity v_y of the elevator versus time. (6)

iii. Sketch a graph of the position y of the elevator versus time. (3)

iv. If the passenger has a mass of $65\,\mathrm{kg}$ and is standing on a scale in the lift, what does the scale read at times t_1, t_2 and t_3? (5)

b. A $10\,\mathrm{kg}$ block initially at rest is hit from underneath by a fast moving ball of mass $1\,\mathrm{kg}$ travelling at a speed of $20\,\mathrm{m\,s^{-1}}$ as shown in Figure 5. Once it hits the block, the ball rebounds downwards at a velocity of $12\,\mathrm{m\,s^{-1}}$.
   i. Explain what is meant by principle of conservation of linear momentum. (2)
   ii. Determine the velocity of the block. (3)
   iii. What is the maximum height reached by the block? (3)

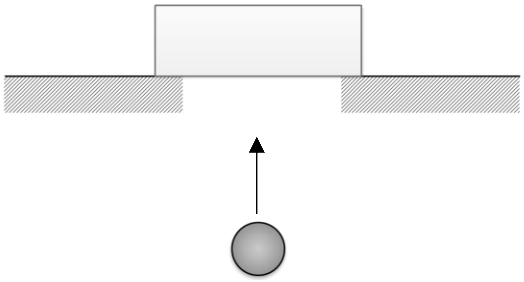

Figure 5

(Total: 25 marks)

10.

a. For a material under stress, describe what is meant by the terms proportionality limit, elastic limit, yield point and plastic behaviour. (4)

b. By use of stress-strain graphs, clearly indicate **all** the terms mentioned in part (a) for a ductile and brittle material on separate graphs. (5)

c. Sketch on the same graph, a stress-strain plot for loading and unloading for rubber. (3)

d. Explain, in terms of energy, the energy stored and lost during loading and during unloading. Account for the difference between the two behaviours and how this energy difference is obtained from a stress-strain graph. (2, 3)

e. A wire of Young's modulus E_1 has its upper end attached to the ceiling. A second wire of Young's modulus E_2 is attached at the lower end of the first wire and a load of mass m is attached on the other free end. Both wires have the same cross-sectional area and same original unstretched length.
   i. Show that the extensions are related by
   $$E_1 \Delta l_1 = E_2 \Delta l_2,$$
   where Δl_1 and Δl_2 are the extensions in first and second wire respectively. (4)
   ii. If the series of wires is thought of as a single wire of effective Young's modulus E, show that
   $$E = \frac{2E_1E_2}{E_1 + E_2}.$$
   (4)

(Total: 25 marks)

11.

a. A car battery X of emf E and internal resistance R is not fully charged. In order to recharge it, another car battery Y, referred to as the charging battery, of emf ε and resistance r is connected to it for a brief period of time as shown in Figure 6. Assume that during charging, there is a constant current flow through the circuit.
   i. Describe the difference between emf and potential difference. (2)

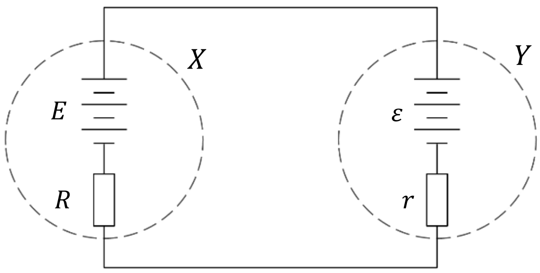

Figure 6

ii. If during charging both emfs were equal, would battery X receive any charge? Explain. (2)

iii. Express the transferred charge in time t in terms of the emfs, the internal resistances and t. (4)

iv. Show that the power P converted to heat in the internal resistances during the charging process is given by $P = \frac{(\varepsilon - E)^2}{r+R}$. (2)

v. What is the power output by the charging battery Y, in terms of the emfs and the internal resistances? (3)

vi. Determine the charging efficiency of the circuit in terms of the emfs. (3)

vii. How can the efficiency of the process be improved if a new charging battery is used? What does this imply for the charging time? (2)

b. Consider the circuit shown in Figure 7.

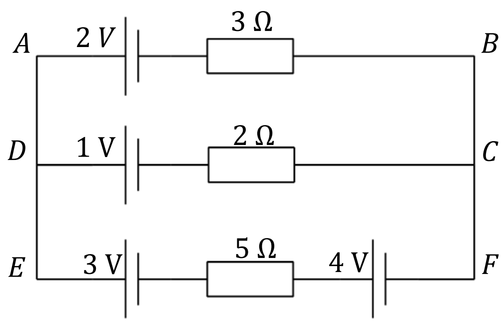

Figure 7

Obtain the magnitude and directions of the current flowing through each of the resistors. (7)

(Total: 25 marks)

12.

a. A car of mass m is travelling on a hilly road which is composed of three sections A, B and C as shown in Figure 8. The three hills are sections of circular shapes, each having different radii. Throughout the whole drive, the car is travelling at constant velocity v. Initially, the driver is at point A moving towards point C.

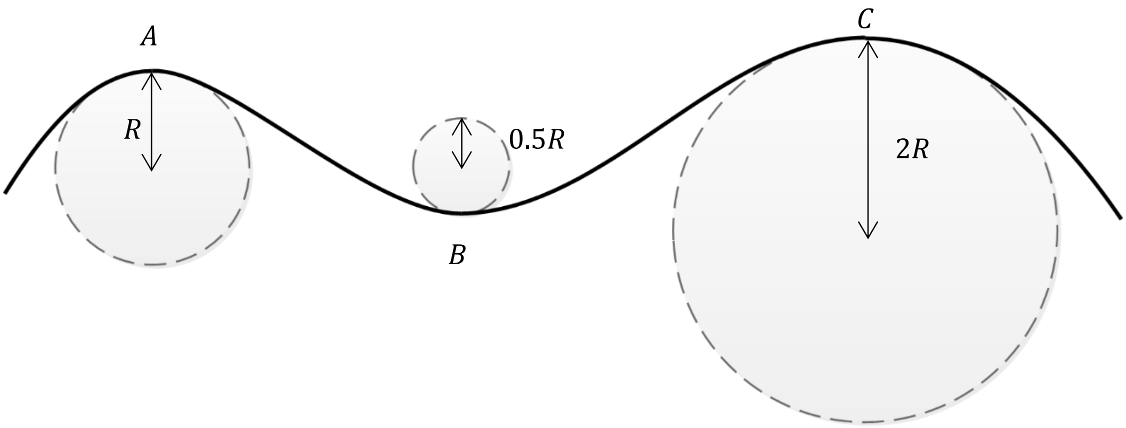

Figure 8

i. Determine the reaction of the ground on the car at each of the three points A, B and C in terms of the mass of the car, its velocity and hill radius. (3)

ii. Compare and contrast the apparent weight of the car at each point. (2)

iii. Show that the reactions R_A, R_B and R_C at points A, B and C are related through

$$R_B = 3mg - 2R_A$$
$$R_C = \frac{mg}{2} + \frac{R_A}{2}$$

(2)

iv. Derive an expression for the maximum velocity of the car at point A if the car is to remain in contact with the road. If the car maintains this velocity, obtain the resulting reactions at points B and C in terms of the mass. (3)

v. The car now starts at point C and drives down to A. Explain what happens to the car at points A and B if the car velocity at C is such that the car just remains in contact with the road at C. (2)

b. A $500\ \mathrm{g}$ toy model aeroplane consists of a string of length $50\ \mathrm{cm}$ attached to the top of the plane and is set into a circular motion as shown in Figure 9. The aeroplane is making 55 revolutions per minute and is flying level. To maintain this motion, the toy generates a lift in the direction perpendicular to the wings.

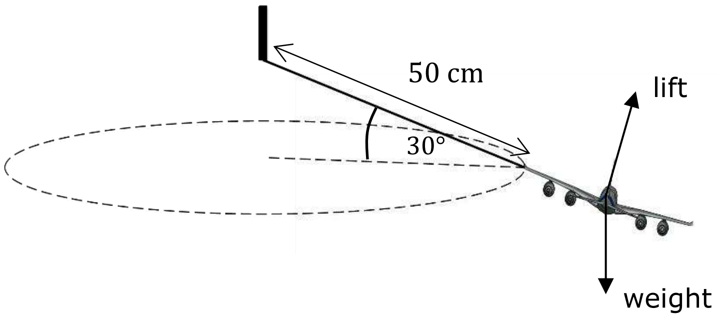

Figure 9

i. Determine the linear velocity of the aeroplane. (4)

ii. Determine the tension in the string and the required lift force to maintain this circular motion. (4)

Assume now that the angle is zero.

iii. Obtain the new expressions for the lift force and the tension in the string. (2)

iv. What will happen to the tension in the string and the lift force if the angular speed is kept constant but the length increases? (3)

(Total: 25 marks)

13.

a. Uranium ${}^{235}_{92}\mathrm{U}$ decays by first undergoing reaction A giving thorium ${}^{231}_{90}\mathrm{Th}$ which then decays through another reaction B to yield protactinium ${}^{231}_{91}\mathrm{Pa}$. The reactions and data on the mass of isotopes is given in Table 1.

Table 1

		Isotope	Mass
Reaction A	${}^{235}_{92}\mathrm{U} \rightarrow {}^{231}_{90}\mathrm{Th} + \mathrm{X}$	${}^{235}_{92}\mathrm{U}$	235.0439 u
Reaction B	${}^{231}_{90}\mathrm{Th} \rightarrow {}^{231}_{91}\mathrm{Pa} + \mathrm{Y}$	${}^{231}_{90}\mathrm{Th}$	231.0363 u
		${}^{231}_{91}\mathrm{Pa}$	231.0359 u
		X	4.0015 u
		Y	0.0005 u

i. Explain what is meant by random decay of a radioactive isotope. (2)

ii. Identify the missing terms X and Y in each nuclear equation. Hence identify the type of decay in reactions A and B. (4)

iii. Define what is meant by nuclear binding energy and mass defect. (2, 2)
iv. Using the information provided, obtain the energy released in reactions A and B in MeV. (6)
v. Which of the reactions from A or B is most likely to happen spontaneously? Explain your answer. (4)

b. Deuterium burning or deuterium fusion is a nuclear fusion reaction that occurs in stars. It is also a potential fusion nuclear energy source on Earth. This can be achieved through the nuclear reaction $^{2}\mathrm{H} + {}^{2}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + {}^{1}\mathrm{n}$.
i. Explain briefly what is meant by nuclear fusion. (2)
ii. The energy released in one such reaction is 5.2164×10^{-13} J. One such reaction also uses 6.7×10^{-27} kg of deuterium fuel. Calculate the energy that is given off by 0.500 kg of deuterium. (2)
iii. Only 75% of the released energy can be converted to useful electrical energy. What happens to the remaining 25% of the energy? (1)

(Total: 25 marks)

14.

a. A solid cylinder of mass m is initially at rest. A light string of negligible thickness is wound around the cylinder. The cylinder is then set into motion along a rough surface by having the string pulled with a constant horizontal force P as shown in Figure 10. F is the frictional force at the surface. After a distance of 1.5 m, the wound string becomes totally unwound.

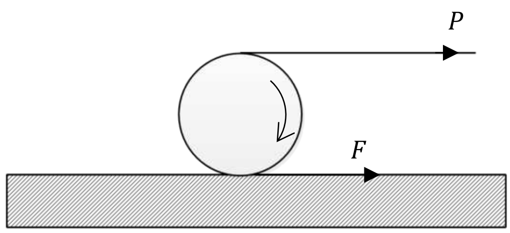

Figure 10

i. If the linear acceleration of the cylinder is a, show that $P = ma - F$. (2)
ii. The moment of inertia I of a cylinder is given by $\frac{1}{2}mr^2$ where r is the radius of the cylinder. Show that $P = \frac{1}{2}ma + F$. (4)
iii. Use the equations in parts (i) and (ii) to show that the frictional force F is one third of the pulling force P, that is $F = \frac{P}{3}$. (3)
iv. If the mass of the cylinder is 5 kg, calculate the linear acceleration of the cylinder when it is being pulled with a force of 10 N. (1)
v. Calculate the velocity of the cylinder after it has travelled the distance of 1.5 m. (3)
vi. Determine the time elapsed to travel this distance. (2)

b. A uniform 1 metre ruler has two small spherical objects A and B attached, one at each end. The spherical object on the left side is of mass M and that on the right is of mass $2M$. The ruler's mass is assumed to be negligible. The ruler is rotated in a vertical plane along the centre of mass of the whole system in a vertical plane at a constant rotational speed ω. Initially, the ruler is horizontal.
i. Determine the distance of the centre of mass of the system from spherical object B. (3)
ii. Obtain the moment of inertia of the ruler in terms of M. (4)
iii. Determine the linear velocities of objects A and B in terms of ω. (3)

(Total: 25 marks)

15.

a. A circuit is composed of 5 identical cells each having emf E and internal resistance r connected in series to an external resistor of resistance R. Another circuit is made of n cells having emf E and internal resistance r connected in parallel to an external resistor having the same external resistance of the first circuit R.

i. Show that the current in the series circuit is given by $I_{series} = \frac{5E}{5r+R}$. (3)

ii. Show that the current in the parallel circuit is given by $I_{parallel} = \frac{E}{\left(\frac{r}{n}+R\right)}$. (3)

iii. Show that the condition for the current flowing in the external resistor R to be equal in both circuits is met when $5r\left(1-\frac{1}{n}\right) = 4R$. (4)

iv. If the cells in the parallel circuit were to be replaced by a single cell, describe the effective behaviour of such a cell as the number n is increased. (2)

b. Pure silicon has 14 electrons in its respective shells, with four of them lying in the outermost shell. The silicon is then doped with two types of impurities, those with valence 3 and those with valence 5.

i. Explain how doping increases the number of holes in silicon if it is doped with a valence 3 impurity. Include a diagram of the resulting crystal structure to explain this process. (3)

ii. Explain what happens in the silicon and its doped variants when an electric field is applied. Your explanation should include a description of what happens to the electrons in the energy bands. (6)

iii. Explain the features of electrical conductivity of pure silicon when the silicon is at a low and a high temperature. (4)

(Total: 25 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

L-Università ta' Malta

ADVANCED MATRICULATION LEVEL
2019 SECOND SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	II
DATE:	3rd September 2019
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 to be $9.81\ \mathrm{m\,s^{-2}}$ 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 faulty car alternator is being tested. The use of an alternator in a car is to restore charge back to the battery. When the alternator, which consists of a rotating coil inside a uniform magnetic field, is rotating at a fixed frequency, the output voltage from the alternator may be described by the equation $V = 12\sin 100t$.

   a. Calculate the periodic time of the alternating voltage output. (3)

   b. The output from the alternator is now connected across a resistive load of $4\ \Omega$.
      i. Write down the equation that describes the variation of current through the load. (3)
      ii. Calculate the root mean square value of the current. (2)
      iii. Calculate the peak value of the power consumed by the load. (2)
      iv. Sketch a graph of power developed across the resistor as it changes with time. (2)

(Total: 12 marks)

2. A trolley of mass $0.40\ \mathrm{kg}$ is attached to two fixed points by springs as shown in Figure 1. When it is displaced horizontally by $0.20\ \mathrm{m}$ from its equilibrium position and released, it undergoes simple harmonic motion with a period of $4.0\ \mathrm{s}$.

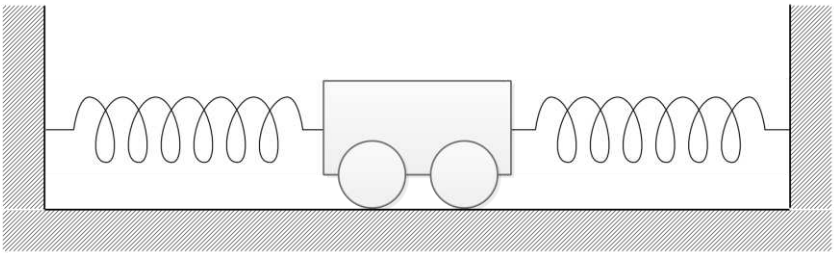

Figure 1

   a. Ignoring any frictional effects, calculate, giving your answers in terms of π:
      i. the maximum speed of the trolley; (3)
      ii. the maximum kinetic energy of the trolley; (2)
      iii. the effective spring constant of the system, k_{eff}. (3)

   b. In practice, one-tenth of its kinetic energy is lost against friction in every complete oscillation. Calculate the kinetic energy of the trolley at the equilibrium position after two complete oscillations. Assume that the kinetic energy when it first passes the equilibrium position is the value calculated in part (a)(ii). (4)

(Total: 12 marks)

3. Many forms of evidence indicate that the Universe is expanding at a very fast rate. One piece of evidence is the 'red shift' of light from distance galaxies.

   a. Briefly describe **TWO** other pieces of evidence that support the expanding universe model. (4)

   b. Explain the meaning of the term 'red shift'. (2)

   c. In 1929, Hubble used the Doppler effect to measure the speed of recession of a number of galaxies located at various distances from Earth.
      i. State Hubble's law. (2)
      ii. Represent Hubble's law graphically. (2)

   d. A galaxy is receding away from Earth at a speed of about $7.2 \times 10^{7}\ \mathrm{m\,s^{-1}}$. Given that one estimate of the Hubble constant is $1.7 \times 10^{-18}\ \mathrm{s^{-1}}$, calculate how far this galaxy is from Earth. (2)

(Total: 12 marks)

4.
   a. Define the term electric field strength at a point. (1)

   b. Copy the diagram in Figure 2 and draw on it the electric field lines around two positive equal charges A and B. Mark with the symbol 'X' the point where the resultant electric field strength is zero.

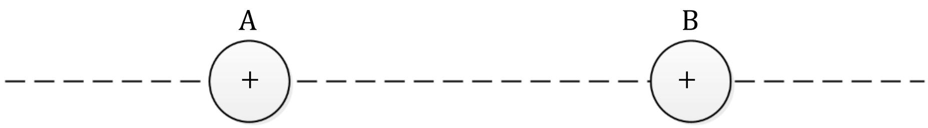

Figure 2

(3)

   c. Point charges C, of $+2.0\ \mathrm{nC}$, and D, of $-3.0\ \mathrm{nC}$, are $200\ \mathrm{mm}$ apart in a vacuum as shown in Figure 3. A positive unit test charge at point P is $120\ \mathrm{mm}$ from C and $160\ \mathrm{mm}$ from D.

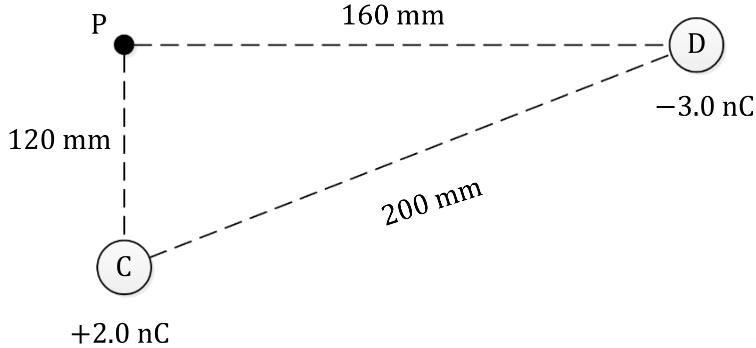

Figure 3

      i. Calculate the electric field strength at P due to point charge C. (2)
      ii. Calculate the electric field strength at P due to point charge D. (2)
      iii. Draw a free body diagram showing the forces acting on the positive unit test charge at P and calculate the magnitude and direction of the resultant force acting on the test charge. Directions indicated should be as measured from the horizontal. (6)

(Total: 14 marks)

5.

a. State the **THREE** main mechanisms with which heat transfer may occur and briefly describe how the three mechanisms are different from each other. (6)

b. The following are observations from everyday situations. In each case, explain the observations in terms of the above-mentioned mechanisms.
   i. After a marathon event aluminium foil blankets are issued to athletes. Why? (2)
   ii. Why are hot drinks such as coffees and teas often poured in ceramic containers rather than glassware? (2)

(Total: 10 marks)

6. Two cylindrical metal rods, A and B are placed as shown in Figure **4.** A is a copper cylinder of length $0.5\ \mathrm{m}$ while B is a silver cylinder of length $0.3\ \mathrm{m}$. Both have the same diameter of 4 cm. A layer of lagging is also placed around the cylinders. The end of cylinder A is kept at a temperature of 75℃ while cylinder B is kept at a temperature of 10℃ when a steady state condition is reached.

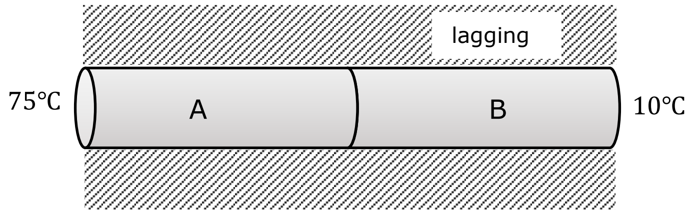

Figure 4

a. Explain what is meant by steady state condition. How may this be verified? (3)

b. Suggest a suitable lagging material. Give a reason for your answer. (2)

c. The thermal conductivity of copper and silver are $385\ \mathrm{W\,m^{-1}\,K^{-1}}$ and $406\ \mathrm{W\,m^{-1}\,K^{-1}}$ respectively. Find:
   i. the temperature at the junction between the two metal rods, and; (4)
   ii. the rate of heat flow through the copper bar. (3)

d. Draw **TWO** graphs; one that shows how the temperature changes along the length of the two metal rods when the rods are lagged and one that shows the temperature changes along the length of the rods when only the copper rod is unlagged. (4)

(Total: 16 marks)

7.

a. Describe an experiment which you would use to find the exact focal length, f, of a thin converging lens. In your description include:
   i. a list of the apparatus that is needed; (1)
   ii. a diagram of how the apparatus should be set up; (2)
   iii. a description of the method used to carry out the experiment, including a table of the data to be recorded from the experiment; (3)
   iv. a labelled graph and the calculations that are required to obtain the focal length of the lens. (2)

b. Calculate the image distance of an image produced from a converging lens of focal length 12 cm when an object is placed:
   i. 15 cm; (1)
   ii. 6 cm (1)
   from the lens and for each case, state TWO properties that define the type of image produced. (1, 1)

(Total: 12 marks)

8.

a. Define the specific heat capacity of a material. (2)

b. Briefly describe how the specific heat capacity of a solid metal block may be found using the electrical method. In your description include:
   i. a list of the apparatus that is needed; (2)
   ii. a diagram of how the apparatus should be set up; (2)
   iii. a description of the method used to carry out the experiment, including a list of the data to be recorded from the experiment and a list of precautions; (3)
   iv. the calculations that are required to determine the specific heat capacity of the metal block. (1)

c. Find the specific heat capacity of a block of aluminium given that one such block of mass 2 kg has its temperature changed by 4 °C in a period of 10 minutes by a 12 V heater through which a constant current of 1 A flowed through. (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 source of monochromatic light from a red laser illuminates a double slit to produce an interference pattern on a screen.
   i. Explain the term interference. Distinguish between constructive and destructive interference. (3)
   ii. List the conditions that must be fulfilled in order to demonstrate interference of light and describe how each can be achieved in practice. (3)
   iii. State what happens to the interference pattern when
      - the slit separation is decreased; (2)
      - the separation between the source and the screen is increased. (2)
   iv. Why does the number of fringes that can be observed decrease when the monochromatic light is changed to a white lamp and a yellow filter? (3)

b. Two sources of light, one with a wavelength of 440 nm and another of 630 nm are incident on a diffraction grating of 600 lines per mm.
   i. Draw a diagram that shows how the incident light beam from one of the sources diffracts and produces an interference pattern on the screen. (4)
   ii. Calculate the angular separation between the second-order fringes for these two light sources. (4)
   iii. Calculate the maximum number of orders that can be obtained by using this grating and the 630 nm light source? Explain your reasoning. (4)

(Total: 25 marks)

10.

a. Distinguish between transverse and longitudinal waves and mention **ONE** example of each type of wave. (4)

b. The speed of a sound wave through a solid depends on the internal structure of the solid. Through the use of a diagram, explain why this is so. (2)

c. A travelling sine wave of frequency $800\ \mathrm{Hz}$ and amplitude $0.015\ \mathrm{m}$ is moving with a velocity of $50\ \mathrm{m\ s^{-1}}$ in the positive x-direction.
   i. Write down the wave equation that represents the motion of the wave. (2)
   ii. Determine the wavelength λ of the wave. (2)
   iii. Calculate the phase difference between two points on the wave which are $0.125\ \mathrm{m}$ apart. (2)

d. The progressive wave in part (b) is now reflected back along its original path forming a stationary wave.
   i. State how progressive and stationary waves differ in terms of energy transfer, the amplitude at points along the wire and the phase difference between points along the wave. (4)
   ii. Using values obtained through part (c), calculate the distance between two consecutive nodes in the above stationary wave. (2)
   iii. What is the phase difference between two vibrating points, one of which lies on an antinode while the other lies $2\ \mathrm{cm}$ away from it? Explain your answer. (2)

e. Two strings, A and B have their ends attached between two fixed supports. The strings are $15.0\ \mathrm{m}$ long. String A has a mass of $78.0\ \mathrm{g}$ and a tension of $180.0\ \mathrm{N}$. The second string B has a mass of $58.0\ \mathrm{g}$ and a tension of $160.0\ \mathrm{N}$. A pulse is generated in each string simultaneously.
   i. On which string, A or B, will the pulse move faster? (2)
   ii. Once the faster pulse reaches the far end of its string, how much later will the slower pulse arrive at the end of its string? (3)

(Total: 25 marks)

11.

a.
   i. State Newton's Law of Gravitation. (2)
   ii. Define gravitational field strength, g, at a point in a gravitational field. (2)
   iii. Write down an equation for the gravitational field strength, g, on the Earth's surface in terms of the mass of the Earth, M_e, the radius of the Earth, R_e, and the constant, G. (2)
   iv. State the conditions under which the equation written down in part (a)(iii) is valid. (2)

b. The moon is a natural satellite of planet Earth.
   i. Show that the period of rotation T of the moon around Earth is related to the radius of the orbit of the moon around Earth r_m, and the mass of the Earth M_e, by the equation $T^2 = \frac{4\pi^2 r_m^3}{GM_e}$. (4)
   ii. State **THREE** assumptions which underly the derivation of the equation in part (b)(i). (3)

iii. Given that the Earth-Moon distance r_m is 3.84×10^8 m and moon orbits once around the Earth in exactly 27.322 days, use the equations derived in part (a)(iii) and in part (b)(i) to find a value for the acceleration of free fall, g, on the Earth's surface. (4)

c. A satellite of mass m is orbiting Earth in an orbit of radius r with speed v.

i. Define the gravitational potential at a point in a gravitational field. (2)

ii. Write down an expression for the gravitational potential energy E_p of the satellite, in terms of the quantities given. (2)

iii. Derive an expression for the kinetic energy E_k of the satellite. (2)

(Total: 25 marks)

12.

a.

i. Derive an expression for the combined capacitance of two capacitors with capacitances C_1 and C_2 when connected in series. (3)

ii. Two capacitors of 25 μF and 100 μF respectively are joined in series with a d.c. supply of 6 V. Calculate the charge on each capacitor and the p.d. across the 25 μF capacitor. (2, 1)

b. A capacitor has a capacitance of 47 μF.

i. Briefly describe the features in capacitor construction that can give even higher capacitance values despite retaining a relatively small physical size. (2)

ii. The capacitor is charged through a resistor R of 220 kΩ from a 9 V d.c. supply. Draw a diagram of a suitable circuit that may be used for charging. (3)

iii. What is the time-constant of the circuit? (2)

iv. Sketch a graph to show how the current through the resistor varies with time. Indicate clearly the value of the initial current through the resistor. (4)

v. What is the voltage across the resistor when $t = 0.40\ s$ have elapsed? (4)

vi. Calculate the energy stored by the capacitor when it is fully charged. (2)

vii. The capacitor takes only a few seconds to charge fully. What value of the resistance would you connect instead of R to increase the time taken by the charging process to about 1 minute? (2)

(Total: 25 marks)

13.

a. State Faraday's and Lenz's laws of electromagnetic induction. (2, 2)

b. Describe an experiment to demonstrate Lenz's law. In your description include:

i. a list of the apparatus that is needed; (1)

ii. a diagram of how the apparatus should be set up; (2)

iii. a description of the method used to carry out the experiment, and (2)

iv. a description of the observations that support Lenz's law. (1)

c. Explain how Lenz's law is a direct consequence of the principle of the conservation of energy. (3)

d. A coil of self-inductance 24 mH and having negligible resistance is connected in series with a resistor of resistance 150 Ω, a switch and a d.c. power supply of 10 V. The switch is closed.

i. Define self-inductance. (3)

ii. Calculate the rate of change of current when the switch is closed. (4)

iii. Find the value of the energy stored in the coil's magnetic field when a steady current flows through. (2)

iv. Why does a spark jump across the switch if the circuit is opened? (3)

(Total: 25 marks)

14.

a. In 1879, Edwin Hall discovered that an electrical potential difference is set up transversely in a current carrying conductor when it is under the influence of an applied magnetic field that is perpendicular to the flowing electric current. This effect is called the Hall Effect.

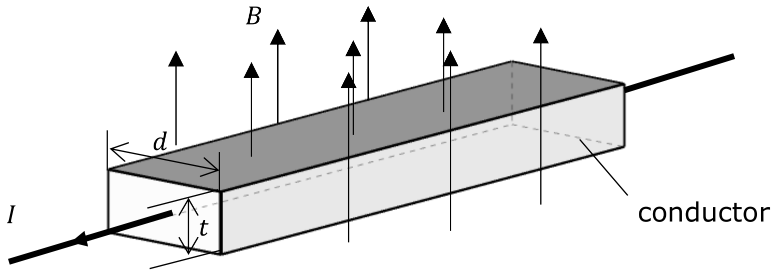

Figure 5

i. Describe in terms of the movement of charge carriers how the Hall Effect originates. (3)

ii. On a copy of the diagram in Figure 5, sketch the charge particle build-up on the specimen conductor, indicating clearly the polarity of the charge build up. Take the specimen conductor to have electrons as the majority charge carriers. (3)

iii. Show that the Hall voltage V_H, in terms of the current I, magnetic field strength B, number of charge carrier per unit volume n is given by $V_H = \frac{BI}{net}$, where t is the thickness of the specimen and e is the electronic charge. (6)

b. A copper sample of uniform thickness t equal to $1.5\ \mathrm{mm}$, is placed in a magnetic field B of flux density $2.0\ \mathrm{T}$ perpendicular to its largest surfaces. A current I of $3.0\ \mathrm{A}$ flows through the sample. Assume that in copper there are 1.0×10^{29} free electrons per cubic meter.

i. Calculate the Hall voltage. (2)

ii. Give a reason for the small order of magnitude of the Hall voltage calculated in part (c)(i). (2)

iii. Explain why Hall voltage is much more measurable with semiconductor specimens rather than metal specimens. (2)

c. Describe an experimental investigation to determine how the magnetic flux density due to a long straight conductor carrying a current, varies with the radial distance from the wire. Your investigation should include:

i. a list of the apparatus that is needed; (1)

ii. a diagram of how the apparatus should be set up; (2)

iii. a description of the method used to carry out the experiment, including a list of the data to be recorded from the experiment, and; (2)

iv. a labelled graph displaying the expected results. (2)

(Total: 25 marks)

15.

a. Distinguish between isothermal and adiabatic processes. (4)

b. How can an isothermal and an adiabatic change be approximated in practice? (4)

c. A cylinder of an engine can be considered to undergo a cycle of changes in pressure, volume, and temperature. One such cycle is represented in Figure 6 below.

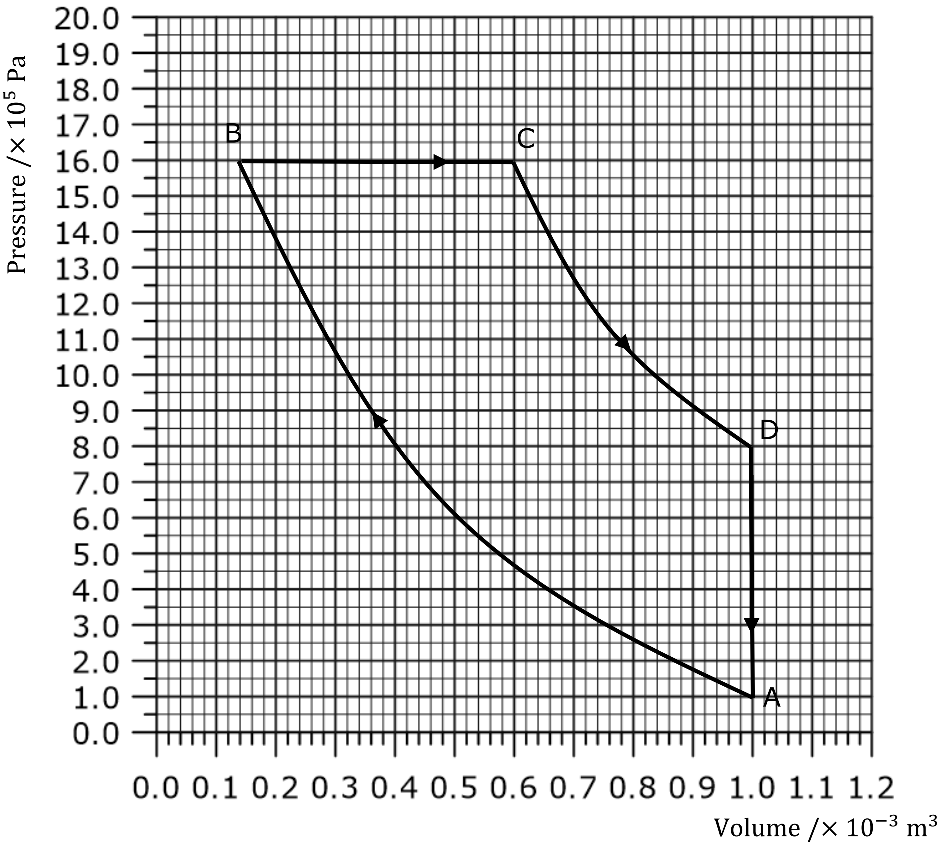

Figure 6

The temperatures of the gas at A and B are 300 K and 672 K respectively.

i. Use the ideal gas equation and data from the graph, to find the temperatures at C and at D. (4)

ii. Calculate the work done on the gas in the section B to C and D to A of the cycle. (4)

iii. Calculate the number of moles of gas present in the cylinder. (2)

iv. If 1.2 kJ of heat is supplied to the gas in the section of the cycle from B to C, find a value for the molar heat capacity c_p at constant pressure. (2)

v. Calculate the increase in internal energy of the gas in the same section, B to C. (3)

vi. Explain why the total change in the internal energy of the gas during a complete cycle must be zero. (2)

(Total: 25 marks)

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2019 SECOND SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	III – *Practical*
DATE:	29th August 2019
TIME:	2 hours 5 minutes

Experiment: Experiments with a mass-spring system and a bifilar pendulum.

Apparatus: stand and clamp, steel spring, metre ruler, light strings, toothpicks, stopwatch, wooden beam and several washers/masses.

Diagram:

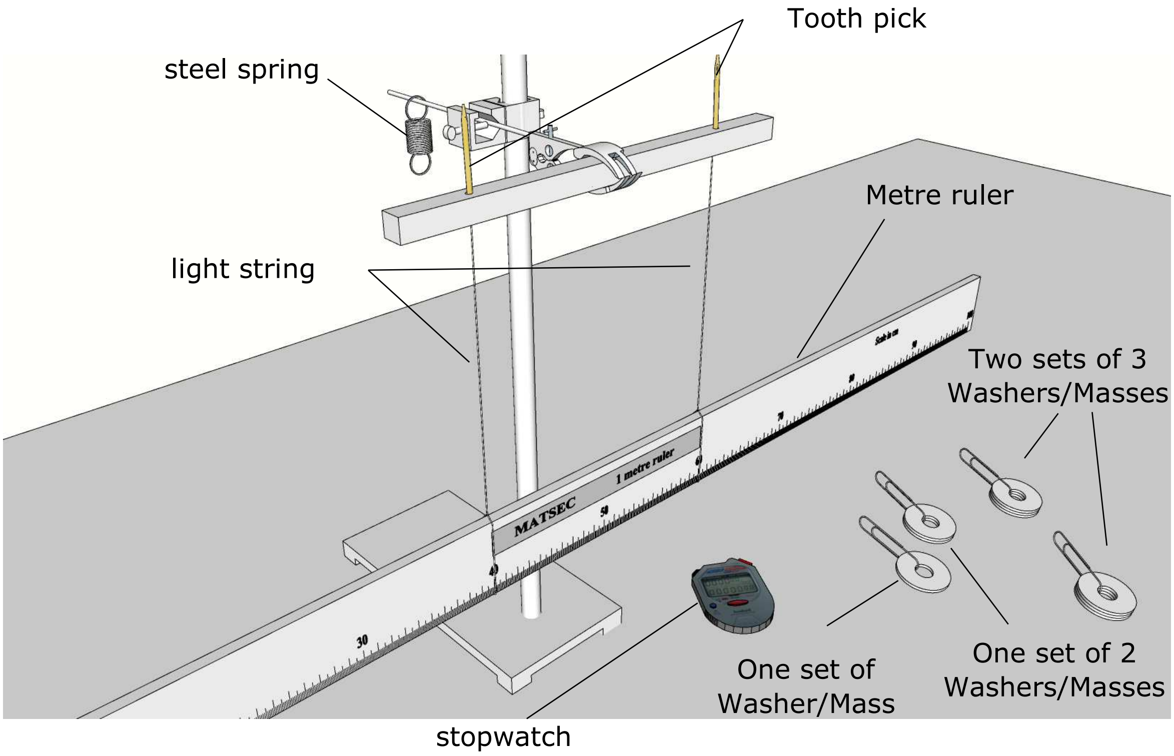

Figure 1 The experimental setup

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.
2. Simple harmonic oscillations of a mass on a steel spring will be used to determine the unknown mass m of steel washers.
3. State the **TWO** conditions necessary for an object to undergo simple harmonic motion.

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(4)

4. In the apparatus provided one should find washers kept together by a large paper clip in different sets of one, two and three washers. These washers will act as the masses.
5. Attach to the lower end of the spring, **ONE** set of three washers, corresponding to $n = 3$ in Table 1.
6. With the masses attached, gently pull down on the masses and release so that the system oscillates vertically.
7. Record the time it takes to complete twenty oscillations. Record this in the column for the first reading of T_{20} in Table 1. Repeat another two times to have three repeated readings and record the time for twenty oscillations in the columns for the 2nd and 3rd reading. (3)

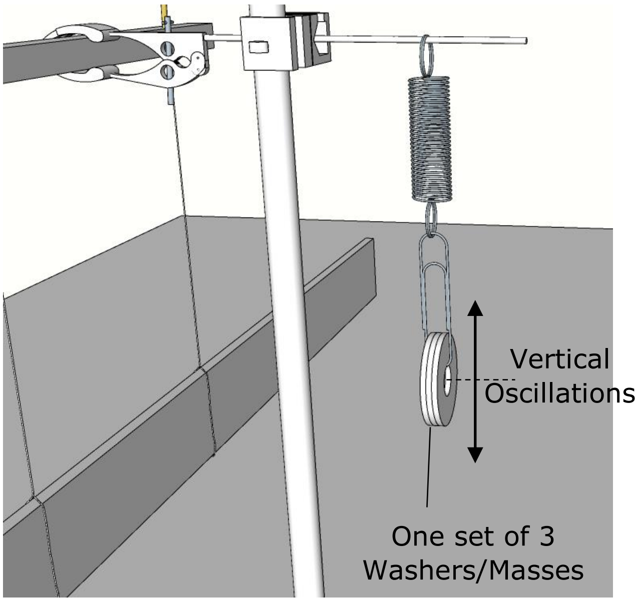

Figure 2

8. Repeat steps 6 and 7 for the number of washers n given in Table 1. Use different combinations of the sets of washers provided to get the requested number of masses indicated in Table 1. (18)

Table 1

Number of washers/masses	1st Reading	2nd Reading	3rd Reading			
n	T_{20}/s	T_{20}/s	T_{20}/s	$\overline{T_{20}}/\mathrm{s}$	T/s	$T^2\ /\mathrm{s}^2$
3						
4						
5						
6						
7						
8						
9						

9. Complete Table 1 by working out the average value for twenty oscillations $\overline{T_{20}}$, the periodic time T and T^2. (7)

10. It is known that the periodic time of a mass-spring system is given by $k^{\frac{1}{2}}T = 2\pi n^{\frac{1}{2}} m^{\frac{1}{2}}$, where m is the mass of a single washer and k is the spring constant.

11. Write the equation in Step 10 in the form $y = mx + c$ such that the independent variable x is n and the dependent variable y is T^2.

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(3)

12. Plot a graph of T^2/s^2 on the y-axis against n on the x-axis. (10)

13. Use the graph to determine the mass m of a single washer, provided that the spring constant is $12.5\ \mathrm{N\ m^{-1}}$.

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(5)

14. One source of error arises from the fact that the mass of the paper clips was not taken into consideration. Given that the mass of each paper clip is $1.6\ \mathrm{g}$, use the value of the mass of the washers obtained in Step 13 to calculate the maximum percentage difference between the assumed attached masses and the real effective masses.

(6)

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Method – Part B:

15. This part of the experiment will investigate the twisting oscillations of a metre rule supported by two strings.
16. Hang the **TWO** sets of **THREE** washers on each side of the meter ruler $5\ \mathrm{cm}$ from each end as shown in Figure 3.

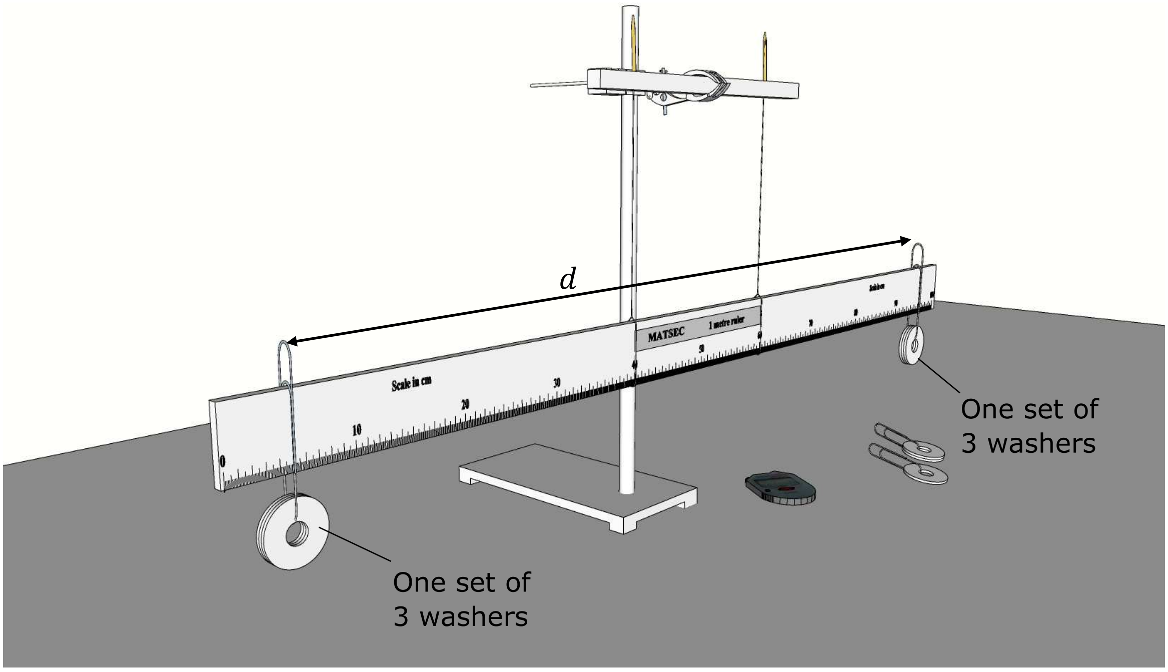

Figure 3

17. Set the metre ruler twisting with small amplitude oscillations about the vertical axis through its centre. The metre ruler should oscillate as shown in Figure 4.

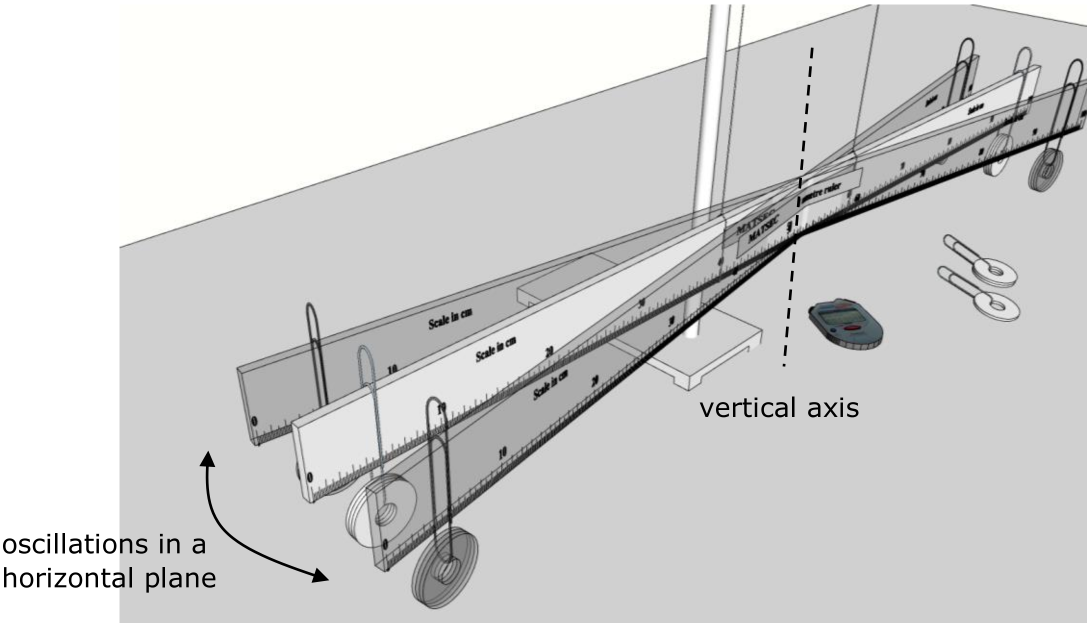

Figure 4

18. The time T_{10} for ten oscillations of the metre ruler will be measured for five different values of the distance d between the two masses.

19. For the distance $d = 0.90\ \mathrm{m}$ between the two masses, set the ruler oscillating. Measure and record in Table 2 the corresponding period of time T_{10} of small twisting oscillations for this loaded ruler. Repeat the time measurements another two times to have repeated readings.
(3)

20. Repeat step 19 for the distances d shown in Table 2. Ensure that the masses are always at equal distances from the ends of the ruler. (12)

Table 2

		1st reading	2nd reading	3rd Reading			
d /m	d^2/m^2	T_{10} /s	T_{10} /s	T_{10} /s	$\overline{T_{10}}$/s	T /s	T^2 /s^2
0.90							
0.84							
0.78							
0.72							
0.66							

21. Complete Table 2 by working out d^2, the average value for ten oscillations $\overline{T_{10}}$, the periodic time T and T^2. (5)

22. It is known that the periodic time T of the oscillations depends on the distance d between the masses by the equation

$$T^2 = 3mKd^2 + 0.167KM_{ruler}$$

where K is a constant, m is the mass of a single washer and M_{ruler} is the mass of the ruler.

23. Plot a graph of T^2/s^2 on the y-axis against d^2 /m^2 on the x-axis. (10)

24. Use the graph and the value of the mass of the washer m in kg obtained in step 13 to determine the value of the constant K and state its units.

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(5)

25. Determine the mass of the ruler M_{ruler}.

(5)

26. State **ONE** source of error present in this part of the experiment and **ONE** corresponding precaution.

(4)

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