L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2023 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	I
DATE:	20th May 2023
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. Daniel Bernoulli was a Swiss mathematician and physicist who deduced an important result for fluid flow. The mathematical relationship is shown in the following equation:

$$\frac{1}{2}\rho v^2 + \rho g h + P = Total\ Pressure$$

where v is the velocity of the fluid, ρ is the fluid density, g is the acceleration due to gravity, h is the height and P is the static pressure. The relationship simply states that the total pressure is a constant and is always the sum of three components: $\frac{1}{2}\rho v^2$, $\rho g h$ and P.

a. Show that the base SI units of all three terms on the left-hand side are the same. (4)

b. State whether the velocity, the density, the acceleration due to gravity and the height are vector or scalar quantities. (2)

c. Calculate the "*Total Pressure*" in a pipe carrying a fluid whose density is 1.3 gcm^{-3}, its velocity is 20 ms^{-1}, the height is 0.98 km and whose static pressure is 2 bar. Give your answer in MPa. (1 bar = 100,000 Pa) (4)

(Total: 10 marks)

2. A well has a bucket suspended by a rope which is wound around a cylindrical wooden drum as shown in Figure 1.

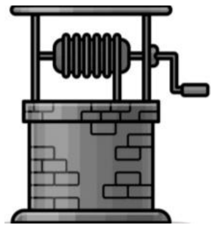

Figure 1

a. What energy transformations are occurring from the moment the bucket is released from the top, until the moment it is about to hit the water surface? (Assume that the bucket is falling freely). (3)

b. Two wooden drums are available. Drum 1 has a mass of 4 kg and drum 2 has a mass of 28 kg. The empty bucket has a mass, m, of 2.0 kg. The moment of inertia of a solid cylinder about its central axis is $I = \frac{1}{2}Mr^2$

i. Show that the velocity of the falling bucket at any point is independent of the radius of the drum. (4)

ii. Show that the velocity of the bucket when using drum 1 is twice that when using drum 2. (3)

(Total: 10 marks)

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3. A supercomputer complex is backed up by diesel engine generators in case of power outages. The supercomputer building's peak power use is of 1.5 MW. The diesel engines are able to kick in and deliver the required power in 5 s. To cover for these 5 s a large flywheel is kept spinning at 100 rpm (revolutions per minute) all the time in a vacuum chamber. This is used to keep turning the electrical generator until the diesel generators kick in. In the following calculations, assume that the flywheel is a solid stainless-steel cylinder and take the density of stainless steel to be 8000 kgm^{-3}.
(The moment of inertia of a solid cylinder about its central axis is $I = \frac{1}{2}Mr^2$).

   a. Determine the minimum energy that should be stored in the flywheel to cover the whole 5 s power outage until the diesel generators kick in. (3)

   b. The electrical engineers operating the electrical generator require that during the 5 s power outage the speed of the flywheel does not go below 50 rpm. By taking the initial angular velocity as 100 rpm and the final angular velocity as 50 rpm over these 5 s, determine the minimum moment of inertia of the flywheel. (6)

   c. State how the size of the flywheel can be reduced. (1)

(Total: 10 marks)

4. A metal filament extrusion machine is used alongside a rotating puller as shown in Figure 2. The puller changes the tension such that the filament is extended while it is still hot, and therefore the diameter is reduced. The stress at the yield point is 30 MPa, and the diameter of the filament at this point is 1.5 mm.

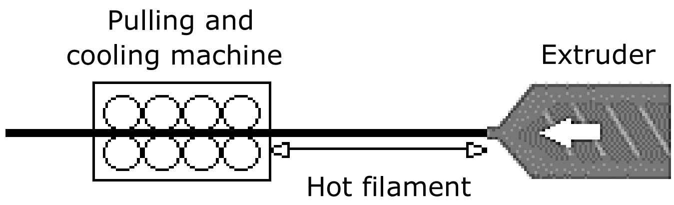

Figure 2

   a. Sketch a stress-strain graph for the hot metal filament. On your graph, label and define the key points. (6)

   b. By referring to the stress-strain graph, in what region should the puller be working in order to be able to create this extension and reduce the wire's diameter? Give a reason for your answer. (2)

   c. Calculate the minimum tension that the puller has to provide in order to permanently change the length of the filament. (2)

(Total: 10 marks)

5. Regenerative braking systems are a type of kinetic energy recovery system that transfers the kinetic energy of an object in motion into stored energy to slow the vehicle down, and as a result increases fuel efficiency. An electric scooter has a battery of capacity 36 kC. The following graph shows the current flowing from the battery to the motor (positive current), and from the regenerative braking system to the battery (negative current) during a 6-minute trip. Negative current means that the battery is recharging.

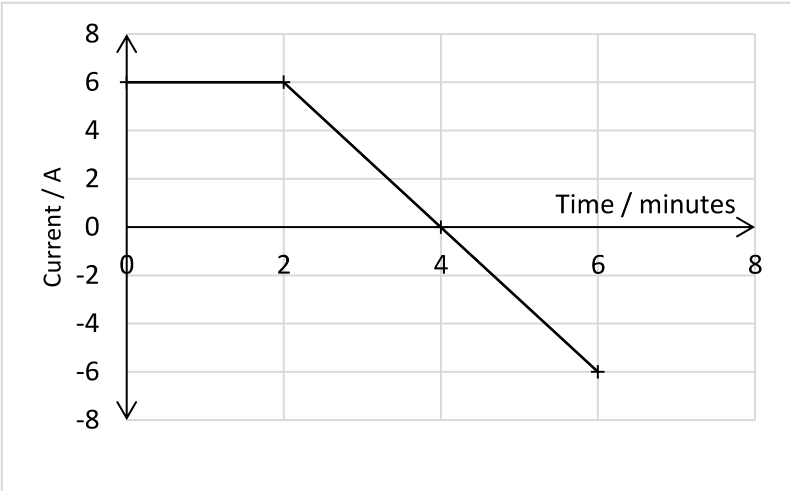

Figure 3

a. If the trip started with a fully charged battery, determine the charge at the 2nd, 4th and 6th minute. (3)

b. Sketch a graph showing how the charge of the battery varies during this trip. (5)

c. Find the net charge expended during the 6-minute trip. Hence, find the average current consumed. (2)

(Total: 10 marks)

6.

a. Define 'electromotive force' (EMF) of, and 'electrical potential difference' across a power supply. Explain the difference between them. (4)

b. A 10 V battery is connected in series with a 5 Ω resistor. The current flowing through the resistor is 1.5 A. Find the internal resistance of the battery. (4)

c. A potential difference of 20 V is applied across a filament lamp. The work done by this potential difference is 50 J over 2 s. Calculate the current through the lamp. (2)

(Total: 10 marks)

Please turn the page.

7. A sun tracking system makes use of four light dependent resistors (LDRs) electrically connected as shown in Figure 4. Each LDR has a resistance of 100 Ω when exposed to sunlight and 1 kΩ when in the shadow. The four LDRs are to be fitted in a plastic enclosure and placed on an unobstructed rooftop. The plastic enclosure has a plastic wall that is intended to create a shadow on a pair of LDRs during the afternoon, as shown in Figure 5.

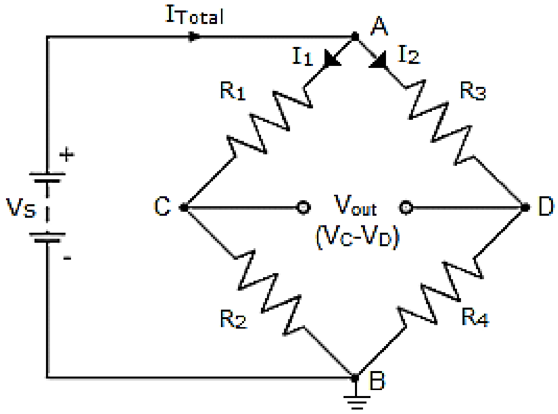

Figure 4

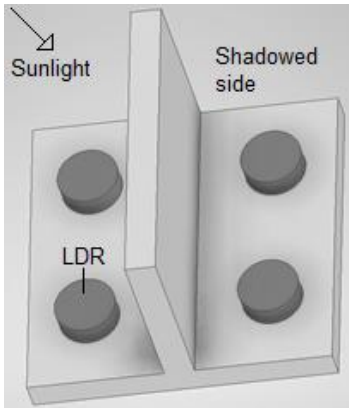

Figure 5

a. Obtain expressions for the potentials V_C and V_D in terms of resistances and V_S only. (4)

b. Determine which LDRs should be placed in the sunlight and which ones should be on the shadowed side in order to maximise the voltage $V_{OUT} = V_C - V_D$. Explain your answer. (4)

c. Calculate the maximum output voltage V_{OUT} in terms of V_S. (2)

(Total: 10 marks)

8. Radon is a radioactive gas released from soil, rocks, and water. It is naturally present in our outdoor air at levels so low that it is not considered harmful. Figure 6 is showing the first part of the decay chain for Radon-222. The half-life of each element is shown underneath each element.

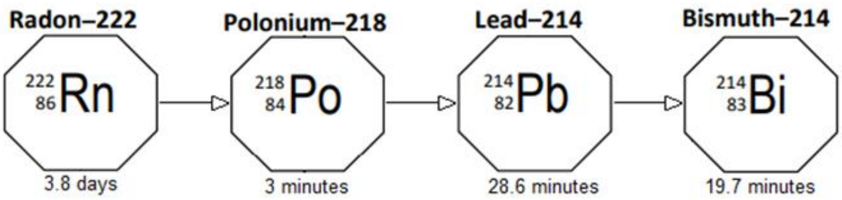

Figure 6

a. Define the term 'isotope'. (2)

b. Which is the least stable element from Figure 6? Justify your answer. (1)

c. Determine the amount of neutrons and hadrons in Bismuth-214. (1)

d. State the decay processes taking place between each element. Explain your answer. (3)

e. From the equation $N=N_0e^{-\lambda t}$, derive a relationship between the half-life and the radioactive decay constant. Hence find the decay constant for Lead-214. (3)

(Total: 10 marks)

SECTION B
Attempt any FOUR questions from this section. Each question carries 20 marks. This section carries 50% of the total marks for this paper.

9.

a. A firework rocket is fired from a canon at an initial velocity of 100 ms^{-1}. The rocket is made to explode 500 m away, as shown in Figure 7. If at the time of explosion, the rocket is travelling with a horizontal velocity of 50 ms^{-1}, calculate:
   i. the angle at which the rocket is fired; (3)
   ii. the height of the point of explosion (labelled as y); (4)
   iii. the velocity of the rocket just before it explodes; (3)
   iv. the maximum height reached by the rocket. (3)

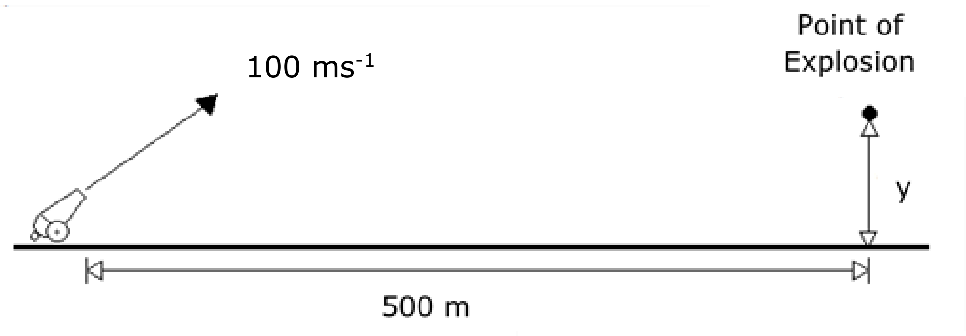

Figure 7 (Not to scale)

b. A skydiver jumps from a plane and shortly afterwards opens up the parachute.
   i. Draw a free body diagram of the forces acting on the skydiver as soon as she jumps (before the parachute opens). (1)
   ii. Draw another free body diagram of the forces acting on the skydiver as soon as the parachute is opened. Comment on the size of forces and type of motion. (2)
   iii. Draw a graph of speed vs time for the whole journey, starting from the moment he jumps off the plane and ending as soon as he reaches the ground. Explain the different sections of your graph, indicating the time at which the parachute is opened by t_0. (3)
   iv. At a certain point in his journey, the skydiver is travelling at constant velocity. What is this velocity called? (1)

(Total: 20 marks)

10.

a. Define the term 'centripetal force'. (2)

b. Derive the equation $a = \frac{v^2}{r}$, where *a* is the centripetal acceleration for a body moving in at constant speed in a circular path. Draw a diagram to show your reasoning. (7)

c. An astronaut is on a space station. The space station is orbiting Earth at 229 km above sea level and travelling at a speed of 28000 km hr^{-1}. (Earth's radius = 6371 km).
   i. Calculate the centripetal acceleration required to keep the station in orbit. (2)
   ii. Calculate the angular velocity of the astronaut.Give your answer to 3 significant figures. (2)
   iii. Calculate the speed at which the station has to travel for the astronaut to experience weightlessness. Assume that the change in acceleration due to gravity between the space station and Earth's surface is negligible. (3)

Question continues on next page.

d. Consider a plane banking at an angle θ in order to turn as shown in Figure 8. Derive an equation for the angle of banking θ in terms of the radius r, the plane's velocity v and the acceleration due to gravity g. (2)

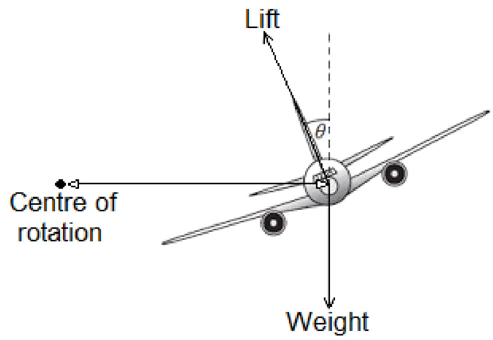

Figure 8

e. The maximum banking angle that a passenger plane is allowed to make is 25°. If the plane is flying at 250 ms^{-1}, what is the minimum turning radius that can be safely undertaken by the plane? (2)

(Total: 20 marks)

11.

a. Define the terms 'moment', 'couple' and 'torque'. (3)

b. A uniform metre ruler weighs 100 g and is balanced in static equilibrium as shown in Figure 9.

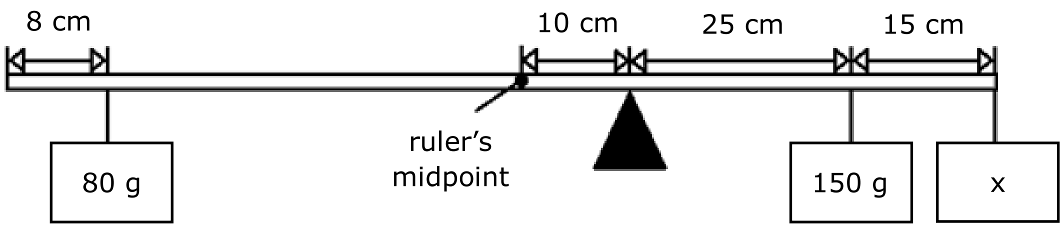

Figure 9

i. Define the term 'centre of gravity'. (1)

ii. State the conditions for static equilibrium of a rigid extended body under the action of a set of coplanar forces. (2)

iii. Calculate the unknown mass, x. (5)

iv. Calculate the total reaction force on the ruler. (2)

c. A decoration is hung in static equilibrium using elastic strings attached to walls as shown in Figure 10. The decoration is placed equidistant to both walls.

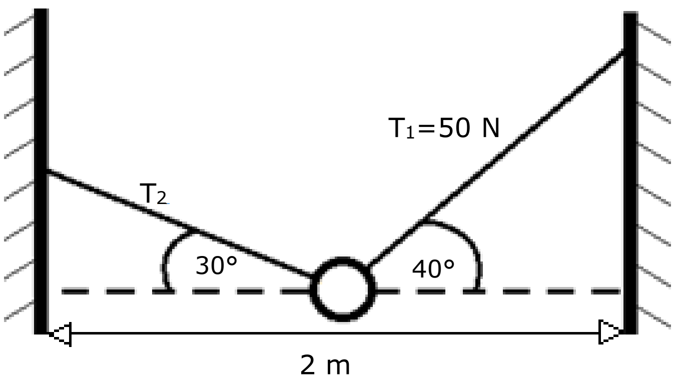

Figure 10

i. One string is at a tension T_1=50 N. Find the tension T_2 within the other string. (2)
ii. Find the mass of the decoration. (1)
iii. The decoration is pulled downwards by 10 cm and held in place at this position. The strings are still attached to the walls at their original positions (the strings are stretched further). Calculate the ratio of the tensions in the strings, $\frac{T_1}{T_2}$. (4)

(Total: 20 marks)

12.

a. Explain the terms ductile material and brittle material. Include appropriate diagrams in your explanation and give **ONE** example of **each** type of material. (6)

b.

i. A metal wire is stretched within its limit of proportionality. Derive a relationship between the stiffness constant and Young's modulus for a wire of cross-sectional area *A* and unstretched length, *L*. (4)
ii. A copper wire is 200 mm long and has a diameter of 2 mm. Determine the change in length if a force of 15 kN is applied. Assume that the material remains within its elastic limit. (Young's modulus of copper = 1.1×10^{11} N m^{-2}). (4)

c. Springs A and B have spring constants k_1 and k_2 respectively, and k_1 is twice k_2.

i. If spring A is compressed by 5 mm, find by how much must spring B be compressed in order to store the same amount of energy as spring A. (3)
ii. Springs A and B are now connected in series (end to end). Express the effective spring constant in terms of k_2. (3)

(Total: 20 marks)

13.

a. Consider a copper wire with a diameter of 1 mm carrying a current of 5 A.

i. Define the term 'drift velocity' and explain what gives rise to this velocity. Hence, explain why a light bulb turns on almost instantaneously when a switch is closed. (4)
ii. Sketch a typical path of an electron travelling through a conducting wire. Clearly label the directions of the electric field and the electron's drift velocity. (1)
iii. If the drift velocity inside the copper wire is 4.5×10^{-4} ms^{-1}, calculate the free electron density of copper. (2)

b.

i. Distinguish between pure and impure semiconductors. Identify both types of impure semiconductors and briefly explain the differences between them. (4)
ii. How can both types of impure semiconductors be used to rectify an AC current? Explain your answer using the terms 'depletion layer' and 'bias'. (5)
iii. Sketch a simple diagram to support your explanation in part (ii). Include the relevant electrical symbol alongside your diagram. (2)
iv. Sketch and label an appropriate IV graph to back up your explanation in part (ii). (2)

(Total: 20 marks)

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14.

a. Consider the circuit shown in Figure 11.

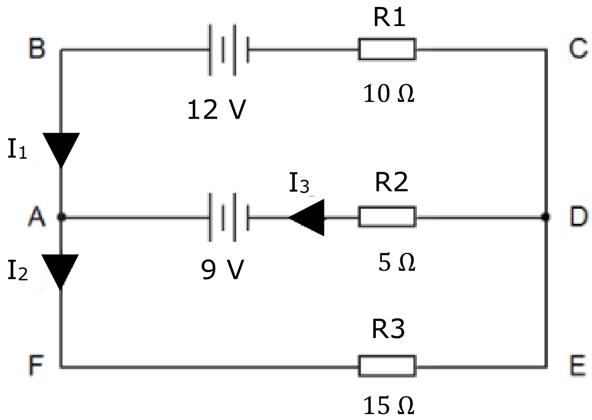

Figure 11

i. State Kirchhoff's laws and identify the associated conservation laws. (2)

ii. Hence find the values of I_1, I_2 and I_3. (7)

iii. Calculate the power dissipated as heat in the circuit. (2)

b. Denise would like to accurately measure the EMF of her car battery. Alfred told her that it would be more accurate to employ a null measurement technique, rather than simply connecting the battery to a voltmeter or an ammeter and a known resistance.

i. Explain why Alfred has given Denise such a recommendation. (3)

ii. Explain how Denise can use a potentiometer to accurately measure the EMF of her battery using a null measurement technique. Draw a diagram and include any necessary calculations in your explanation. (6)

(Total: 20 marks)

15.

a. Sketch and label the structure of a photocell. Include the direction of electron flow. (2)

b. Describe an experiment to determine Planck's constant. The description should include:

i. a detailed diagram; (3)

ii. brief description of the procedure followed; (3)

iii. data tabulation; (1)

iv. a plot of the relevant graph (Identify x and y intercepts); (4)

v. any calculations necessary to determine Planck's constant. (2)

c. Classical wave theory is inconsistent with the relationship observed between emitted photocurrent and the intensity of the incoming light.

i. On the same axes, sketch **TWO** curves to illustrate how photocurrent changes with applied potential difference for two values of intensity of the incoming light. Identify the x-intercept for each curve. Clearly label both curves. (4)

ii. Explain how your curves illustrate the inconsistency predicted by classical wave theory. (1)

(Total: 20 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2023 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	II
DATE:	20th May 2023
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 $g = 9.81\,\mathrm{m\,s^{-2}}$ 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. Define molar heat capacity at constant volume C_v for a gas. (1)

b. 100 J of energy are required to increase the temperature of n moles of air by 2 °C at constant pressure. Given that C_p = 2.5R and R = 8.31 J mol^{-1} K^{-1}, calculate the number of moles of air. (3)

c. Find the energy required to increase the temperature of the same amount of air by 2 °C at constant volume. (4)

d. Explain why the amounts of energy required in parts (b.) and (c.) are different. (2)

(Total: 10 marks)

2.

a. Draw the gravitational field lines and at least **ONE** equipotential surface for the gravitational field of a point mass. Label your diagram accordingly. (2)

b. A weightlifter lifts 200 kg when performing a deadlift at the gym.
   i. Will the weightlifter’s mass and weight change if she goes to the Moon? Explain. (2)
   ii. Calculate the gravitational potential at the surface of the Earth and at the surface of the Moon. (2)
   iii. Calculate the gravitational field strength at the surface of the Earth and at the surface of the Moon. (2)
   iv. If the weightlifter performs the same exercise on the moon, with the same lifting capability, what is the maximum mass that can be lifted on the moon? (2)
   [Earth’s mass = 6.0x10^{24} kg; The Moon’s mass = 7.4x10^{22} kg; Earth’s radius = 6370 km; The Moon’s radius = 1740 km]

(Total: 10 marks)

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3.

a. Define qualitatively (with words) magnetic flux and magnetic flux density. Define the term magnetic flux linkage of a solenoid. (3)

b. Two straight current carrying wires are placed 5 cm away from each other as shown in Figure 1. The wires are surrounded by air.

i. Calculate the force per unit length exerted on **each** wire. (3)

ii. Deduce whether the wires experience repulsion or attraction and explain how this is consistent with one of the laws of motion. (2)

iii. Sketch the resultant magnetic field around the wires. (2)

(Total: 10 marks)

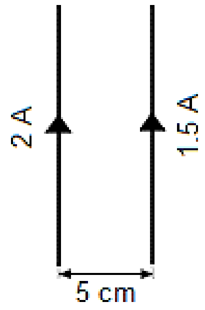

Figure 1

4.

a. State Faraday's Law of electromagnetic induction. (2)

b. Consider a bar magnet placed next to a conducting loop as shown in Figure 2.

i. State the direction of the induced current when the bar magnet is moved away from the loop. (1)
(Give your answer as clockwise or anti-clockwise).

ii. Will the conducting loop repel or attract the bar magnet when current is induced? (1)

iii. Name another law of electromagnetic induction that is required to answer parts (b)(i) and (b)(ii). Name also the associated conservation law. (2)

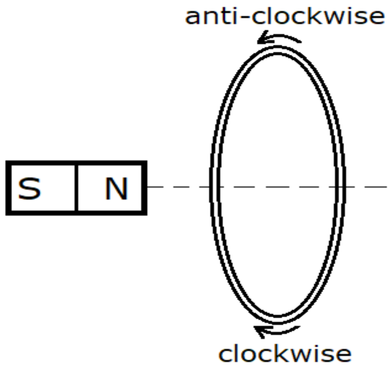

Figure 2

c. Starting from Faraday's law, derive the equation for the induced emf in a straight conductor of length *l*, when moving in a uniform magnetic field *B*, and with a velocity *v*, such that *l*, *B* and *v* are all perpendicular to each other. (4)

(Total: 10 marks)

5.

a. An alternating voltage with a root mean square value of 230 V is supplied to an electric kettle with a resistance of 50 Ω. Calculate the peak current through the kettle. (3)

b. Identify the **TWO** types of reactance. Write an expression for each one, defining **all** symbols used. (2)

c. Three capacitors, C_1, C_2 and C_3 are connected as shown in Figure 3. Their total reactance is 100 kΩ. If C_1 and C_3 have a capacitance of 0.2 μF and 0.01 μF respectively, what is the capacitance of C_2? (5)

(Total: 10 marks)

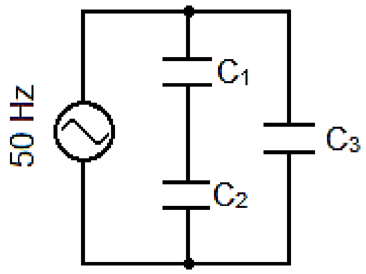

Figure 3

6.

a. State the principle of superposition of pulses and waves. Mention **TWO** conditions required for standing waves to occur. (2)

b. Consider a guitar string fixed at both ends.

i. Draw the wave pattern of a standing wave including at least **ONE** whole wavelength. On the same diagram, label a point of maximum displacement and a point of minimum displacement by using the correct key words. (2)

ii. If the tension in the string is quadrupled, show how the frequency of the standing wave is affected. Identify and explain any assumptions that are required. (6)

(Total: 10 marks)

7.

a. A marine biologist works most of his days inside a submarine. Sometimes it is useful for him to see the land while the submarine is still underwater.

i. State the optical phenomenon used to accomplish this. (1)

ii. Draw a simple ray diagram to illustrate this application. On your diagram label any important angles, the observer and sea level. (3)

b. Consider an image being formed as shown in Figure 4.

i. What do A and B represent? (1)

ii. State **all** the properties of the image formed. (3)

iii. Use the lens equation to determine where an object must be placed to obtain an image which has the same size as the object. (2)

(Total: 10 marks)

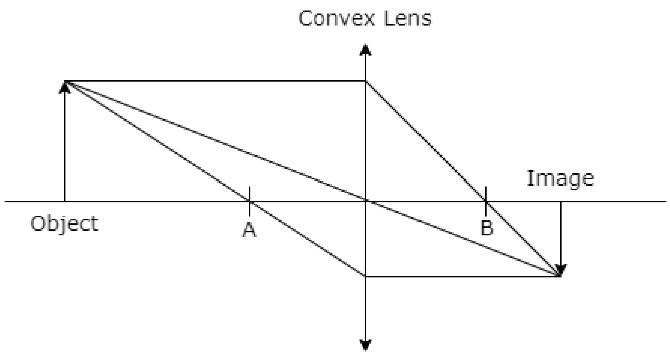

Figure 4

8.

a. Name the **THREE** criteria required for a celestial body to be considered as a planet. (3)

b.

i. State Hubble's Law including the relevant formula. Define **all** symbols used. (3)

ii. Which cosmological phenomenon gave rise to Hubble's law? Explain briefly this phenomenon and mention its implication on the size of the universe. (4)

(Total: 10 marks)

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SECTION B
Attempt any FOUR questions from this section. Each question carries 20 marks. This section carries 50% of the total marks for this paper.

9.

a. Figure 5 illustrates a cycle of three heat transfer processes, AB, BC and CA.

i. Identify the type of each heat transfer process. (3)

ii. Explain the processes mentioned in part (a)(i). (3)

iii. From the first law of thermodynamics, identify which terms, if any, are equal to zero for each process. (3)

iv. What does the shaded area represent? (1)

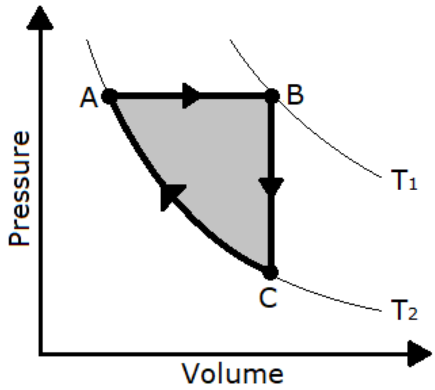


Figure 5

b. A block of ice weighs 50 g and it is stored at a temperature T. 152 kJ of heat energy is required to completely transform the block of ice into water vapour. Find the initial temperature of the ice block, T (in Kelvin). (10)
(Assume there are no heat losses and the vapor is not heated further after vaporization).

(Useful quantities: Latent heat of fusion of ice = 336 kJ kg^{-1};
Specific heat capacity of ice = 2100 J $kg^{-1}K^{-1}$;
Specific heat capacity of water = 4200 J $kg^{-1}K^{-1}$,
Latent heat of vaporization of water = 2250 kJ kg^{-1}.)

(Total: 20 marks)

10.

a. Figure 6 shows a laboratory setup used to analyse the properties of gases. It consists of three flasks, A, B and C of the same volume and filled with air. These flasks are connected through tubes of negligible volume. These tubes are opened and closed using two-way valves labelled S_1 and S_2. Initially, both valves are closed. The air inside the flasks can be considered to be an ideal gas.

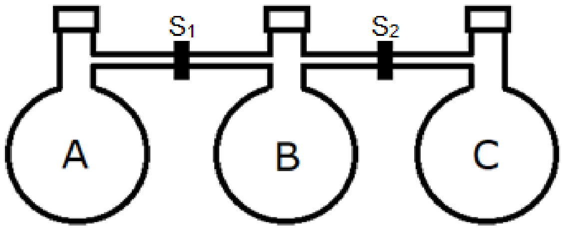


Figure 6

i. List **FOUR** properties of an ideal gas. (4)

ii. Initially A and B contain the same amount of gas. The pressure and temperature in flask A are 10^5 Pa and 5 °C respectively. The pressure in flask B is 1.2×10^5 Pa. Calculate the temperature in flask B. (4)

iii. Valve S_1 is opened and the final temperature of A and B is 300 K after equilibrium conditions are reached. Calculate the final pressure in flask A. (4)

iv. Suppose that valve S_2 is now opened. The final temperature of the whole system is 310 K after equilibrium conditions are reached. If initially flask C was kept at a temperature of 290 K and a pressure of 1.1×10^5 Pa, calculate the final pressure of the system. (4)

v. How would the answer to part (iv) change if valve S_2 was opened first? (1)

b. On the same axes, sketch the following graphs of PV/T vs P:

i. ideal gas; (1)

ii. real gas at a temperature T_1; (1)

iii. real gas at temperature $T_2 > T_1$. (1)

(Total: 20 marks)

11.

a. Heat can be transferred in different modes, one of which is thermal conduction.

i. Identify **THREE** methods of heat transfer other than conduction. (3)

ii. Briefly describe thermal conduction in conductors on the atomic scale. (3)

b. A brass rod has a cross sectional area of 10 cm^2 and a length of 15 cm. It is fused at one end with an iron rod of a cross sectional area of 3 cm^2 and a length of 20 cm as shown in Figure 7. The temperature at the outer end of each rod is shown in the figure. The total rate of heat transfer inside the brass rod is twice that inside the iron rod. Calculate the temperature T where the two rods meet. (7)

(Thermal conductivity of: Brass = 109 W m^{-1} K^{-1}; Iron = 79.5 W m^{-1} K^{-1})

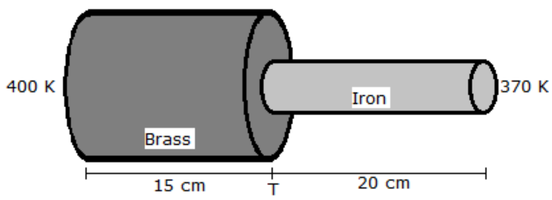


Figure 7

c.

i. Describe a blackbody in terms of its absorption and emission properties. (2)

ii. On the same axes sketch **TWO** graphs of blackbody radiation intensity vs wavelength corresponding to two different temperatures. Label your graphs as T_1 and T_2, where $T_2 > T_1$. (4)

iii. What does the area under these graphs represent? (1)

(Total: 20 marks)

Please turn the page.

12.

a. Sketch the electric field between two particles of equal and opposite charge. (2)

b. Define the electric field strength and the electric potential, at a point. (2)

c. Describe the electric field strength and the electric potential inside a hollow charged conductor. (2)

d. An electron is accelerated through a uniform electric field from rest inside an old cathode ray tube (CRT) television. The electron reaches the screen at a velocity of 2.3×10^{7} ms^{-1}.

i. Calculate the potential difference between source and the screen. (3)

ii. Calculate the distance between the source and the screen if the electric field strength is 3.75 kV m^{-1}. (2)

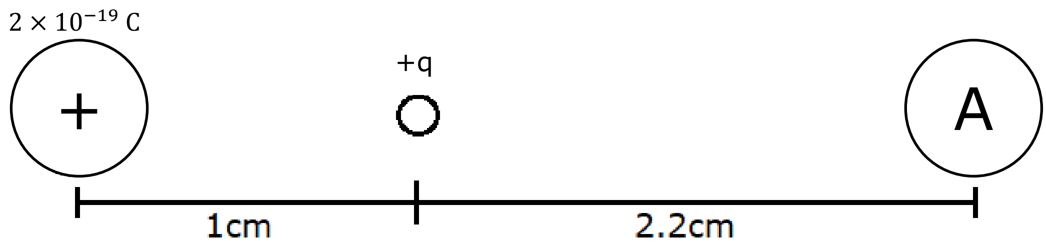
iii. Calculate the time it takes for the electron to reach the screen. Give your answer in nanoseconds. (3)

e. A positive point charge *q* is placed between another two point charges fixed in their place as shown in Figure 8.

i. Calculate the charge of A for the middle point charge to remain stationary. State the polarity of A. (4)

ii. How would *q* move if it was negatively charged? (1)

iii. If all the charges are free to move, would *q* remain stationary? (1)



(Total: 20 marks)

13.

a. Figure 9 shows a circuit used to study the charging and discharging of capacitors.

i. Define the capacitance of a capacitor. (1)

ii. A charge of 1.35×10^{-3} C is accumulated when the capacitor is fully charged. Find its capacitance. (2)

iii. State how the switches should be set in order to discharge the charged capacitor. (2)

iv. Find the time taken for the charged capacitor to dissipate half of its accumulated charge. (4)

v. On two separate axes, sketch well labelled graphs of charge and current against time across the capacitor while charging. Label the time constant and the corresponding values on the y-axis. (There is no need to work out the labelled values). (8)

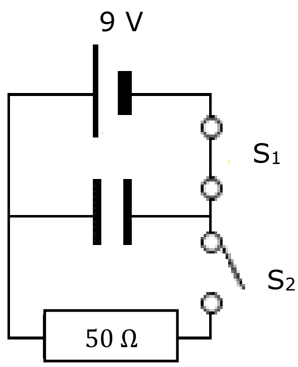


Figure 9

b. A 15-pF parallel plate capacitor has a distance of 1 mm between its plates and an area of overlap of 5 cm^2. Find the relative permittivity of its dielectric. (3)

(Total: 20 marks)

14.

a. Explain the main difference between an electric motor and an electric generator. Identify the magnetic force that drives one of these devices. State how energy is converted in both devices. (6)

b. Bertu needs to replace the transformer of his laptop charger. His charger supplies an output DC voltage of 19 V.

i. Sketch and label the basic structure of a transformer. Identify the type of transformer sketched. (4)

ii. Why are step-up transformers used in order to supply electricity from a power station to the electric grid? (3)

iii. What should be the type of voltage supplied to Bertu's transformer? Explain your answer. (2)

iv. The transformer bought by Bertu is 95% efficient. It is supplied with an RMS voltage of 240 V, and a primary current of 60 mA. Find the output current. (3)

v. Mention **TWO** ways how a transformer can be made more efficient. (2)

(Total: 20 marks)

15.

a. Describe in detail an experiment to accurately determine the speed of sound in air using the progressive wave method. The description should include:

i. a labelled diagram; (2)

ii. the method used; (3)

iii. any precautions that are taken; (2)

iv. a table of all the data collected; (3)

v. any calculations that are made. (3)

b.

i. Identify the regions of the electromagnetic spectrum with the smallest and largest wavelengths. (2)

ii. Name **ONE** application for **each** region mentioned. (2)

c. A ray of light with a frequency of 4.28×10^{14} Hz passes through a glass window that has a refractive index of 1.5. Calculate the change in wavelength as light is passing through the window. (3)

(Total: 20 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2023 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	III - Practical
DATE:	6^{th} June 2023
TIME:	2 hours 5 minutes

Experiment: Investigating the physical properties of a paper clip.

Apparatus: Stand and clamp, paper clips, weight, cork, pin and five (5) pieces of bent wire.

Diagram:

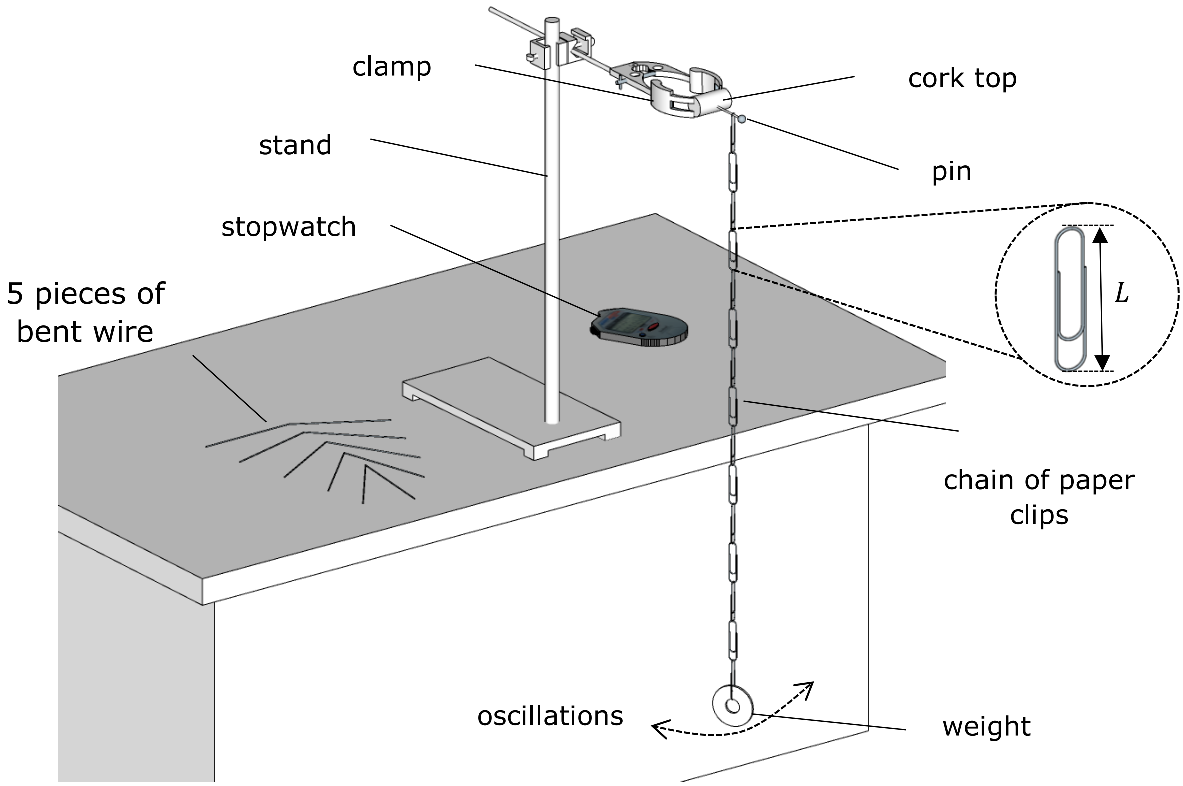


Figure 1: The experimental setup

Method – Part A:

1. The apparatus shown in Figure 1 was set up.

2. Simple harmonic oscillations of a pendulum made up of a chain of paper clips will be used to determine the length L of one paper clip.

3. Observe the equipment and ensure that the links are all free to move relative to one another and all the paper clips are the same way up.

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4. State whether the value of the weight attached at the end of the chain of paper clips will affect the periodic time of the oscillations.

____

____

____ (1)

5. There are fifteen paper clips making up the pendulum. The length of the pendulum will be changed by changing the number of paper clips hanging down from the pin. **DO NOT unlink the paper clips.**

6. For the first reading, the whole length of the pendulum will be used and thus all the fifteen paper clips should be hanging down from the pin.

7. Gently displace the weight to one side and release it so that the pendulum starts to perform small oscillations in a vertical plane, as shown in Figure 1. Record the time it takes the pendulum to complete 20 oscillations. Record this in the column for the first reading of T_{20} in Table 1. (1)

8. 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. (2)

9. Repeat steps 7 and 8 and each time shorten the length of the pendulum by changing the number of paper clips hanging from the pin according to the values of n indicated in first column of Table 1. (Remember DO **NOT** unlink the paper clips, instead hang from a different paper clip). (12)

Table 1

Number of paper clips	1st Reading	2nd Reading	3rd Reading				
n	T_{20}/s	T_{20}/s	T_{20}/s	$\overline{T_{20}}/\mathrm{s}$	T/s	$\log T$	$\log n$
15							
13							
11							
9							
7							

10. Complete Table 1 by working out the average value for twenty oscillations $\overline{T_{20}}$, the periodic time T, $log\,T$ and $log\,n$. (4)

11. It is known that the periodic time of the simple pendulum system as set up in this experiment is given by $T = kn^p$, where k and p are both constants.

12. By taking logarithms on both sides, show that the expression in step 11 can be written as $log\, T = p\, log\, n + log\, k$.

____

____

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____ (3)

13. Plot a graph of $log\, T$ on the y-axis against $log\, n$ on the x-axis and draw the best straight line graph through the plotted points. (8)

14. Use the graph, and corresponding values of any point on your best straight line, to determine the values of the constants p and k respectively.

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____ (7)

15. The constant k is given by $k = 2\pi\sqrt{\frac{L}{g}}$, where L is the length of one paper clip and g is the acceleration due to gravity with a value of $9.81\ \mathrm{m\,s^{-2}}$.

16. Determine the length L in meters of a single paper clip.

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____ (2)

17. If one were to **straighten out** one of the paper clips, its straightened-out length L_0 would be given by the equation $L_0 = 2.9L$. Use your results obtained in step 16 to determine the straightened-out length L_0 of a single paper clip.

____

____

____ (1)

Please turn the page.

Method – Part B:

18. In this part of the experiment, the mass per unit length of the metal making up a single paper clip will be determined. Remove and set aside the chain of paper clips. **Make sure that these do not get tangled.** On the pin fixed to the cork top, you will suspend one of the five wires, so that the arrangement is as shown in Figure 2.

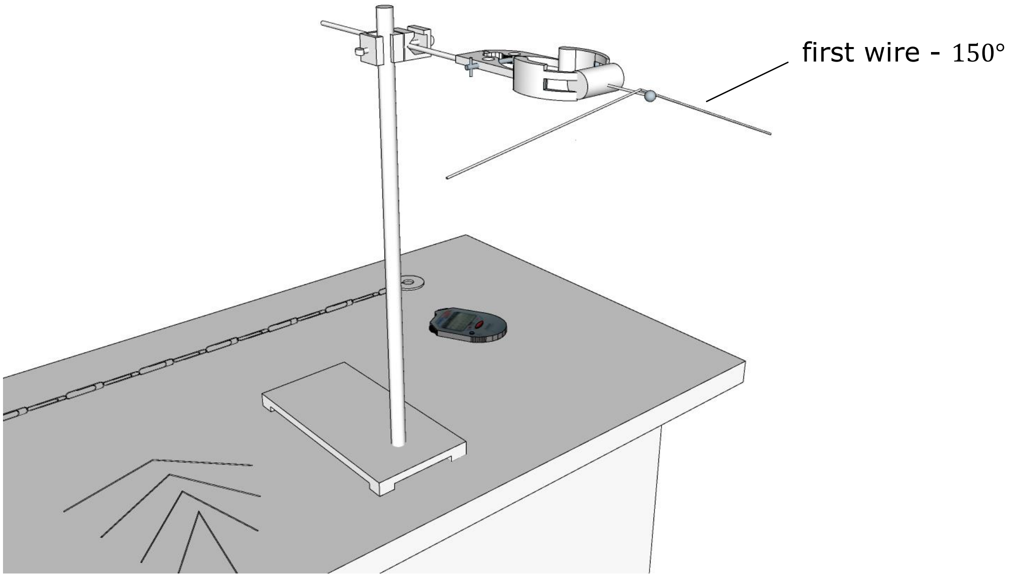

Figure 2

19. The five different wires provided are each of the same length but are bent to a different angle. The length of each wire Z is equivalent to the straightened-out length of 2.5 paper clips, that is, $\boldsymbol{Z = 2.5L_0}$.

20. Select the wire that is bent the least, that is, the wire that has the largest angle and measure its angle using the protractor in Figure 3 below. The angle measured should match the largest angle θ given in Table 2.

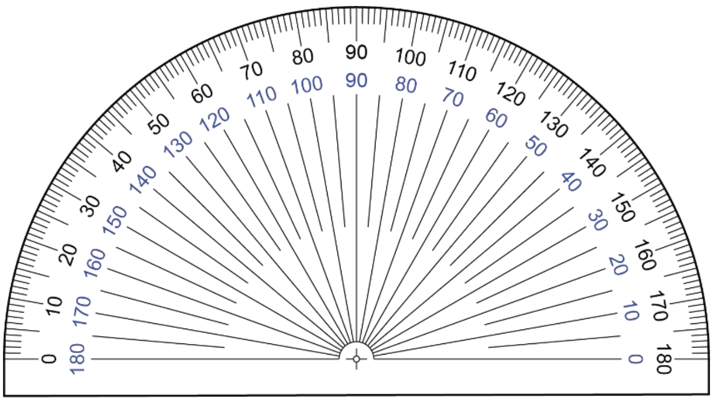

Figure 3

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21. Displace the wire from equilibrium position and release it so that it performs small oscillations in a vertical plane, as shown in Figure 4. Measure the time it takes to perform 10 oscillations and record this in the column marked 1st reading of Table 2. (1)

22. Repeat another two times to have three repeated readings in all and record the time for 10 oscillations in the columns for the 2nd and 3rd reading of Table 2. (2)

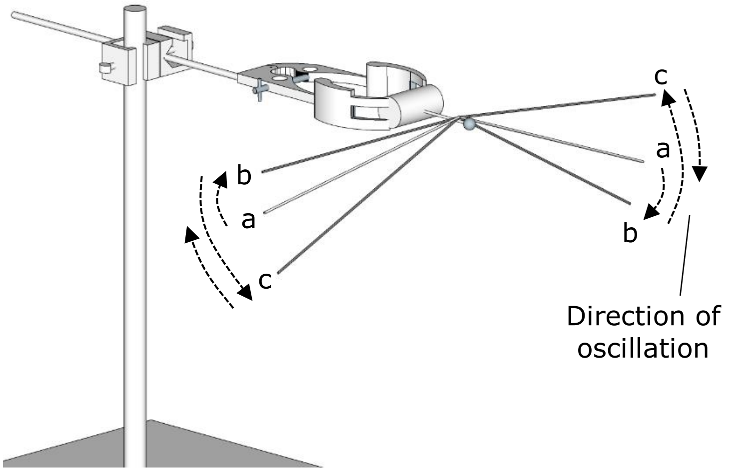

Figure 4

23. Repeat steps 20, 21, 22 and 23 for the four remaining wires. Always measure the angle of the bent wire and ensure that it matches one of the angles in Table 2. If there are any slight differences in the angle, manually adjust the angle of the wire to match the angle given in the table. (12)

Table 2

	1st Reading	2nd Reading	3rd Reading				
θ	T_{10}/s	T_{10}/s	T_{10}/s	$\overline{T_{10}}/s$	T/s	$\cos\theta$	$\frac{1}{T^4}\ /s^{-4}$
150°							
120°							
90°							
60°							
30°							

24. Complete Table 2 by working out the average value for ten oscillations $\overline{T_{10}}$, the periodic time T, $\cos\theta$ and $\frac{1}{T^4}$. (4)

25. The relationship between the periodic time of oscillations of the wire and the bent angle is given by $\frac{1}{T^4} = A\cos\theta + B$, where A and B are constants.

26. Plot a graph of $\frac{1}{T^4}$ on the y-axis against $\cos\theta$ on the x-axis. (8)

27. Use the graph to determine the constant A and state its unit.

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____ (3)

28. A theoretical treatment of this oscillator shows that $A = \frac{1}{2}\left(\frac{0.02g}{4\pi^2 m}\right)^2$, where m is the mass of the wire. Use this equation to determine the mass m of the wire.

(4)

29. Use the value of the mass m of the wire obtained in step 28, the straightened-out length L_0 obtained in step 17 and the information given in step 19 to determine the mass per unit length $\mu = \frac{m}{Z}$.

(3)

30. State **ONE** possible source of error and **ONE** corresponding precaution that could be taken to improve the setup or the procedure.

(2)

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DO NOT WRITE ABOVE THIS LINE