MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2015

SUBJECT:	PHYSICS
PAPER NUMBER:	I
DATE:	9th May 2015
TIME:	9.00 a.m. to 12.00 noon

A list of useful formulae and equations is provided.

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

Section A

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

Question 1

a. Distinguish between scalar and vector quantities. **[2 marks]**

b. It is possible for the product of two vector quantities to be a scalar. Give an example of two such quantities. **[2 marks]**

c. A dart player is 3.00 m away from a dart board. She throws the dart with a horizontal velocity from a height of 1.80 m. The dart strikes the board at a point 1.50 m above the ground. Assuming that air resistance is negligible, calculate:
   (i) the time of flight of the dart;
   (ii) the initial velocity of the dart;
   (iii) the velocity of the dart when it hits the board.

[2, 2, 3 marks]

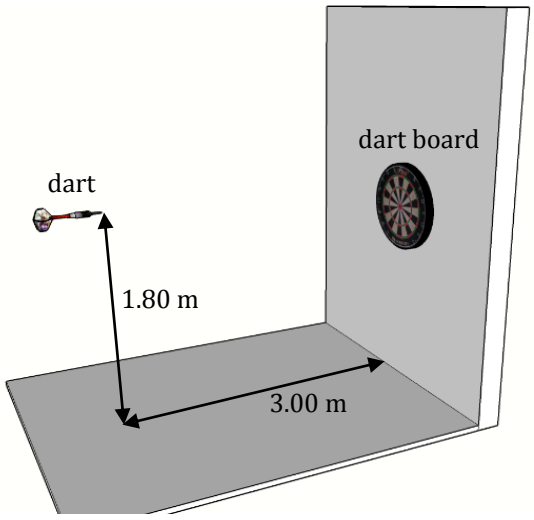

Figure 1

d. The time T for an electric charge q and mass m to move through one whole circle in a magnetic field of intensity B is given by the following equation.

$$T = \frac{2\pi m}{Bq}$$

Show that the equation is correct in terms of its base units. **[3 marks]**

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Question 2

a. State the principle of conservation of energy. **[2 marks]**

b. An athlete makes use of a treadmill to exercise. One day, he programs the machine to run 1000 m on level ground. The next day, he sets the same distance but inclines the treadmill at 10° to the horizontal. The athlete completes the distance in the same time as on the previous day but feels more tired. Explain why, from a physics point of view. **[2 marks]**

c. Two boys want to test a 20 kg four wheeled cart which they built. They take it up a road inclined at 5° to the horizontal. The boys release the cart from the top. It takes 15 s to travel 50 m to the bottom of the road. Assume that no opposing forces act along the inclined road.
   (i) Calculate the gain in kinetic energy at the bottom of the incline. **[2 marks]**
   (ii) Calculate the velocity of the cart at the end of the incline. **[2 marks]**
   (iii) Had there been opposing forces such as friction, how would this have affected your answers above? **[1 mark]**
   (iv) On reaching the bottom of the incline the cart keeps travelling along the level road, where an opposing force of 50 N acts on it. Calculate the distance moved by the cart on the level road. **[3 marks]**

Question 3

a. A motorcyclist travels at 80 km h^{-1} for 25 minutes along a level road which leads directly into a built up area. It takes him 15 minutes to clear a 5 km stretch of road in the built up area. On leaving this area, he continues travelling at 60 km hr^{-1} for 35 km before reaching his destination. Calculate:
   (i) the total distance travelled; **[3 marks]**
   (ii) the total time in minutes of the journey; **[2 marks]**
   (iii) the average speed in km per hour for the whole journey. **[2 marks]**

b. Sketch a velocity-time graph for the journey of the motorcyclist. **[3 marks]**

Question 4

A model jet aircraft of mass 400 g is suspended by a control wire of length L. The jet revolves with a constant linear speed v in a horizontal circle of radius r. The control wire makes an angle θ with the vertical direction.

a. Draw a free-body diagram of the forces acting on the model jet. **[2 marks]**

b. Show that the linear speed can be expressed as

$$v = \sqrt{rg \tan\theta}$$

[4 marks]

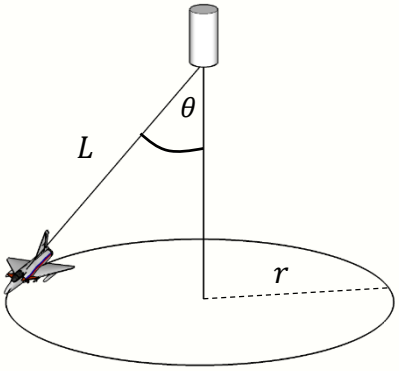


Figure 2

c. The linear speed is now increased with the jet aircraft elevating such that the control wire is now horizontal. The length of the control wire is 1.5 m. If the control wire can withstand a maximum tension of 30 N, what is the maximum frequency at which the jet aircraft can revolve?

[3 marks]

d. The jet's path is now turned so that the circular path is in a vertical plane.
   (i) Draw a force diagram of the new set-up with the jet placed at the position of maximum tension in the control wire. **[2 marks]**
   (ii) Find the linear speed at this point of maximum tension. **[3 marks]**

Question 5

a. The resultant of all the forces acting on a body is zero. Briefly explain whether this is enough for the body to be in static equilibrium and state any principles referred to. **[3 marks]**

b. A trap door of negligible mass measures 0.80 m by 0.80 m. It is fixed to the wall through a hinge from one side and by a string from the other side opposite the hinge as shown in Figure 3. The other end of the string is attached to a point on the wall 1.10 m vertically above the hinge. A cat of mass 15 kg rests 0.25 m away from the hinge.
   (i) Calculate the tension in the string. **[2 marks]**
   (ii) Find the magnitude and direction of the reaction at the hinge. **[5 marks]**
   (iii) The cat slowly starts moving further away from the hinge until the string snaps. If the breaking tension of the string is 175 N, determine the distance of the cat from the hinge when the string snaps. **[2 marks]**

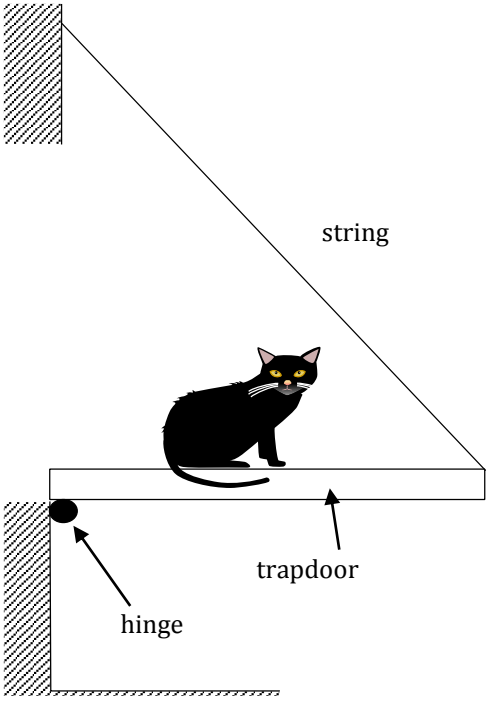


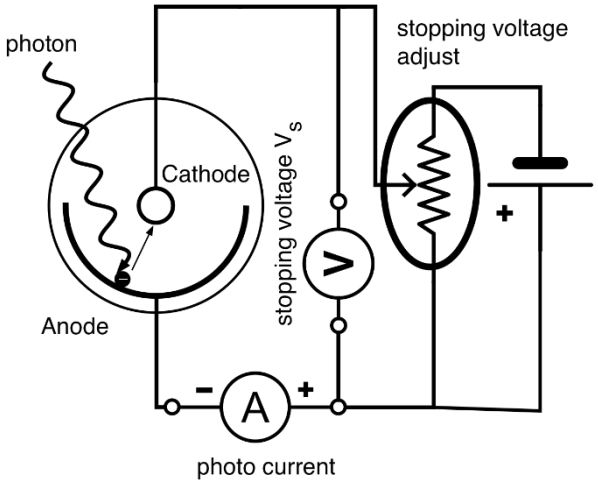
Figure 3

Question 6

The *photons* of a light beam have a characteristic energy. If an electron within some material absorbs the energy of one photon and acquires more energy than the *work function* of the material, it is ejected.

a. Explain the terms *photons* and *work function* in this context. **[4 marks]**

b. When a clean metal plate was irradiated with light of wavelength 550 nm, a stopping potential of 0.224 V had to be applied to stop the photo electrons from leaving the surface. When the wavelength of light was changed to 380 nm, the stopping potential had to be raised to 1 V. Calculate:
   (i) the value of the Planck's constant; **[4 marks]**
   (ii) the work function in eV for the metal plate. **[2 marks]**



c. Calculate the maximum velocity of the ejected electrons from the metal surface illuminated with light of wavelength 550 nm when no stopping potential is applied. **[2 marks]**

Question 7

a. The conventional direction of an electric current is opposite to the drift velocity of electrons. Briefly discuss whether there would be any advantage in changing this convention. **[2 marks]**

b.
(i) How would you join a number of ohmic resistors to give two combinations: one with a maximum and one with a minimum resistance? **[2 marks]**
(ii) How would you change the potential difference across both combinations in order to double the total current flowing through each of the resistors? **[2 marks]**
(iii) What difference would this make to the power dissipated in both combinations? **[2 marks]**

c. A reel of constantan wire of diameter 0.5 mm is marked as having a resistivity of $4.9 \times 10^{-7} \Omega$ m.
(i) Calculate the conductivity of this wire. **[1 mark]**
(ii) Determine the length of wire needed to make a resistor of 12 Ω. **[2 marks]**
(iii) If three such lengths of this wire are cut, how can they be connected so that their combined resistance is more than 12 Ω but less than 20 Ω? Calculate the value of their total resistance. **[3 marks]**

Question 8

a. State Kirchoff's First and Second circuit laws. **[4 marks]**

b. Two cells of 9 V and 12 V are connected to a number of resistors as shown in Figure 4.

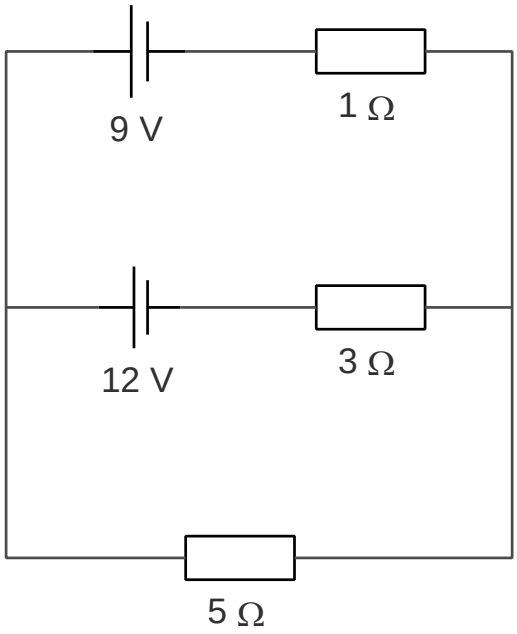


Figure 4

Calculate:
(i) the current through the 5 Ω resistor. **[4 marks]**
(ii) the current through the 9 V cell. **[2 marks]**
(iii) the current through the 12 V cell. **[2 marks]**

Section B

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

Question 9

a. A video clip on the internet shows a Helium filled balloon tied by means of a string to the floor of a car. As the car accelerates forward, the balloon tilts forward as shown in Figure 5.

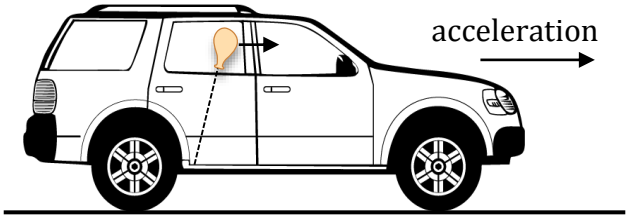


Figure 5

(i) State Newton's First law of motion. **[2 marks]**

(ii) By making reference to Newton's First law, explain what happens to the air in the car, and hence why the balloon tilts forward instead of backwards. **[3 marks]**

b. A force is applied to a mass such that it accelerates forward. Show that the force applied is proportional to the rate of change of momentum. **[3 marks]**

c. State two conditions required for Newton's Third law of motion to hold. **[2 marks]**

d. A small van of mass 1500 kg pulls a boat on a trailer by means of tow bar. If the total mass of the boat and trailer is 400 kg and the van starts from rest and accelerates to 6 m s^{-1} in 35 s, calculate:

(i) the force exerted by the van. Indicate any assumption/s made; **[4 marks]**

(ii) the tension in the tow bar; **[2 marks]**

(iii) the resultant force acting on the van alone. **[1 mark]**

e. A man watering his garden using a water hose tries to wash a canopy which is 5 m vertically above him. Given that the density of water is 1000 kg m^{-3} and the diameter of the hose is 2 cm, calculate:

(i) the minimum speed of water coming out from the hose required to reach this height; **[2 marks]**

(ii) the mass of water leaving the hose per second; **[3 marks]**

(iii) the momentum of the water per second as it leaves the hose; **[1 mark]**

(iv) the force on the hose due to the water coming out of it. **[2 marks]**

Question 10

a. A large centrifuge, like the one shown in Figure 6, is used by astronauts to get them accustomed to the acceleration of a rocket launch. The centrifuge takes 32 s to speed up from rest to its top speed of 1 rotation every 1.3 s. The radius of the circle in which the astronaut moves is 6.8 m.

Figure 6

(i) Distinguish between the angular velocity and angular acceleration of a body moving in a circle. **[2 marks]**

(ii) Why is it necessary for a force to act on a body if it is to move in a circle? **[2 marks]**

(iii) Calculate the maximum angular velocity of the astronaut in the centrifuge. **[1 mark]**

(iv) Determine the **tangential** acceleration of the astronaut while the centrifuge is speeding up. **[3 marks]**

(v) Show that the maximum centripetal acceleration is greater than $16g$, where g is the acceleration due to gravity. **[2 marks]**

b. A car of mass 650 kg goes around a turn on a level road which forms part of a circular arc of radius 50 m. The total reaction at the wheels is normal to the road and the motion is opposed by a frictional force, F, acting on the tyres.

(i) Draw a force diagram of the set-up. **[2 marks]**

(ii) If the car is moving with a speed of 10 m/s, determine the reaction on the tyres and the frictional force. **[3 marks]**

The car then moves through a section of road that is now banked at an angle θ to the horizontal. This section of road is covered with a layer of ice making it frictionless and has a radius of curvature of 30 m.

(iii) Draw a force diagram of the second set-up. **[3 marks]**

(iv) Derive an expression for the banking angle θ and hence show that the banking angle is independent of the mass of the car. **[3 marks]**

(v) Determine the maximum speed that a car can enter this banked section of road if the angle of banking cannot exceed 12°. **[2 marks]**

(vi) Will the centripetal acceleration produce any change in the linear velocity of the car as it moves from the circular arc on to the banked section of road? Explain your answer. **[2 marks]**

Question 11

a. Define moment of inertia of a rigid body. **[2 marks]**

b. Hybrid cars can be made with flywheels instead of batteries. In these "flybrids", the kinetic energy recovered during braking spins a flywheel. The recovered kinetic energy is stored in the spinning wheel, to be released upon acceleration. The amount of energy a flywheel stores depends on its mass and the speed at which it rotates. A flywheel fitted in such a prototype engine can restore up to 60 kW of power in a period of 5 minutes.

(i) State an advantage that this type of "flybrids" could have over conventional hybrid cars. **[2 marks]**

(ii) What is the total energy stored in the rotating flywheel? **[2 marks]**

(iii) Assuming that the moment of inertia of the flywheel is $0.90\ \text{kg m}^2$, calculate the angular velocity of the flywheel and the number of revolutions per minute. **[4 marks]**

(iv) Some car manufacturers stopped researching this type of engine as they stated that the system is not "energy dense" enough for a passenger car. Briefly discuss this statement. **[2 marks]**

c. Define the angular momentum of a rotating body. **[2 marks]**

d. An Olympic ice skater spins about a vertical axis with her arms extended horizontally as part of her routine. While she is spinning, she lowers her arms so that they point vertically down and her moment of inertia drops from $2.5\ \text{kg m}^2$ to $1.2\ \text{kg m}^2$ but her rate of rotation increases.

(i) Explain why this has to happen. **[4 marks]**

(ii) Calculate her new rate of rotation with her arms lowered if initially she was rotating at $4.0\ \text{rad s}^{-1}$. **[2 marks]**

(iii) Calculate the increase in her rotational kinetic energy. **[3 marks]**

(iv) Where does this "extra" energy come from? **[2 marks]**

Question 12

a. Sir George Thomson was one of the first physicists who obtained a diffraction pattern using a beam of electrons directed towards a thin gold foil. Electron diffraction had first been suggested by Louis-Victor de Broglie and the experiment by Thomson confirmed what was then known as the De Broglie hypothesis. In the experiment by Thomson, electrons in a vacuum tube were accelerated from rest through a p.d. of 5000 V.

(i) Briefly describe how electron diffraction occurs. Reference to diagrams is expected. **[3 marks]**

(ii) Calculate the wavelength of the associated electron waves. **[3 marks]**

b. High energy electrons are also used to investigate the structure of nucleons such as neutrons and protons. The electron, muon and tau particles, their corresponding neutrinos and their anti-particles are fundamental particles called leptons. Neutrons and protons are not fundamental particles as they are made up of quarks. Quarks form particles called hadrons. The table below shows the six varieties of quarks.

Name	Up	Down	Charm	Strange	Top	Bottom
Charge	$+\frac{2}{3}e$	$-\frac{1}{3}e$	$+\frac{2}{3}e$	$-\frac{1}{3}e$	$+\frac{2}{3}e$	$-\frac{1}{3}e$
Mass	$\frac{1}{3}m_p$	$\frac{1}{3}m_p$	$1.7m_p$	$0.5\ m_p$	$186\ m_p$	$4.9\ m_p$

(i) State what is meant by the term *fundamental particle*. **[1 mark]**

(ii) Give one other fundamental difference between quarks and leptons. **[2 marks]**

(iii) Show that a hadron composed of two up quarks and a down quark has the correct basic properties to be a proton. **[4 marks]**

c. Archeologists working on a site found what appeared to be small old pieces of wood. They wanted to establish the age of the wood by comparing the activity of the isotope of carbon ${}^{14}_{6}C$ in the old pieces of wood with that of living wood. The activity in the old pieces of wood was 35 counts per minute per 10.0 grams of wood while that of living wood is 15 counts per minute per gram of wood.

(i) What is an isotope? **[1 mark]**

(ii) Derive the relationship between the decay constant and the half-life of a radioactive element. **[3 marks]**

(iii) Assuming that the half-life of Carbon-14 is approximately 5570 years, what is the value of the decay constant? **[2 marks]**

(iv) Calculate, in years, the age of the old pieces of wood. **[4 marks]**

(v) Do you think that this method would be suitable to find exactly how old is a piece of furniture estimated to be less than 100 years old? Explain your answer. **[2 marks]**

Please turn the page.

Question 13

a. Define the terms *potential difference* and *electromotive force* and explain the difference between them. **[4 marks]**

b. A 500 W flood light is connected to a 240 V supply by copper wires of diameter 0.3 mm. Assuming the wire carries 10^{29} free electrons per m^3, calculate:
   (i) the speed of the free electrons; **[3 marks]**
   (ii) how many electrons would pass through the flood light in five minutes; **[2 marks]**
   (iii) the number of kilowatt hours used if it is left switched on for 24 hours. **[1 mark]**

c. An air-conditioning unit rated at 2.5 kW, 240 V is connected to the mains supply. If the drift velocity of the electrons in the wire is 1.25×10^{-4} m s^{-1}, what would be a suitable diameter for the wire? **[3 marks]**

d. Explain the difference in electrical conduction between metallic conductors and insulators in terms of the energy levels in an atom. **[6 marks]**

e. What is the difference between an intrinsic and an extrinsic semiconductor? **[6 marks]**

Question 14

a. State Ohm's Law. **[2 marks]**

b. Derive an equation for the combined resistance of two resistors connected in series. **[3 marks]**

c. A linear variable resistor is connected in series with a battery of voltage V_0. A lamp is connected in parallel to this potential divider set-up as shown in Figure 7.

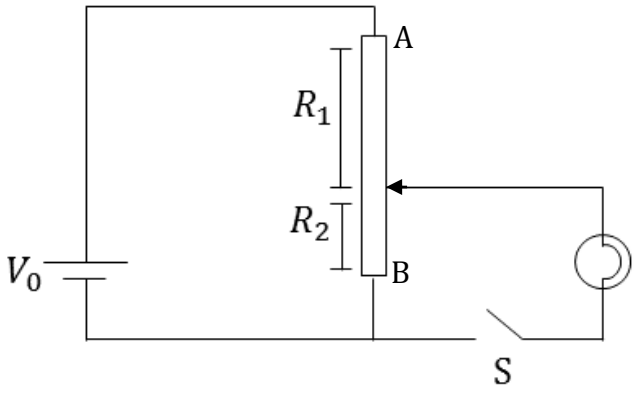


Figure 7

(i) Derive a relation for the potential difference V_2 across the resistor R_2 when the switch is open and when it is closed. Your expressions should be in terms of V_0, R_1, R_2 and the resistance of the lamp R_L. **[3, 5 marks]**

The battery has a voltage of 12 V, the variable resistor is 50 cm long and when lit the lamp offers a resistance of 3 Ω. When S is open a current of 2 A flows through the resistor R_2.

(ii) Find the current that flows through the lamp when S is closed if the connection point is 20 cm from end B of the variable resistor. **[3 marks]**

d. A cell of e.m.f 3 V and internal resistance 1.1 Ω is connected in series with a 5 Ω resistor and a parallel branch of two resistors of 12 Ω and 6 Ω respectively. Calculate:
   (i) the total resistance of the circuit; **[3 marks]**
   (ii) the current through the cell; **[2 marks]**
   (iii) the current through each resistor; **[3 marks]**
   (iv) the terminal p.d. **[1 mark]**

Question 15

a. Explain the terms *tensile stress*, *tensile strain* and *Young's modulus* of elasticity. **[3 marks]**

b. Two fibres each hold a 10 kg mass at their lower end. Both fibres are 1m long and have an effective circular cross-sectional radius of 15 mm. One fibre is made of a glass substance while the other a metal composite.
   (i) On the same graph sketch stress-strain curves for each of these fibres. Explain the qualitative difference between them. **[4 marks]**
   (ii) The Young's modulus of the glass fibre is 60 GPa and the metal fibre undergoes an extension that is one third that of the glass fibre. Find the extension in the glass fibre and the Young's modulus of the metal fibre. **[3 marks]**

c. Derive an equation for the energy stored per unit volume in a wire of length l and cross-sectional area A when acted upon by a force F which produces an extension Δx. **[4 marks]**

d. Describe an experiment to accurately measure the Young's modulus of the metal fibre. Your description should include:
   (i) a labelled diagram of the apparatus used; **[2 marks]**
   (ii) a description of the method used to carry out the experiment, including a table of the data to be recorded from the experiment; **[2, 1 marks]**
   (iii) any one source of error and one corresponding precaution; **[1, 1 mark]**
   (iv) a labelled graph; **[2 marks]**
   (v) the calculations that are required to obtain the Young's modulus from the graph. **[2 marks]**

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Section A

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Question 1

"A temperature scale can be set up by using *fixed points* together with a property which varies continuously and *reproducibly* with temperature".

a. State the meaning of the terms *fixed points* and *reproducibly*. **[2 marks]**

b. Give TWO examples of fixed points of temperature. **[2 marks]**

c. Explain the disadvantages of using coloured water in liquid-in-glass thermometers. **[2 marks]**

d. Briefly describe how you would use a property which varies continuously and reproducibly with temperature to measure the temperature of tap water on the scale of your thermometer. **[6 marks]**

Question 2

To test a small instant water heater, a *constant* stream of water is made to flow along the inside of the heater. The heater is switched on, and, after *steady conditions* have been reached, the temperatures T_1 and T_2 of the cold and warm water are noted. The mass m of water flowing through the tube per second and the electrical power P of the heater are measured.

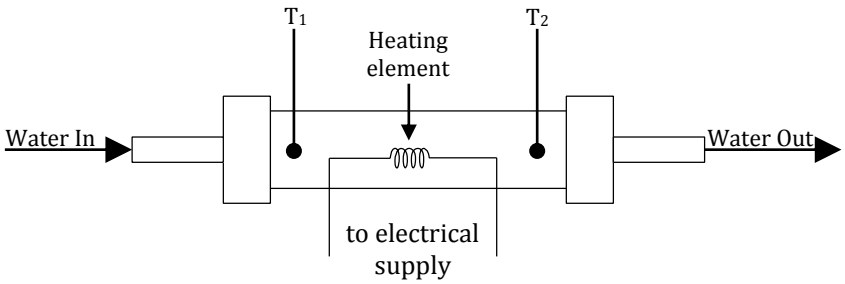

Figure 1

a. How does the observer know that steady conditions have been reached? **[1 mark]**

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b. How may the mass of the water flowing per second through the tube be measured? **[3 marks]**

c. The power P of the heater is 1000 W. The rate of flow of water through the tube is 0.020 kg s^{-1}. The initial temperature of the water is 16.0°C.
   (i) Calculate the temperature of the water after flowing through the tube. Take the specific heat of water to be 4200 J kg^{-1} K^{-1}. **[2 marks]**
   (ii) What important assumption have you made in your calculation? **[1 mark]**
   (iii) In the calculation above the thermal capacity of the water heater itself was not considered. Why? **[1 mark]**

d. 10 kg of water per minute may flow through an instant water heater installed in a bathroom.
   (i) Make appropriate assumptions to *estimate* the power of such a heater. **[2 marks]**
   (ii) Name one advantage and one disadvantage of using such an instant water heater in a bathroom. **[2 marks]**

Question 3

One way of measuring thermal conductivities of materials involves a very short pulse of intense laser light that is allowed to fall on one side of a specimen of the material in the form of a disc. The temperature on the other side of the material is measured as it changes with time. The thermal conductivity of the material is then calculated from the equation

$$k = \frac{0.139\rho c d^2}{T_{1/2}}$$

where ρ is the density of the material, c its specific heat capacity, d is the thickness of the disc, and $T_{1/2}$ is half the time it takes the temperature of the backside of the disc to reach its maximum value.

a. On the same time axis, sketch graphs to show how you would expect the temperature of the backside of the disc to increase with time when the disc is made of:
   (i) a good conductor; and
   (ii) a bad conductor with the same dimensions, and about the same density and specific heat capacity as in (i). **[2 marks]**

b. Show that the expression on the right-hand side of the equation for k is consistent with the definition of k. **[4 marks]**

c. Calculate $T_{1/2}$ for a copper disc 5.00 mm thick, if the thermal conductivity for copper is 400, its specific heat capacity 390, and its density 900, all in SI units. **[3 marks]**

d. What type of thermometer may be used to measure such a rapidly changing temperature? Explain your answer. **[3 marks]**

Question 4

A stream of electrons produced by an electron gun, G, passes through a vertical electric field between two horizontal deflecting metal plates, M, as shown in Figure 2. The electrons travel inside an evacuated tube.

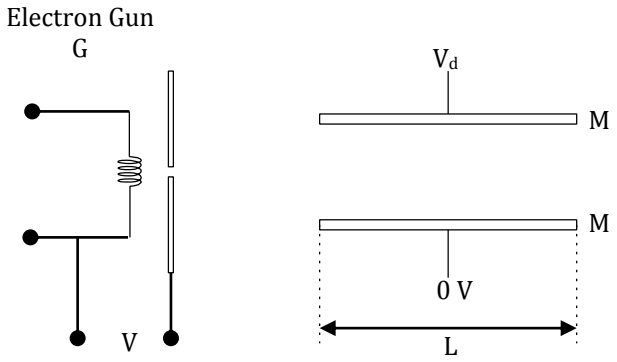

Figure 2

a. The mass of the electron is m and its charge is e.
   (i) If the electron gun accelerating voltage is V, write down an equation for the velocity, v, of the electrons emitted by the electron gun. **[1 mark]**
   (ii) On which principle is your equation based? **[1 mark]**

b. The plates M, are L metres in length.
   (i) Show that the time of travel, t, between the plates is given by
   $$t = L\sqrt{\frac{m}{2eV}}$$
   (ii) Explain why, in deriving your equation for t, the vertical deflection of the electrons need not be considered. **[3 marks]**

c. If the voltage between the deflecting plates is V_d and the separation of the plates is x metres, what is the electric field strength E between the plates? **[1 mark]**

d. Derive expressions for:
   (i) the deflecting force, F, and
   (ii) the vertical acceleration, a,
   of the electrons while travelling between the horizontal plates. **[2 marks]**

e. Show that the vertical deflection y, of the electrons while inside the deflecting electric field is given by
   $$y = \frac{L^2 V_d}{4Vx}$$

f. Explain qualitatively why the vertical deflection, y, is independent of the charge on the electron. **[4 marks]**

Question 5

The data from experiments to study the variation of the reactance of an *ideal* capacitor C and an *ideal* inductor L with frequency are plotted in Figure 3.

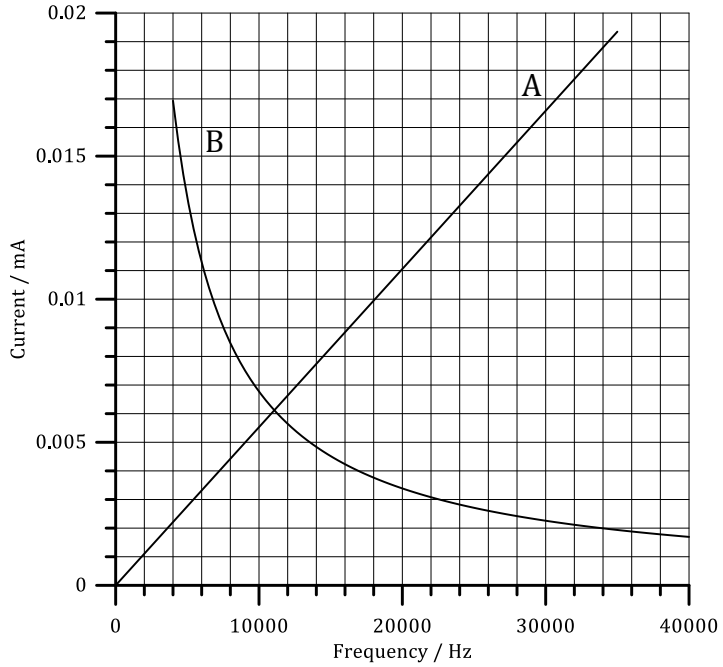

Figure 3

a. Explain what is meant by the term *ideal* as applied to a capacitor and an inductor. **[2 marks]**

b. Draw a circuit containing suitable measuring instruments and a signal generator to perform such experiments. **[3 marks]**

c. The output of the signal generator is adjusted to maintain a potential difference of 2.0 V across C or L at all frequencies. Which graph corresponds to C and which to L? **[2 marks]**

d. Use the graphs to find the values of C and L. **[4 marks]**

e. Explain why no thermal energy is produced when a current flows through a pure capacitor or a pure inductor. **[3 marks]**

Question 6

A ray of red light is incident onto a lens surface at an angle of 35° to the normal. After it passes through the lens it cuts the principal axis at point X.

a. The refractive index of the lens for red light is 1.60. Calculate:
   (i) the angle θ;
   (ii) the speed of light inside the lens. **[2 marks]**

b. Why does dispersion occur when white light enters glass? **[1 mark]**

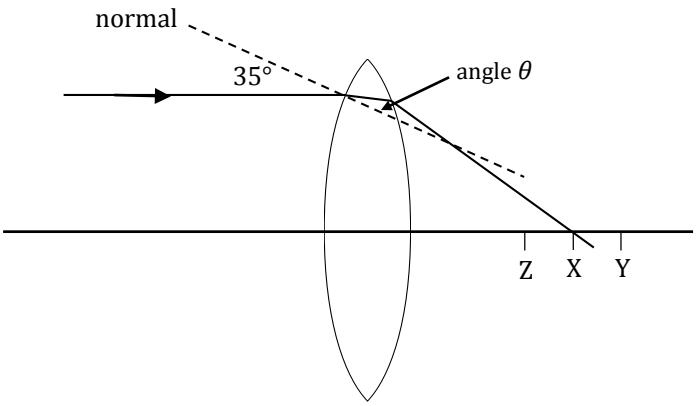

Figure 4

c. The red light is replaced by blue light incident at the same angle. At which of the points, X, Y or Z, will the blue ray cross the principal axis? Explain your answer. **[2 marks]**

d. The lens is now immersed in water of refractive index 1.33, and red light is still incident at the angle shown in the diagram.
   (i) What is the new value of the angle θ? **[3 marks]**
   (ii) Will the emergent ray cross the principal axis to the right or to the left of point X? **[1 mark]**

e. How would you expect the focal length of the lens to change if the lens were thinner? **[1 mark]**

f. A screen is placed at X with its plane perpendicular to the principal axis of the lens. What should be observed on the screen when a white light source is used? **[1 mark]**

g. Where would you place a small light source, a screen, and a plane mirror to measure the focal length of the lens? **[1 mark]**

Question 7

The pitch (frequency) of sound heard from repeated tapping of a cup of hot liquid, such as milk, to which soluble powder, such as chocolate, has been added, rises as the tapping continues. The phenomenon, called *the hot chocolate effect*, is explained by the change in the speed of sound in the liquid produced by the presence of air bubbles.

The note heard is the frequency of a quarter wavelength *standing wave* formed between the base of the cup and the liquid surface. The speed of sound in the liquid is much higher than in air, so that air bubbles in the liquid lowers the speed of the standing wave. Repeated tapping of the cup lowers the number of bubbles in the liquid.

a. Which of frequency, wavelength, and speed of sound remains constant while the tapping of the cup continues? Give a reason for your answer. **[2 marks]**

b. A longitudinal stationary wave is formed in the liquid between the liquid surface and the bottom of the cup.
   (i) What is a longitudinal wave?
   (ii) How is a stationary wave formed in the liquid? **[3 marks]**

c. Let the distance between the base of the cup and the liquid surface be L. If the speed of the sound wave is v, what is the frequency of the note emitted when the cup is tapped? **[2 marks]**

d. How does the frequency of the note change with depth of liquid in the cup? **[1 mark]**

e. Will a displacement node form at the water surface or at the bottom of the cup? Explain your answer. **[2 marks]**

f. Where do you expect to find a pressure node? **[1 mark]**

g. For a fixed depth of liquid, when will the note with the highest frequency be heard? **[1 mark]**

Question 8

An ideal gas is under the conditions represented by the point A in the P-V diagram.

AB represents a *reversible isothermal* expansion of the gas, while AC is a *reversible adiabatic* expansion.

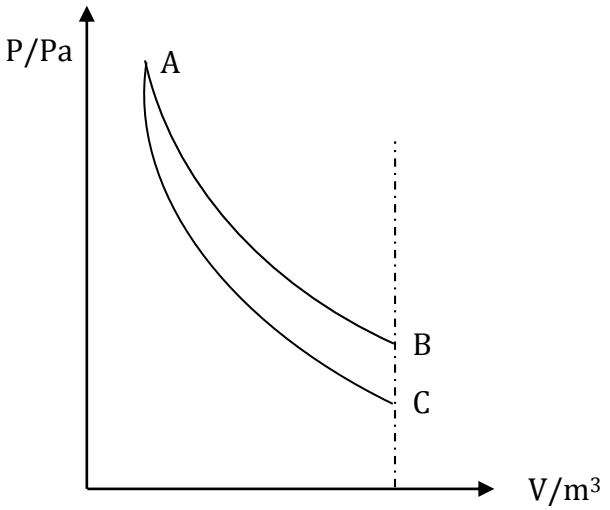

Figure 5

a. What is meant by a *reversible expansion* in the context of these processes? **[2 marks]**

b. Distinguish between *isothermal* and *adiabatic* processes. **[2 marks]**

c. State, with reasons, at which of the points A, B, or C the gas
   (i) is at the lowest temperature;
   (ii) has the least internal energy. **[4 marks]**

d. In which of the processes, AB or AC, does the gas do the smaller amount of work? Explain your answer. **[2 marks]**

e. In the process AB, how can work be done by the gas without a fall in temperature? **[2 marks]**

f. Why is the adiabatic curve steeper than the isothermal? **[2 marks]**

Section B

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

Question 9

The pressure exerted by a mass m of an ideal gas of molar mass M can be written in the form

$$P = \frac{m}{M}\frac{RT}{V}$$

a. Indicate briefly the experimental evidence on which this equation is based. (You are not expected to describe experimental details). **[6 marks]**

b. A cylinder, A, of volume 0.080 m^3 contains helium at a temperature of 273 K and a pressure of 90.0 kPa. The molar mass of helium is 4.00×10^{-3} kg $mole^{-1}$.
   (i) Calculate the mass of helium in the cylinder. **[2 marks]**

   The cylinder is now connected to an evacuated cylinder, B, of the same volume. Cylinder B is kept at a temperature of 373 K. Helium flows from one cylinder into the other and after a time steady conditions are reached.

   (ii) Write down an expression for the mass of gas inside each cylinder in terms of the pressure of the gas in the cylinders. Hence, determine the pressure of helium in the system. **[10 marks]**

c. The pressure of an ideal gas can be expressed in the form

$$P = \frac{1}{3}\rho < c^2 >$$

where ρ is the density of the gas and $< c^2 >$ its mean square speed.

(i) Calculate the r.m.s. speed of the helium atoms in each cylinder. **[4 marks]**

(ii) Use the kinetic theory of gases to explain qualitatively how the gas has the same pressure in each cylinder even though the cylinders have different temperatures. **[3 marks]**

Question 10

a. An uncharged conducting sphere is suspended from a fixed point by a thin nylon thread. A charged metal plate is then placed close to the sphere.

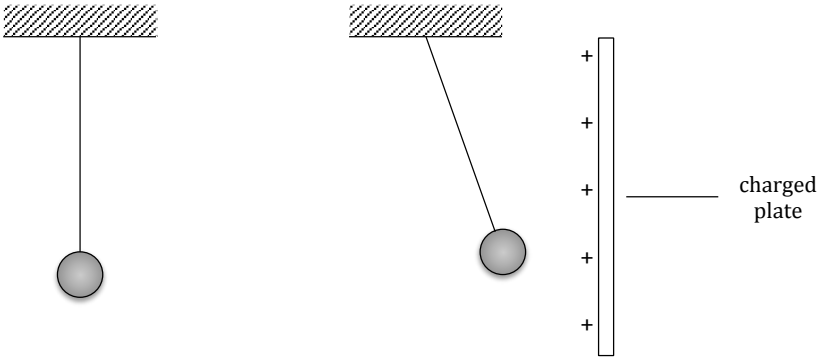

Figure 6

(i) Describe how the plate may be charged positively. **[3 marks]**

(ii) Explain why the uncharged sphere is attracted to the metal plate. **[1 mark]**

(iii) The sphere is now allowed to touch the plate. Describe and explain the motion of the sphere, if any. **[2 marks]**

(iv) The plate is now removed. Draw a diagram to show the flux of the electric field around the sphere. **[2 marks]**

(v) Sketch a graph of electric field strength against distance from the centre of the sphere. **[2 marks]**

(vi) Why is there no electric field inside the sphere? **[2 marks]**

b. The potential V at a distance *r* away from a sphere of radius *a* carrying a charge *Q,* is given by the equation

$$V = \frac{Q}{4\pi\varepsilon_o r}$$

(i) Sketch a graph of electric potential against distance from the centre of the sphere. **[2 marks]**

(ii) What is the potential inside the sphere? **[1 mark]**

(iii) How is the graph you have sketched related to the graph in (a) (v) above. **[1 mark]**

c.

(i) Draw a circuit diagram to show how you would investigate the charging and discharging of a capacitor through a resistor. **[2 marks]**

(ii) The capacitor has a capacitance of about 100 μF. Give approximate values for the e.m.f. of the cell, the resistance of the resistor and the full scale reading of the ammeter you would use in the experiment. **[2 marks]**

(iii) Sketch graphs to show how you would display the experimental results. **[2 marks]**

(iv) Describe how you would use one set of results to obtain a value for the capacitance of the capacitor if the resistance of the resistor is known. **[3 marks]**

Question 11

Planets outside our solar system are called exoplanets. Figure 7 shows an exoplanet of mass m and its star of mass M. The Star and the planet move in circular orbits about their common centre of mass C. The distances from C to the centres of the Star and the planet are R and r respectively. These quantities are related by the equation $MR = mr$.

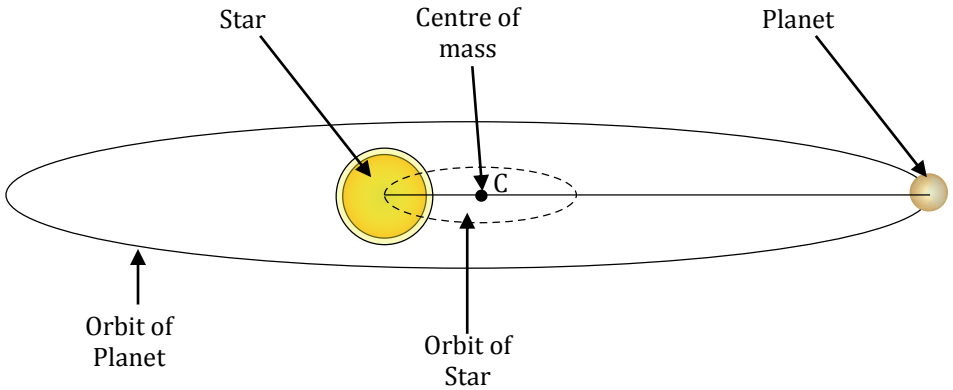

Figure 7

a.

(i) Write down an equation for the gravitational force acting on the planet due to the Star. **[1 mark]**

(ii) What is the magnitude and direction of the gravitational force acting on the Star? **[1 mark]**

(iii) Name and write down the law on which your answer is based. **[2 marks]**

b. Any light from the planet is usually too weak to be observed from Earth. Observations are made on the Star. Moreover, the radius of the Star's orbit, R, is too short to be observed. However, the Star's radial velocity, v_s, that is, the velocity by which it moves towards or away from the Earth – can be detected from displacement in the Star's spectral lines due to the Doppler effect if it is assumed that an observer on Earth sees the Star-planet system edge on. The Doppler shift is given by the equation

$$\frac{\Delta\lambda}{\lambda} = \frac{v_s}{c}$$

where $\Delta\lambda$ is the change in wavelength λ, and c is the speed of light.

(i) Explain the term Doppler effect in this context. **[2 marks]**

Hydrogen gas emits an emission line of wavelength 656.32150 nm in the laboratory. Suppose a spectrum from a Star shows the same line shifted to 656.32106 nm.

(ii) Is the Star moving towards or away from an observer on Earth? Explain your answer. **[2 marks]**

(iii) How is the Star moving with respect to the observer when
(A) there is no Doppler shift;
(B) when the Doppler shift is maximum? **[2 marks]**

(iv) Calculate the velocity v_s of the moving Star. **[2 marks]**

(v) The star completes one revolution in a time period P of 25.2 days. What is the radius, R, of the Star's orbit? **[3 marks]**

c. If the speed of the planet in its orbit is v_p, write down an equation for the centripetal force acting on it. **[1 mark]**

d. Hence, show that, if r is very much larger than R, then $r^3 = \frac{GMP^2}{4\pi^2}$. **[5 marks]**

e. If the mass of the Star is 1.2×10^{30} kg, calculate:

(i) the radius, r, of the planet's orbit; **[2 marks]**

(ii) the mass, m, of the planet. **[2 marks]**

Question 12

a. A load hangs on the free end of a vertical helical spring of natural length 20.0 cm. When the load is in equilibrium, the spring is 30 cm long. The load is then pulled down several centimetres and released. After release the load oscillates along the vertical through the spring.

(i) Show that the mass performs simple harmonic oscillations after release. **[5 marks]**

(ii) What is the period of oscillation of the mass? Derive any equation you use. **[6 marks]**

(iii) Why do the oscillations gradually decrease in amplitude as the mass continues to oscillate? **[1 mark]**

(iv) Suppose that the spring is replaced by an elastic string. Give a reason why the oscillations may not be simple harmonic. **[1 mark]**

b. The loaded spring is now hung from a peg fixed to the rim of a small wheel which can be rotated at a slow variable speed, as shown in Figure 8.

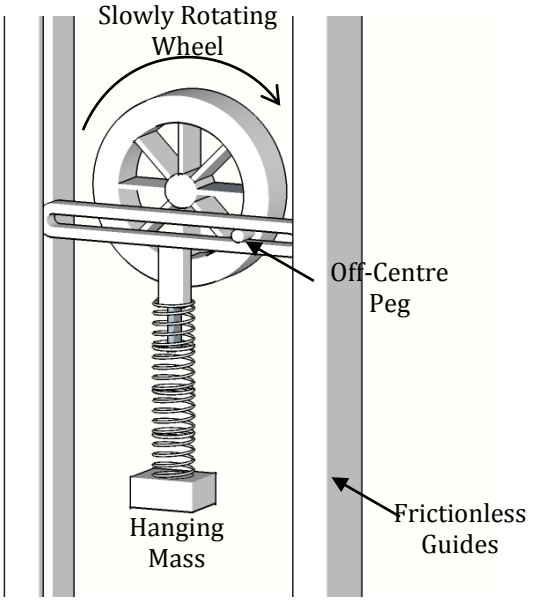

Figure 8

(i) Describe the motion of the hanging mass as the speed of the motor is increased gradually from zero. **[4 marks]**

(ii) Sketch a graph, A, of amplitude against driving frequency. Calculate the driving frequency when the amplitude is maximum. **[3 marks]**

(iii) How will the motion of the mass be affected if the experiment is repeated with a large, light sheet of polystyrene glued to the bottom of the hanging mass? **[3 marks]**

(iv) Use the same pair of axes you have used in b (ii) to draw a new graph, B, of amplitude against driving frequency. **[2 marks]**

Question 13

a. Describe how you would demonstrate the diffraction of microwaves by a single slit.
Your description should include an appropriate diagram, approximate relevant dimensions, and a graph to show how the microwave intensity varies across the diffraction pattern.
[8 marks]

b. A quality control system used to measure thread spacing in fabrics consists essentially of a laser, the fabric sample, and a screen. The figure below shows the main features of the system as well as part of the interference pattern obtained on the screen.

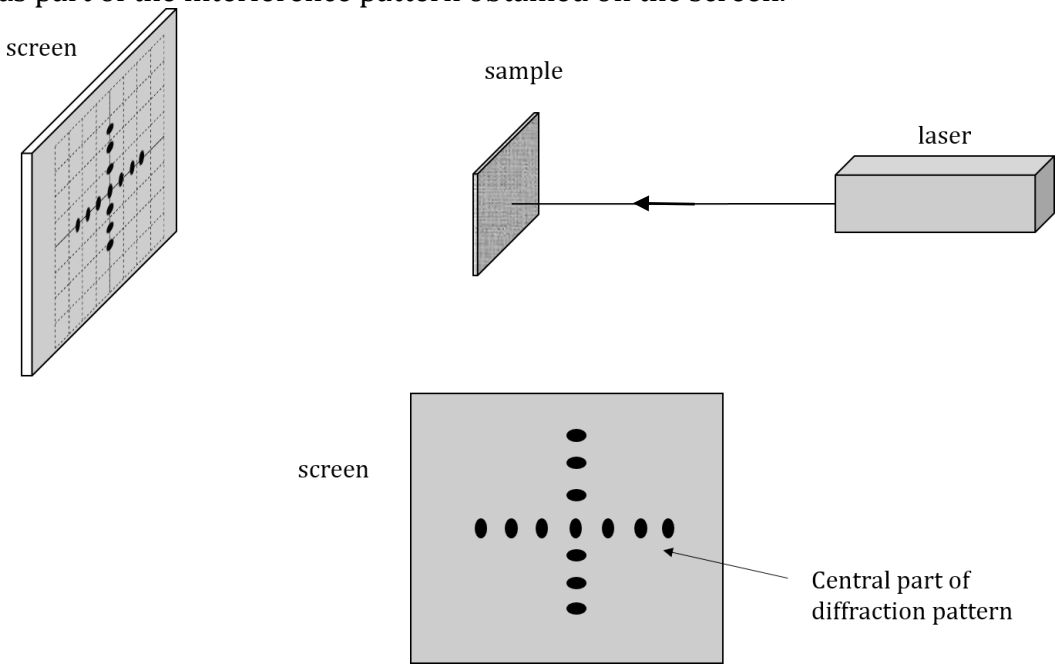

Figure 9

(i) Explain fully how the diffraction pattern is produced. Illustrate your answer by means of an appropriate diagram. **[5 marks]**

(ii) When a fine beam of laser light of wavelength 488 nm is used, the mean separation of the maxima in the horizontal direction is 5.00 mm. The distance between the sample and the screen is 3.20 m.
Calculate the spacing between the threads in the sample assuming that the sample acts as a transmission diffraction grating. **[3 marks]**

(iii) By making an appropriate calculation, show that, if the two adjacent spaces between the threads are assumed to act as Young's slits, the same spacing between threads, as in part (ii), would be obtained. **[3 marks]**

(iv) Explain why the distance between the maxima was measured to a hundredth of a millimetre while the distance between sample and screen was measured to a centimetre. **[2 marks]**

(v) Describe and explain how the pattern on the screen changes when the sample is stretched horizontally. **[4 marks]**

Question 14

a. A charged body has an electric field around it. State when a magnetic field exists around a charged body. **[1 mark]**

b. The diagram shows a rigid copper wire frame, F, a sensitive electronic balance, B, and a permanent magnet M.

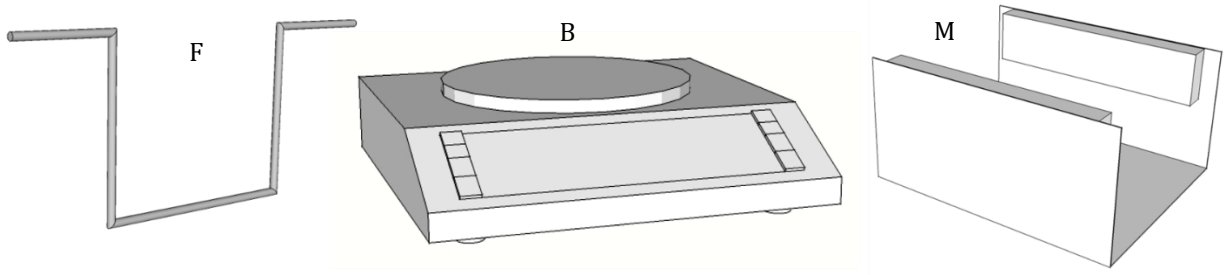

Figure 10

Describe carefully how, using this and other laboratory apparatus, you would determine the flux density, *B*, between the poles of the electromagnet.

In your description you should:
(i) draw an appropriate circuit diagram, and
(ii) give special attention to the procedure you would adopt to obtain as reliable a result as the apparatus is capable of producing.

Describe also how the final result may be obtained from an appropriate graph. **[13 marks]**

c. Another method for finding the flux density of a magnetic field uses a Hall probe.

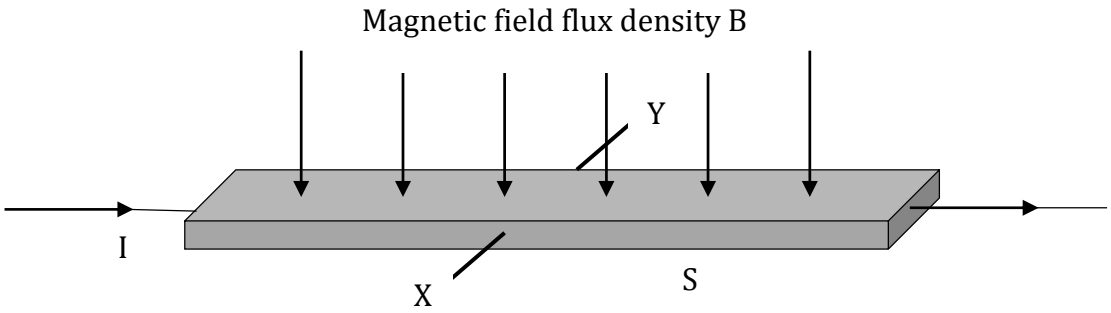

Figure 11

The diagram in Figure 11 shows a sheet of an n-type semiconductor, *S*, carrying a current *I*. The sheet is placed with its plane perpendicular to a magnetic field of flux density *B* while carrying a current *I* as shown in the diagram.

(i) Explain why a voltage, V_H, is observed across the terminals *X* and *Y*. **[4 marks]**
(ii) Obtain an expression for V_H in terms of, *n*, the number of charge carriers per unit volume of the n-type semiconductor, the current *I*, the thickness, *t*, of the sheet *S*, the flux density, *B*, and the electronic charge *e*. **[5 marks]**

d. Which of the experiments mentioned in (b) and (c) would you prefer to determine the flux density of a magnetic field? Give a reason for your answer. **[2 marks]**

Question 15

a. State the laws of electromagnetic induction. **[3 marks]**

b. In order to illustrate the law relating the magnitude of the induced e.m.f. to the rate of change of flux, a student set up the apparatus shown in the figure. The short bar magnet was attached to the axle of a d.c. motor and placed along the axis of a fixed coil. The coil was connected to the Y-plates of an oscilloscope, while the motor was connected to a variable d.c. supply so that its rate of rotation could be varied. For a certain rate of rotation, the time base speed of the oscilloscope was adjusted to obtain a steady trace on the oscilloscope screen.

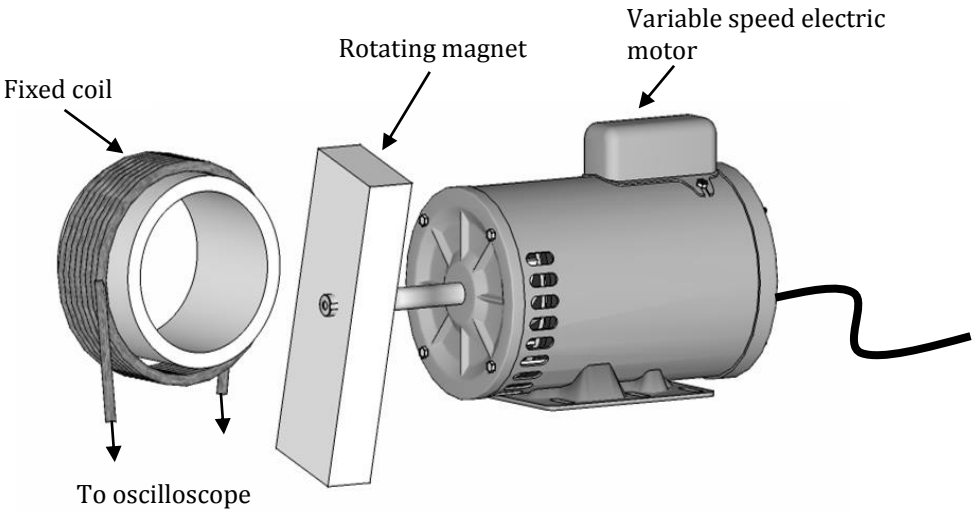

Figure 12

(i) Explain why an e.m.f. is induced in the coil when the magnet is rotated in front of the fixed coil. **[2 marks]**

(ii) Would the effect have been the same had the magnet been kept fixed and the coil rotated about a vertical axis? **[1 mark]**

(iii) Why is it preferable to rotate the magnet rather than the coil? **[1 mark]**

(iv) Sketch a graph to show what you would expect the student to observe on the oscilloscope screen. **[3 marks]**

(v) On the same axis, sketch another graph to show the trace on the oscilloscope screen when the rate of rotation of the motor is doubled. **[3 marks]**

(vi) Compare the graphs in (iv) and (v) and explain any differences. **[3 marks]**

(vii) If two complete cycles fill the 10 cm wide oscilloscope screen, what is the rate of rotation of the magnet when the time base is set at 2.5 ms cm^{-1}? **[2 marks]**

(viii) When the frequency of rotation of the motor was 50 revolutions per second, the peak to peak induced e.m.f. in a coil of 150 turns was 200 mV. What was the change of flux during one turn of the magnet? **[2 marks]**

c. In a second experiment, a tight-fitting iron rod is inserted inside the coil. The coil is connected to a rapidly changing alternating voltage supply. It is found that when the supply is switched on

- the temperature of the iron core rises; and
- the coil burns out when the iron core is removed while the supply is still on.

Explain these observations. **[5 marks]**

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2015

SUBJECT:	PHYSICS
PAPER NUMBER:	III – *Practical*
DATE:	2nd June 2015
TIME:	2 hours

Experiment: Experiments with pendula

Apparatus: stand and clamp, stopwatch, string and bob, drinking straw, metre ruler, toothpick, 30 cm ruler, pins and cork

Important Note:

- Pay proper attention when using pins/needles.
- Take the acceleration due to gravity $g = 9.81$ m s^{-2} unless otherwise stated

Failure to follow these instructions may incur damage to the apparatus and loss of time.

Diagram:

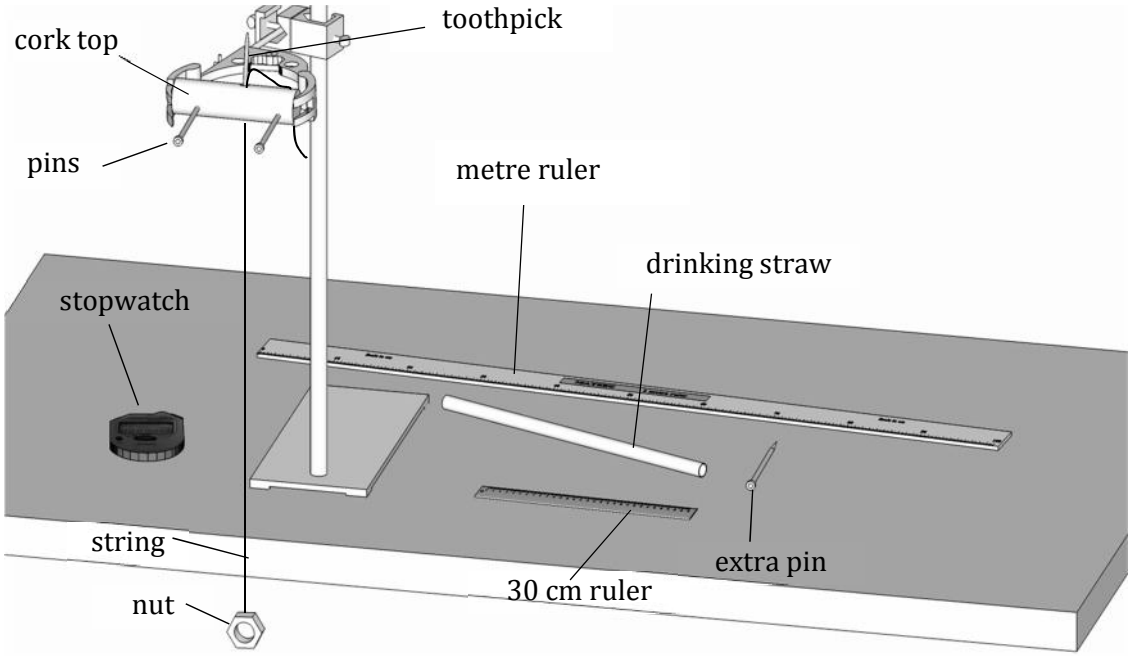

Figure 1 The experimental setup

Method – Part A:

1. The apparatus is set up for you. Make sure that you have all the apparatus that is shown in the diagram of Figure 1.
2. You will now carry out the simple pendulum experiment.

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3. The string provided has one end tied to a nut while the other end passes through a hole drilled in the cork top. A toothpick inserted in the hole provides the necessary friction to keep the string from sliding.
4. Place the nut on the paper inside the adjacent frame and draw its outline.
5. Draw lines of symmetry to find the centre of the shape of the nut.
6. Measure the distance d_1 in metres from the centre of the nut shape to one of its vertices.

   $d_1 =$ _____ $\pm$ _____m

[1 mark]

7. Measure the perpendicular distance d_2 in metres from the centre of the nut shape to one of its edges. $d_2 =$ _____ $\pm$ _____m

[1 mark]

8. The average of the two distances d_1 and d_2 is given by $d = \frac{d_1+d_2}{2} =$_____ m

[1 mark]

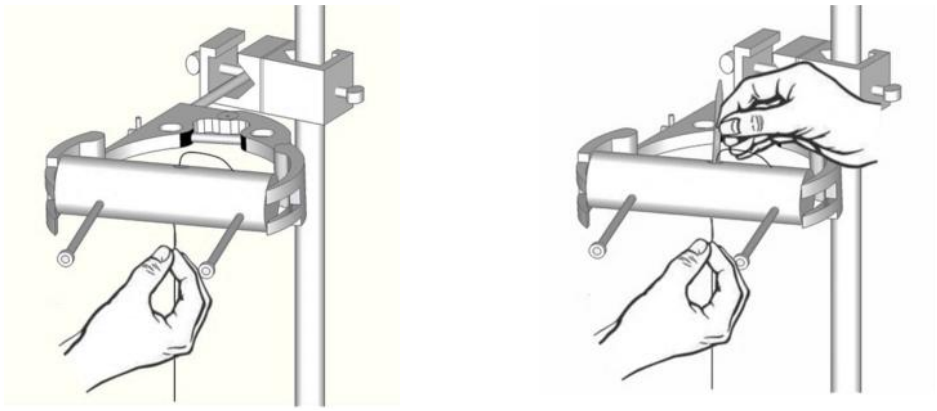

Figure 2

9. To change the length of the pendulum, remove the toothpick, adjust the length and re-insert the toothpick in its place. Refer to the diagrams of Figure 2.
10. The length L of the pendulum is the length of the string between the bottom of the cork top and the outer edge of the nut where the string is tied.
11. You will measure the time, T_{20} in seconds, for the nut to perform 20 small planar oscillations for 7 different lengths of the pendulum. The length of the pendulum should span a range between approximately 0.20 m and 0.50 m.

[7 marks]

12. Record all your measurements in Table 1.
13. Take repeated readings.

[14 marks]

Table 1

L / m	T_{20}/s	T_{20}/s	T_{20}/s	$\overline{T}_{20}$/s	T / s	$T^{\overline{2}}$/s$^{\overline{2}}$

14. $\overline{T}_{20}$ is the mean value of the repeated readings taken. Complete Table 1 by filling in the missing data.

[14 marks]

15. Plot a graph of T^2 /s^2 on the y-axis against L /m on the x-axis.

[10 marks]

16. It is given that the periodic time, T is related to the length L of the pendulum by the equation:

$$T^2 = k(L + d)$$

where k is a constant.

17. From the graph determine **two** values for the constant k, the average value of k and state its units.

_____

_____

_____

_____

_____

_____

_____

_____

[4 marks]

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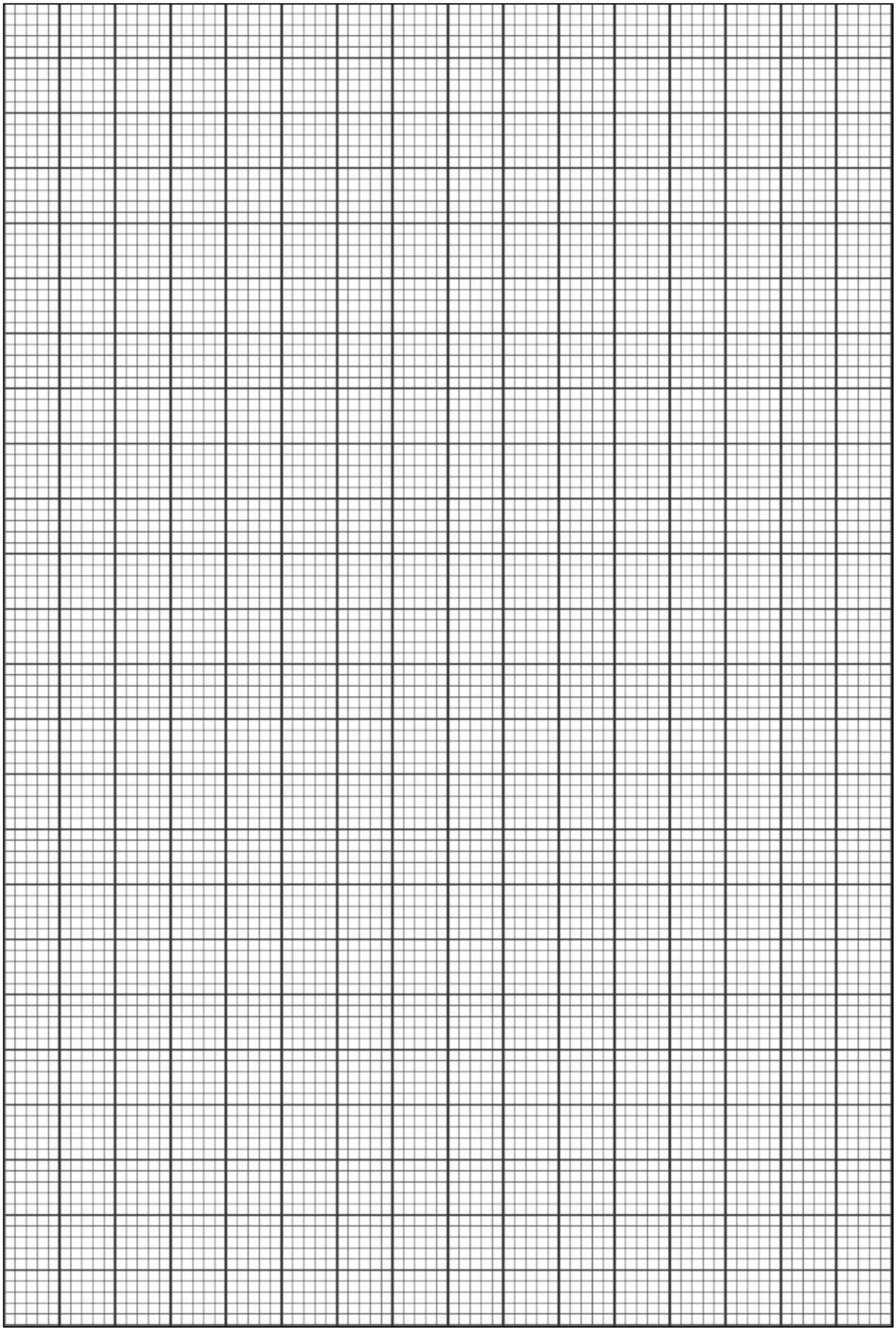


Method – Part B:

18. Remove the nut and string from the hanging position and place them anywhere such that they are not in the way while you work on this second part of the experiment. **Do not remove the string from the cork.**
19. The pins inserted in the cork will serve as a points of support for the oscillations of a drinking straw.
20. Use the 30 cm ruler to measure a distance of 125 mm from one end of the straw and mark it by piercing the straw with the extra pin/needle provided.
21. At a point that is $h = 30$ mm from this mark, push the pin through the straw at right angles to it.
22. Arrange the straw as shown in Figure 3 so that it can swing freely with the pin acting as a pivot.

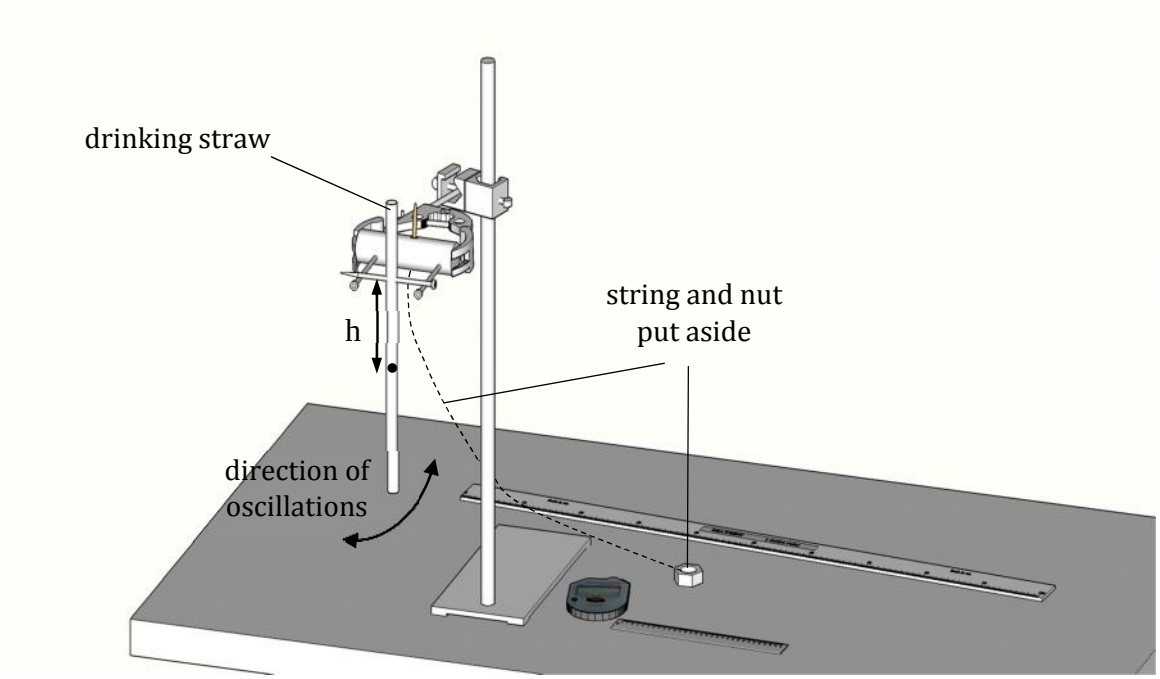


Figure 3

23. Determine the time T_{20} in seconds for 20 oscillations of the straw as it swings with small amplitude in a vertical plane. Record this in the row for $h = 30$ mm in Table 2.

[1 mark]

24. Carefully remove the pin.

25. Obtain further values of T_{20} for the other four different values of given in Table 2.

[4 marks]

26. Take repeated readings.

[10 marks]

Table 2

h / mm	^{2}/mm^{2}	T_{20} /s	T_{20} /s	T_{20} /s	$\overline{T}_{20}$ /s	T /s	T^{2}/ mm s^{2}
30							
35							
40							
45							
50							

27. $\overline{T}_{20}$ is the mean value of the repeated readings taken. Complete Table 2 by working out the missing values for ^{2}, $\overline{T}_{20}$, T and T^{2}.

[10 marks]

28. Plot a graph of T^{2} /mm s^{2} on the y-axis against length ^{2} /mm^{2} on the x-axis.

[10 marks]

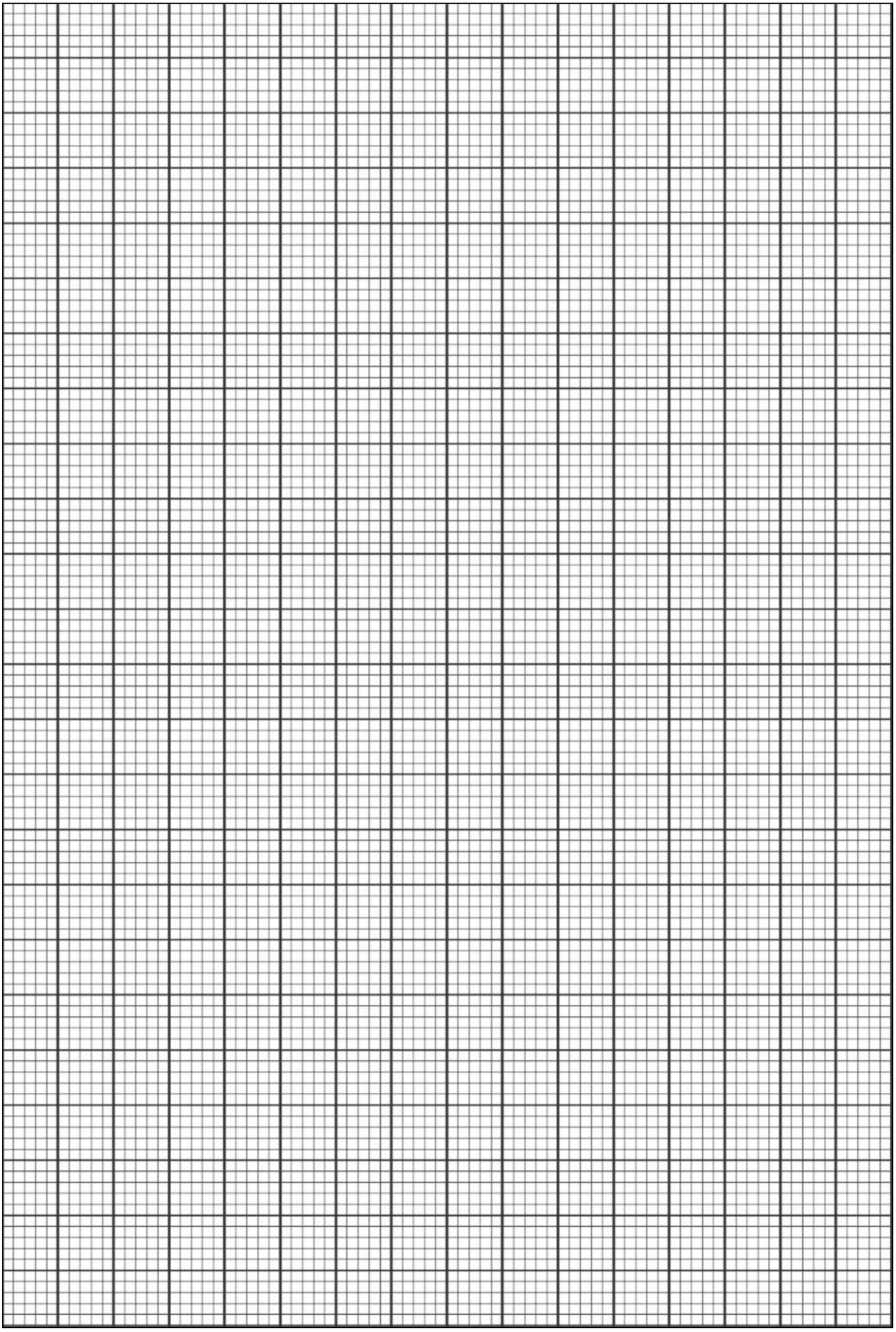
29. It is given that the periodic time T for this pendulum is related to the distance by the equation:

$$T^{2} = p\ ^{2} + \frac{kL^{2}}{12000}$$

where p is a constant, L is the length of the straw in millimetres and k is the constant found in step 17.

30. Use the graph to determine the length L of the straw.

[6 marks]



31. Now measure the length L of the straw in millimetres directly using the 30 cm ruler.
L = _____ ± _____mm

[1 mark]

32. Work out the difference between the two values of L obtained in steps 30 and 31 and express this as a fraction of the length L obtained in step 31.

[4 marks]

33. State **one** source of error and **one** corresponding precaution undertaken, other than repeated readings, during the experiment of part B.

[2 marks]