L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2018 SECOND SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	I
DATE:	3rd September 2018
TIME:	9:00 a.m. to 12:05 p.m.

A list of useful formulae and equations is provided. Take the acceleration due to gravity $g = 9.81\,\mathrm{m\,s^{-2}}$ 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 small sailboat is moving through water at constant velocity in the direction shown in Figure 1.
   a. What is the magnitude of the resultant force acting on the sailboat? Explain your answer. (3)

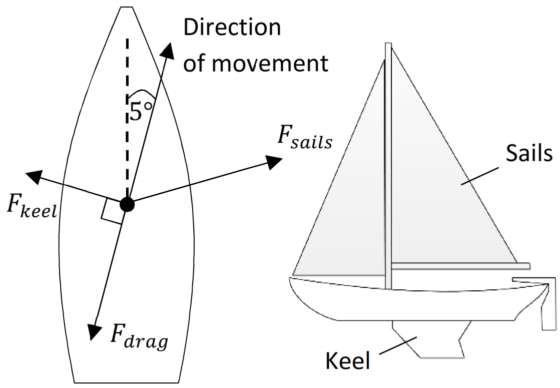

Figure 1

   b. Given that the force on the keel F_{keel} is $400\,\mathrm{N}$ and the drag force F_{drag} is $240\,\mathrm{N}$. The latter acts in a direction that is directly opposite to the direction of the movement of the sailboat. Calculate:
      i. the magnitude of the force F_{sails} exerted by the wind on the sails; (6)
      ii. the angle that the force F_{sails} makes with the direction of movement of the sailboat. (3)

(Total: 12 marks)

2. Figure 2 shows a graph of speed v in metres per second against time t in seconds for a remote-controlled car travelling in a straight line.

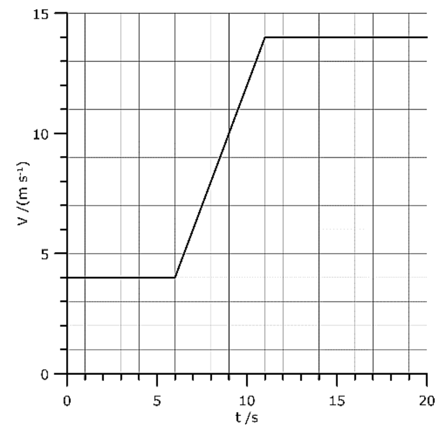

Figure 2

   a. Describe the motion of the car between $t = 0\,\mathrm{s}$ and $t = 6\,\mathrm{s}$. (2)
   b. Determine the acceleration of the car between $t = 6\,\mathrm{s}$ and $t = 11\,\mathrm{s}$. (2)
   c. Calculate the average speed of the car for the same time interval of part (b). (2)
   d. What is the increase in the car's speed between $10\,\mathrm{s}$ and $15\,\mathrm{s}$? (1)

Question continues on next page

e. Calculate the total distance travelled by the car in $20\ \mathrm{s}$. (3)

f. Sketch a graph that shows how the acceleration of the car varied between $t = 0\ \mathrm{s}$ and $t = 20\ \mathrm{s}$. (4)

(Total: 14 marks)

3. A helicopter is lifting two crates, labelled X and Y, simultaneously. One crate with a mass of $180\ \mathrm{kg}$ is attached to the helicopter by a cable. The second crate with a mass of $95\ \mathrm{kg}$ is hanging below the first crate and attached to the first crate by a second cable. The helicopter is accelerating upwards at $1\ \mathrm{m\ s^{-2}}$. Take the tension in the first cable to be T_1 and the tension in the second cable to be T_2.

a. Draw a well-labelled diagram showing the two crates and two cables. Indicate all the forces acting on them. Ignore any drag forces caused by movement of air generated by the helicopter blades. (5)

b. Calculate the tension T_1 in the first cable. (4)

c. If the second cable can withstand a maximum breaking force of $1300\ \mathrm{N}$, determine the maximum acceleration at which the helicopter can lift up the crates. (3)

(Total: 12 marks)

4. A dart gun is used to shoot darts at a fixed target. The dart is inserted in the barrel of the gun where it compresses a spring with a spring constant $k = 400.0\ \mathrm{N\ m^{-1}}$ through a distance of $0.08\ \mathrm{m}$, as shown in **Figure** 3. The mass of each dart is $0.015\ \mathrm{kg}$.

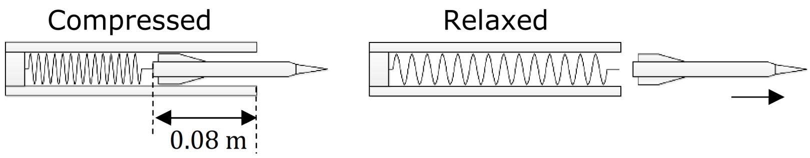

Figure 3

a. State the energy changes taking place when the spring is released. (2)

b. Calculate the speed of the dart as it exits the barrel. Assume that there is no friction between the spring and dart and barrel. (5)

c. The same dart gun is loaded again by compressing the spring the same distance. This time, as the dart is moving out, the spring gets stuck when it is still compressed by 0.04 m. The dart still exits the gun. Calculate the new velocity with which the dart exits the barrel. (5)

(Total: 12 marks)

5. Two wheels A and B are in contact and can rotate freely about a fixed axis through their centre. The radius of wheel A is larger than that of wheel B. Wheel A is rotating with a frequency of $6.0\ \mathrm{Hz}$.

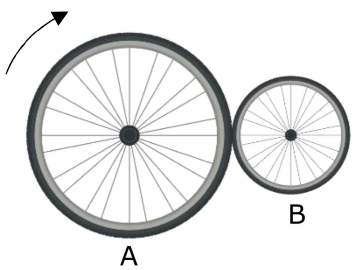

Figure 4

a. Calculate the angular velocity of wheel A. (2)

b. If the radius of wheel A is $0.10\ \mathrm{m}$, determine the linear speed of a point at the edge of wheel A and hence state the linear speed and direction of rotation of a point on the edge of wheel B. (4)

c. Calculate the angular velocity of wheel B if its radius is $0.08\ \text{m}$. (2)

d. Wheel A is given an acceleration at $4.0\ \text{rad s}^{-2}$ for $2.0\ \text{s}$. Calculate the number of rotations completed by wheel B in this time. (6)

(Total: 14 marks)

6. Two carpenters, Peter and John, of equal height, are supporting a uniform wooden beam horizontally on their shoulders. The beam is $2.44\ \text{m}$ long and has a mass of $60\ \text{kg}$. Peter, being a bit stronger than the other, agrees to support the beam $1.00\ \text{m}$ in from one end while John supports the beam at its opposite end. The system of carpenters and beam are in mechanical equilibrium.

a. State **TWO** conditions necessary for mechanical equilibrium. (4)

b. Draw a free body diagram showing all the forces acting on the beam. (4)

c. Calculate the magnitude of the forces exerted by the two carpenters. (4)

(Total: 12 marks)

7. A solid cylinder of mass M and radius R is released from rest and allowed to roll without slipping down an inclined plane. The inclined plane has one end resting on the floor and is tilted at $30°$ with respect to the horizontal. The moment of inertia of the cylinder about an axis through its centre is given by $\frac{1}{2}MR^2$. The cylinder is released from a height of $0.60\ \text{m}$ above the floor.

a. State the energy changes taking place from when it is released and as it is rolling down the inclined plane. (4)

b. Draw a free-body diagram showing all the forces acting on the cylinder as it rolls down. (3)

c. Explain what is meant by the term moment of inertia. (2)

d. Calculate the speed with which the cylinder reaches the lowest end of the inclined plane. (5)

(Total: 14 marks)

8. A radioactive sample has equal numbers of oxygen isotopes $^{15}_{8}\text{O}$ and $^{19}_{8}\text{O}$ nuclei. The half-lives of both isotopes are given in Table 1.

Table 1

Isotope	Half-life /s
$^{15}_{8}\text{O}$	122.24
$^{19}_{8}\text{O}$	26.88

a. Explain the terms isotopes and half-life. (4)

b. Use the half-lives given in Table 1 to determine how long it will take before there are twice as many $^{15}_{8}\text{O}$ nuclei as $^{19}_{8}\text{O}$. (6)

(Total: 10 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. Explain the terms elastic limit, yield point and define Young's modulus of elasticity. (3)

b. A student is determined to find the Young's modulus of a thin copper wire by carrying out an experiment. He is provided with two long thin copper wires and a fixed support. Describe the experiment that he should carry out. Your description should include:

i. a list of any other 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 table of the data to be recorded from the experiment; (2, 1)
iv. a source of error and **ONE** corresponding precaution; (1, 1)
v. a labelled graph; (2)
vi. the calculations that are required to obtain the Young's modulus from the graph. (2)

c. Two steel wires having the same length L are connected together end to end. The thicker wire has twice the radius of the thinner wire. The thinner wire is attached to a fixed support as shown in Figure 5. An applied force F stretches the combination by 1.2 mm. Take the Young modulus of steel to be Y.

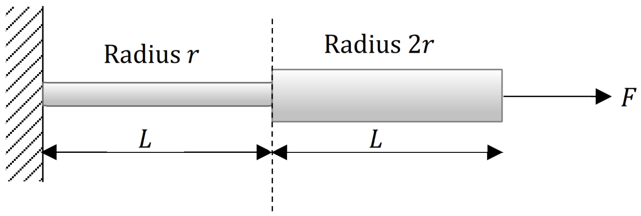

Figure 5

i. Derive an expression for the tensile stress on the thicker wire in terms of F and r. (3)
ii. Show that the extension of the thinner wire Δx_1 is related to the extension of the thicker wire Δx_2 by the expression $\frac{\Delta x_1}{\Delta x_2} = 4$. (3)
iii. Hence, calculate the distance that the midpoint (the joint where the thicker wire is attached to the thinner wire) moves. (3)

(Total: 25 marks)

10.

a. The graph in Figure 6 shows how the current through an electric DC motor changes with time.

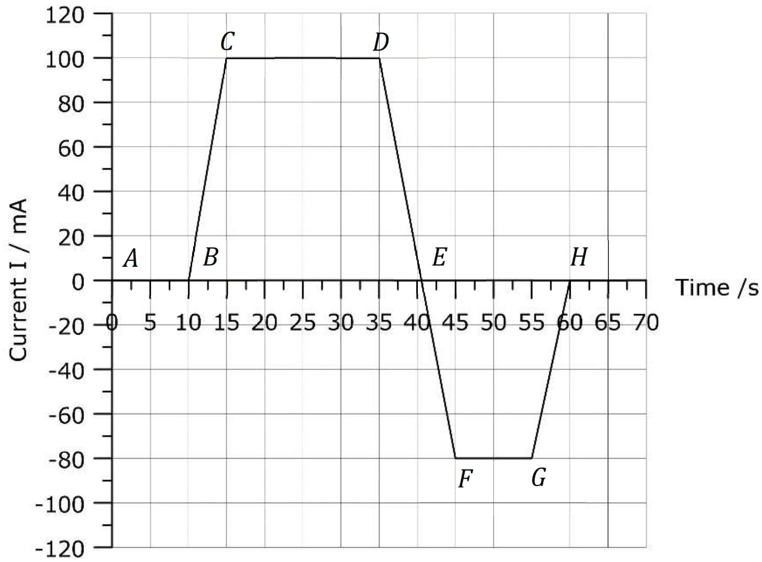

Figure 6

i. Identify the point when the motor was turned on. Explain your answer. (1)

ii. Explain how the total charge passing through the motor can be determined from the graph. (2)

iii. Calculate the rate of increase in current in section BC of the graph. (2)

iv. Explain what is likely to happen to the motor rotational speed with the increase in current. (2)

v. Explain what happens to the rotation of the motor as the current changes as it goes from D-E-F as shown on the graph. (3)

b. Define and distinguish between the terms potential difference and electromotive force. (4)

c. An electrical conductor with n free electrons per unit volume and cross-sectional area A is carrying a current I. Using an appropriate diagram, show that the current through the conductor is related to the drift velocity v of the electrons by the expression $I = nAve$. (5)

d. Briefly explain how the position and width of the conduction band, forbidden band and valence band are different in conductors, semiconductors and insulators. (6)

(Total: 25 marks)

Questions continue on next page

11.

a. A student is provided with a filament bulb and a nichrome wire. She is asked to carry out an experiment to determine which of the two is an Ohmic conductor by observing the IV characteristics. Describe the experiment she should carry out by making particular reference to:

i. the list of equipment that is needed; (2)

ii. a diagram of the circuit to be used; (2)

iii. the procedure to be followed and a table showing the data that needs to be observed and recorded; (2, 2)

iv. a sketch of the **TWO** graphs that she is expected to obtain from the experiment; (2)

v. **ONE** precaution that needs to be taken during the experiment; (1)

vi. how to distinguish between an ohmic and a non-ohmic conductor. (1)

b. A cell with an e.m.f. of 6 V and internal resistance r of $1\,\Omega$ is connected to two resistors R_1 and R_2 in series. R_2 has 3 times the resistance of R_1 and the potential difference across it (R_2) is 4.2 V. Calculate:

i. the voltage across R_1; (2)

ii. the current flowing through the circuit; (3)

iii. the value of resistance R_2. (2)

c. In the circuit shown in Figure 7, $R_1 = 5\,\Omega$, $R_2 = 4\,\Omega$, $R_3 = 2\,\Omega$ and $R_4 = 4\,\Omega$. Use Kirchoff's laws to determine the potential difference across R_2 and R_4. (6)

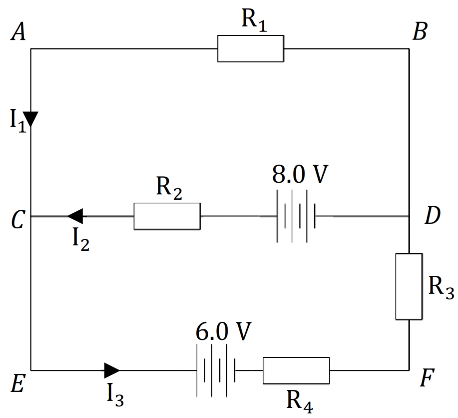

Figure 7

(Total: 25 marks)

12.

a. In 1888, a German physicist Wilhelm L. F. Hallwachs discovered that an insulated negatively charged zinc plate lost its charge when exposed to ultraviolet light. In 1905, Einstein suggested that experimental results in photoelectricity could be explained by applying a quantum theory of light.

i. Briefly explain what Einstein postulated in the quantum theory of light. (3)

ii. State **TWO** aspects of the experimental results that could not be explained through classical physics. (4)

iii. Write down Einstein's equation for the photoelectric effect and explain the meaning of each term in the equation. (3)

b. Light of frequency 4.5×10^{14} Hz ejects electrons from a certain metallic surface. A stopping potential of 1.44 V is needed to stop the liberated electrons.

i. In which part of the electromagnetic spectrum, near the red or the violet end of the spectrum, does the light falling on the metallic surface fall into? Explain your answer. (3)

ii. Calculate the maximum kinetic energy and speed of the liberated electrons. (4)

iii. Determine the wavelength of ultra-violet light which would eject electrons with an energy of 8.93×10^{-19} J from the same surface. (4)

c. An isolated hydrogen atom has the energy levels shown in Figure 8. The energy levels shown are in electron volts, with $n = 1$ being the ground level and $n = \infty$ being the ionisation level.

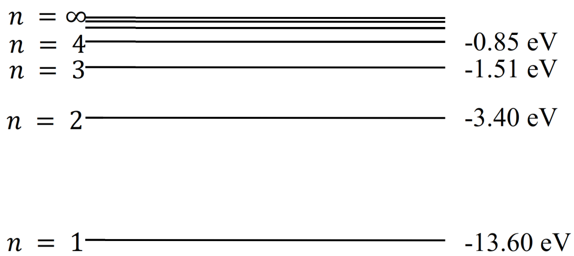

Figure 8

i. Explain what is meant by ground level and ionisation level. (2)

ii. Calculate the energy in Joules released or absorbed in a transition between $n = 4$ and the ground level. (2)

(Total: 25 marks)

13.

a. State Newton's first and third laws of motion. (4)

b. A classic experiment to demonstrate Newton's first law of motion is illustrated in Figure 9. Explain how Newton's first law fits with the observations from this experiment. (4)

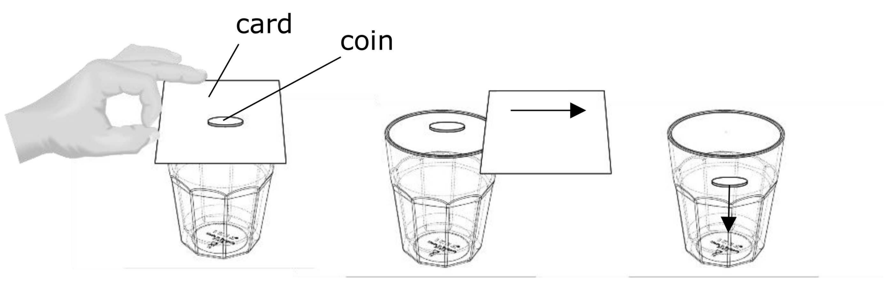

Figure 9

Question continues on next page

c. A biker hangs his bike from a hook fixed to the ceiling of his garage. Consider the following forces:
- Force A - the force of the Earth pulling down on the bike;
- Force B - the force of the bike pulling up on the Earth;
- Force C - the force of the hook pulling up on the bike;
- Force D - the force of the hook pulling down on the ceiling.

i. Which **TWO** forces are equal and opposite because of Newton's third law? (2)
ii. Which **TWO** forces are equal and opposite because of Newton's first law? (2)

d. Define linear momentum and state the law of conservation of momentum. (2)

e. In a game of billiards, John hits the cue ball with an average force of $20\ \mathrm{N}$. The impact of the cue stick with the cue ball lasted $0.028\ \mathrm{s}$. The ball has a mass of $0.160\ \mathrm{kg}$. The cue ball continues to move and hits two balls that are in contact with each other. Assume that all collisions are perfectly elastic, that any movements of the balls are along the original straight-line path of the cue ball and that the balls are identical.

i. Calculate the speed v with which the cue ball moves after being struck with the cue stick. (3)
ii. Explain why the following two situations are impossible:
- Cue ball stops while the two other balls move off together with half the original speed of the cue ball, that is, $\frac{v}{2}$; (4)
- Cue ball stops while the two other balls move off together at $\frac{v}{\sqrt{2}}$. (4)

(Total: 25 marks)

14.

a. A $10.0\ \mathrm{kg}$ block is released from rest on a frictionless plane inclined at an angle of $55°$.

i. Draw a free body diagram showing all the forces acting on the block. (2)
ii. Calculate the magnitude of the force accelerating the block downwards. (2)
iii. Calculate the acceleration of the block. (2)
iv. If the block is released from rest, how long will it take for the block to attain a speed of 10.0 m/s? (2)
v. Calculate the total distance travelled by the block in this time. (2)
vi. Draw a graph showing how the velocity of the block changes with time up to when it reaches $10\ \mathrm{m\ s^{-1}}$. (3)

b. An arrow is fired from a point $1.0\ \mathrm{m}$ above the ground. The initial velocity is $19.6\ \mathrm{m\ s^{-1}}$ at an angle of $30.0°$ above the horizontal.

i. Find the maximum height of the arrow above the ground. (4)
ii. Calculate the speed of the arrow at the highest point in the trajectory. (2)
iii. Determine the x- and y-components of the velocity of the arrow $2.0\ \mathrm{s}$ after it leaves the bowstring. (3)
iv. Calculate the distance from the point of projection where the arrow lands on the ground. (3)

(Total: 25 marks)

15.

a. Verify that the units of the rotational form of Newton's second law $\tau = I\alpha$ are consistent. (4)

b. A merry-go-round in a playground can rotate freely about an axis through its centre. Two children of mass m are on opposite sides of the merry-go-round and are going to push it such that it starts rotating from rest until it reaches N revolutions per minute in time Δt. If the children are assumed as being point masses sitting on the exact edge of the merry-go-round:

i. with the aid of a diagram, explain briefly how the children should push to achieve N revolution per minute in the shortest time possible. (3)

ii. show that the angular acceleration α is given by the expression,

$$\alpha = \frac{\pi N}{30\Delta t}\ \text{rad s}^{-2}$$

(2)

iii. The moment of inertia I of a solid disk of mass M, radius R and diameter D, rotating about an axis through its centre, is given by $I = \frac{1}{2}MR^2$. Derive an expression for the torque τ exerted by the two children on the merry-go-round, in terms of M, m, D, N and Δt. (4)

iv. If the mass of the merry-go-round M is $300\ \text{kg}$ and its diameter D is $2.0\ \text{m}$, calculate the tangential force that each child must exert to increase the rotational speed of the merry-go-round from rest to 25 revolutions per minute in 20.0 seconds. Take the mass m of each child to be $30\ \text{kg}$. (4)

c. When the merry-go-round reaches a rotational speed of 25 revolutions per second, the children stop pushing. While the merry-go-round is still rotating at this speed the children decide to move towards the centre such that they are $0.20\ \text{m}$ from the axis of rotation. Assume that energy losses due to friction are negligible.

i. Explain, the changes, if any, that occur to the total moment of inertia of the system (consisting of the merry-go-round and children). (2)

ii. How will the angular speed of the merry-go-round be affected and calculate any change in angular speed in radians per second. (6)

(Total: 25 marks)

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A list of useful formulae and equations is provided. Take the acceleration due to gravity $g = 9.81\ ms^{-2}$ 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. State the second law of thermodynamics. (2)

   b. i. Define the term efficiency of heat engines. (1)
   ii. Derive an expression for the maximum efficiency of heat engines in terms of temperatures, explaining all terms used. (2)

   c. One mole of ideal gas is used in a reversible heat engine. Part of the heat engine cycle involves the gas being compressed adiabatically from a volume of $0.02\ m^3$ to $0.01\ m^3$ where the pressure becomes 0.3 MPa.
   i. What initial pressure did the gas have in this process? (2)
   ii. Determine the temperatures at both ends of this process. (3)
   iii. Sketch a pressure-volume graph of this process. (3)
   iv. Using part (b), determine the maximum efficiency of this process. (2)

   [Assume an adiabatic constant $\gamma = 1.4$]

(Total: 15 marks)

2. a. i. Describe briefly the setup of a simple experiment to show the random motion of molecules in bodies of gas. (2)
   ii. What **FOUR** assumptions of the kinetic theory of gases did this observation lead to? (4)

   b. Using the assumptions of the kinetic theory of gases for a gas in a vessel, explain the following:
   i. the pressure of a gas increases when its volume is decreased; (2)
   ii. as a gas is heated, while keeping its volume constant, its temperature rises. (2)

   c. i. For a body of gas, what does $\overline{c^2}$ represent? (1)
   ii. Given a body of three particles with speeds of $1\ ms^{-1}$, $4\ ms^{-1}$ and $9\ ms^{-1}$, determine the value of $\overline{c^2}$. (2)
   iii. If the body of three particles moves inside a volume of $6 \times 10^{-25}\ m^{-3}$ and each particle has a mass of 1.6×10^{-25} kg, determine its pressure. (5)

(Total: 18 marks)

3. a. Define the gravitational field strength and the gravitational potential at a point. (4)

   b. i. A capsule of mass m is launched from Earth into space. What does the term escape velocity refer to? (2)

      ii. Derive a relationship to determine the escape velocity of the capsule with an initial upward velocity v, given that the Earth has a mass M. (3)

   c. i. If the Earth's radius is roughly 6.4×10^6 m, estimate the escape velocity for Earth. (2)

      ii. Do you expect the escape velocity on the moon to be greater or less than that of the Earth? Why? (2)

(Total: 13 marks)

4. a. What factors affect the capacitance of a capacitor? (3)

   b. Mention **THREE** possible ways to increase the capacitance of a capacitor. (3)

   c. Two capacitors C_1 and C_2 are set up in parallel with a potential difference V across them, and with charges Q_1 and Q_2 stored on them respectively. Derive an equation for the effective capacitance of the set up. (2)

   d. Define the term time constant of an RC circuit. (2)

   e. A resistor, R, is connected in series with two capacitors connected in parallel. Write down an equation for the effective time constant for this system. (1)

(Total: 11 marks)

5. a. Define magnetic flux density. What is its associated SI unit? (3)

   b. Describe the Hall effect. (2)

   c. Derive a formula for the Hall Voltage, V_H, for a conductor of thickness t, carrying current I. It may be assumed that the conductor contains n charge carriers per unit volume, each of charge Q. (3)

   d. A large laboratory magnet provides a field strength B = 1 T. A current of 20 A is passed through a Hall conductor cubic specimen of side 2 mm. The observed Hall voltage is found to be V_H=0.5 μV.

      i. Determine the number of charge carriers per unit volume. (2)

      ii. If an identical specimen that is eight times the original volume is used, how will the number of charge carriers per unit volume change? (2)

(Total: 12 marks)

6. a. Define the terms self-inductance and mutual inductance. (4)

b. A 12 V battery of negligible internal resistance is connected in series with a coil of resistance 10 Ω. When switched on, the current in the circuit grows from zero. When the current reaches 1 A, the rate of growth of the current is 250 A s^{-1}. Find the self-inductance of the coil. (3)

c. A long solenoid of length l and cross-sectional area A consists of N_1 turns of a length of wire. This is then covered by a second coil of N_2 turns wrapped around it, as shown in Figure 1. The secondary coil has the same length as the first.

i. Determine the mutual inductance, M, assuming that a percentage η of the flux from the solenoid passes through the outer coil. (3)

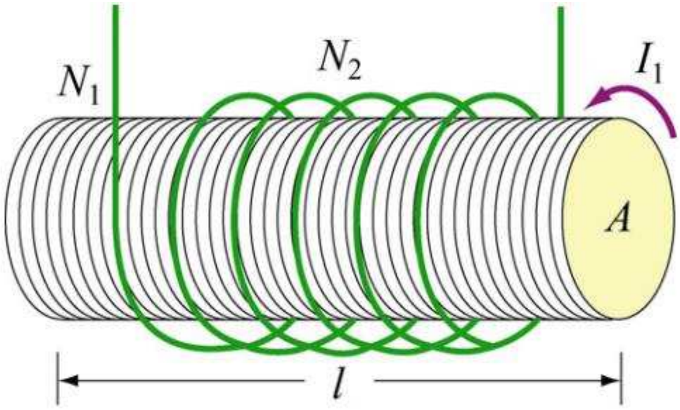


Figure 1: [MIT, 2004]

ii. Show that the mutual inductance, M, in part (a) and the individual self-inductances of the solenoid, L_1, and coil, L_2, are related by the expression $M = \eta\sqrt{L_1 L_2}$. (2)

(Total: 12 marks)

7. a. What are longitudinal and transverse waves? (2)

b. Mention **THREE** characteristics that they share, and **ONE** that they do not. (4)

c. A piece of wire, of length 1 m and mass per unit length 1×10^{-3} kg m^{-1}, is stretched by a load of 2 kg. The length of wire is plucked at its midpoint.

i. What will the wavelength of the standing wave be? (2)

ii. What will the frequency of the resulting wave be? (2)

(Total: 10 marks)

8. a. i. Describe how the set up of the two-slit experiment forms an interference pattern of visible light. (3)

ii. What conditions must exist to form a visible pattern? (2)

b. A screen is placed 13 m away from a double slit aperture whose separation is 2.5 cm.

i. If the distance on the screen between two adjacent fringes is measured to be 0.09 cm, find the wavelength of the light being used. (2)

ii. If the light wavelength is now increased to 2 μm, find the new fringe separation. (2)

(Total: 9 marks)

Questions continue on next page

SECTION B

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

9. a. A closed bottle contains equal volumes of water and air and it is in thermal equilibrium.
   i. In this context, explain the difference between temperature and heat. (3)
   ii. How do the kinetic energies of the water and air molecules compare? Explain your answer. (2)

   A thermometer is now used to record the temperatures of the air and water inside the bottle.
   iii. What condition must be satisfied for the thermometer to take correct measurements of temperature? (1)
   iv. How will the measurement affect the temperature of the bottle system? (1)

   b. Using a constant volume gas thermometer, describe how a temperature scale may be established using an ideal gas and the triple point of water. (5)

   c. Mention **TWO** advantages of using the triple point of water to set up a temperature scale. (2)

   d. A constant volume gas thermometer is used to measure the temperature of water. When it is put in contact with the triple point of water, it measures a pressure of 85 kPa. It is then put in contact with the water under test and it measures 116 kPa.
   i. What is the temperature of the water under test? (3)
   ii. Will the gas thermometer be able to accurately measure any other temperature? Explain your answer. (2)

   A second constant volume gas thermometer is used to confirm the first temperature reading. The triple point of water is again measured to have a pressure of 85 kPa.
   iii. The second thermometer measures the water to have a temperature of 370 K. What will its pressure reading be? (2)
   iv. Give **ONE** reason why the second has thermometer may give a different temperature reading. (2)
   v. Under what conditions would all gas thermometers read the same temperature? (2)

   [Triple point of water is 273.16 K]

(Total: 25 marks)

10. a. i. Describe the terms heat capacity and specific heat capacity. (2)
   ii. Briefly outline an experiment to determine the specific heat capacity of a liquid substance. Include a labelled diagram of the apparatus used, a list of the measurements to be taken, the method used, and a sketch of the expected graph. Mention **ONE** precaution that should be taken in this experiment. (11)

   b. Using concepts in heat, explain the following events:
   i. Snow falls on a mountain during a cold night. The next day the air temperature rises above the freezing point temperature but the snow remains on the mountain for the rest of the day. (2)

ii. A thermometer measures the temperature of a volume of water being heated. As the water approaches its boiling point, the temperature reading becomes steady and ceases to change for a time. (2)

iii. Water vapour is condensing on a surface in an enclosed container. The air inside the container increases in temperature. (2)

c. Four ice cubes are used to cool a glass of orange juice at a temperature of 20 °C. The orange juice has a mass of 0.25 kg. The ice is at -1 °C, with each cube having a mass of 6 g. The glass of juice is kept in a foam container so that heat losses can be ignored. If the glass has a mass of 100 g and is in perfect thermal equilibrium with the orange juice throughout, determine the final temperature of the glass of orange juice assuming that all the ice has melted. It may be assumed that the orange juice has the same specific heat capacity as water. (6)

[Specific heat capacity of glass: 840.0 J kg^{-1} K^{-1}]
[Specific heat capacity of water: 4181.3 J kg^{-1} K^{-1}]
[Specific heat capacity of ice: 2080 J kg^{-1} K^{-1}]
[Specific latent heat of fusion of water: 330.55 kJ kg^{-1}]

(Total: 25 marks)

11\. a. Describe **FOUR** ways that heat can be transported. (8)

b. A planet is composed of a solid inner core surrounded by a series of liquid layers. Explain, using the concepts in part (a), how heat is transported from the core to the planet surface. (3)

c. A copper rod of length 1 m and cross-sectional area 0.314 m^2 connects two heat reservoirs of temperature 75 °C and 30 °C respectively. The rod is well insulated.

i. Determine how much heat will flow between the reservoirs over the course of three hours. (3)

To decrease the rate of transport of heat between the reservoirs, a second rod of identical dimensions is attached to the end of the copper rod. The second rod has a thermal conductivity of 100 W m^{-1} K^{-1}, and the heat transportation over three hours is halved.

ii. Find the intermediate temperature between the rods. (4)

iii. State any assumptions you have made in your calculation. (1)

d. Radiation is produced by a flashlight.

i. Describe how the intensity of the emitted light decreases with distance. (2)

ii. The intensity of the flashlight at 1 m is represented by I_1. At what distance will this intensity decrease to half of this value? (2)

iii. Explain what is meant by saying that the flashlight emitter is a black body. (2)

[Thermal conductivity of copper: k_{copper} = 401 W m^{-1} K^{-1}]

(Total: 25 marks)

Questions continue on next page

12. a. Two level hydrogen balloons, A and B, of negligible mass are floating with their centers at a distance of 1 m apart. The same balloons are also tied to a mass of 150 g using two separate 1 m strings forming an equilateral triangle. Each length of string carries a tension, T. The balloons each carry a charge of -Q and are floating in equilibrium.

i. Sketch a diagram of the setup, showing clearly the tension in the strings. (3)

ii. Sketch a second diagram to show the lines of equipotential around the balloons. (2)

iii. Write down the horizontal and vertical force components for the strings. (2)

iv. Write down **TWO** equations relating these force components to the gravitational and electrostatic forces. (2)

v. Determine the charge on the balloons. (3)

b. Two charges are placed on the x-axis of a coordinate system. A negative charge of magnitude 3.14 μC is placed 0.32 m away from the origin. The second particle of charge +2.72 μC is placed at a point -0.37 m on the x-axis.

i. Determine the electric potential at the origin. (3)

ii. Find a point on the x-axis where this potential is zero. (2)

c. In Figure 2, two parallel plates produce a uniform electric field of field strength 100 Vm^{-1}.

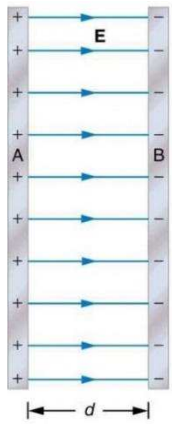


Figure 2

i. Sketch a diagram showing the equipotential field lines between the two plates neglecting any edge effects. (2)

ii. Explain what happens to any charged particle of nonzero mass when placed in this uniform field. Ignore the gravitational force. (2)

iii. An electron is placed on plate B. If the distance between the plates is d = 35 cm, find the acceleration of the electron on collision with plate A. (2)

iv. Sketch the field lines of the plate system as the electron reaches the mid-point between the plates. (2)

(Total: 25 marks)

13. a. What does the root-mean-square value of

i. an alternating current, (2)

ii. an alternating voltage represent? (2)

b. i. Differentiate between resistance and impedance. (2)

ii. Explain the dependence of an inductor’s impedance on the frequency of an alternating current source. (3)

iiii. In this context, describe the term inductive reactance. (2)

iv. How does this differ from capacitive reactance? (2)

c. i. An alternating voltage is applied to an inductor. Sketch a graph of the inductor reactance against frequency. (2)

ii. An alternating voltage is applied to a capacitor. Sketch a graph of the capacitance reactance against frequency. (2)

d. Some people lose the ability to hear higher frequencies as they get older. A hearing aid circuit is designed to boost these frequencies. This consists of an amplifier that boosts all frequencies equally, which is connected in series with an alternating power supply. Would it be best to connect a capacitor or an inductor in this circuit? Explain your reasoning. (2)

e. A 2.5 μF capacitor is connected to an AC power source which has a root-mean-square voltage of 50 V at a frequency of 160 Hz. Determine:
   i. the impedance of the capacitor; (2)
   ii. the root-mean-square current in the circuit; (2)
   iii. the mean rate at which energy is being supplied to the capacitor; (2)

(Total: 25 marks)

14. a. i. State the law of reflection. (2)
   ii. Two light rays are emitted from the same source at different angles and incident on a plane mirror. Explain why the reflected rays can never intersect. (2)

b. i. State Snell's law of refraction. Sketch a ray diagram to depict the law in action using a plane interface. (4)
   ii. Define the term refractive index. State Snell's law in terms of refractive indices. If the speed of light in a substance reduces to 2.76×10^8 m s^{-1}, what is the refractive index of this substance? (5)
   iii. A ray is incident on a water-glass boundary at an angle of 30°. The respective refractive indices are $n_w = 4/3$ and $n_g = 3/2$. Find the angle of refraction at the boundary. (2)

c. i. What does the term total internal reflection mean? At which angle does this phenomenon occur? (3)
   ii. What role does total internal reflection play in the formation of rainbows? (3)
   iii. Mirages are quite common in deserts during peak temperatures. Given that the refractive index of air is lower for higher temperatures, explain how these form. (2)
   iv. The core of a fibre optic cable has a refractive index of 1.44 while the cladding has a refractive index of 1.25. Determine the angle at which total internal reflection starts to take place for a ray of light incident on the cladding-core boundary. (2)

[Speed of Light in vacuum = 3×10^8 m s^{-1}]

(Total: 25 marks)

15. a. Describe the big bang theory and identify **THREE** supportive points of evidence for this theory. (6)

b. i. Explain what is meant by red-shift. (3)
   ii. In the very distant future, how will red-shift effect our observations of other galaxies? (2)
   iii. Within the galaxy, how does red-shift change our observations of stars? (2)

c. i. Describe Hubble's law. (3)
   ii. Sketch a representative graph that obeys this law. (2)
   iii. The galaxy NGC 1232 has a recessional velocity of 1320 km s^{-1}. If the Hubble's constant is given by 70 km s^{-1} Mpc^{-1}, determine the galaxy's distance from the Sun. (2)

d. i. Describe how the Hubble constant is related to the age of the Universe. (3)
   ii. For the galaxy described in part (c), determine the age of the Universe. (You may assume that a year is composed of 365 days). (2)

(Total: 25 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

L-Università ta' Malta

ADVANCED MATRICULATION LEVEL
2018 SECOND SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	III – *Practical*
DATE:	30th August 2018
TIME:	2 hours 5 minutes

Experiment: Experiments with Pendulums

Apparatus: stand and clamp, cork top with two pins, additional pin, light string tied to a nut, metre ruler, reusable putty.

Diagram:

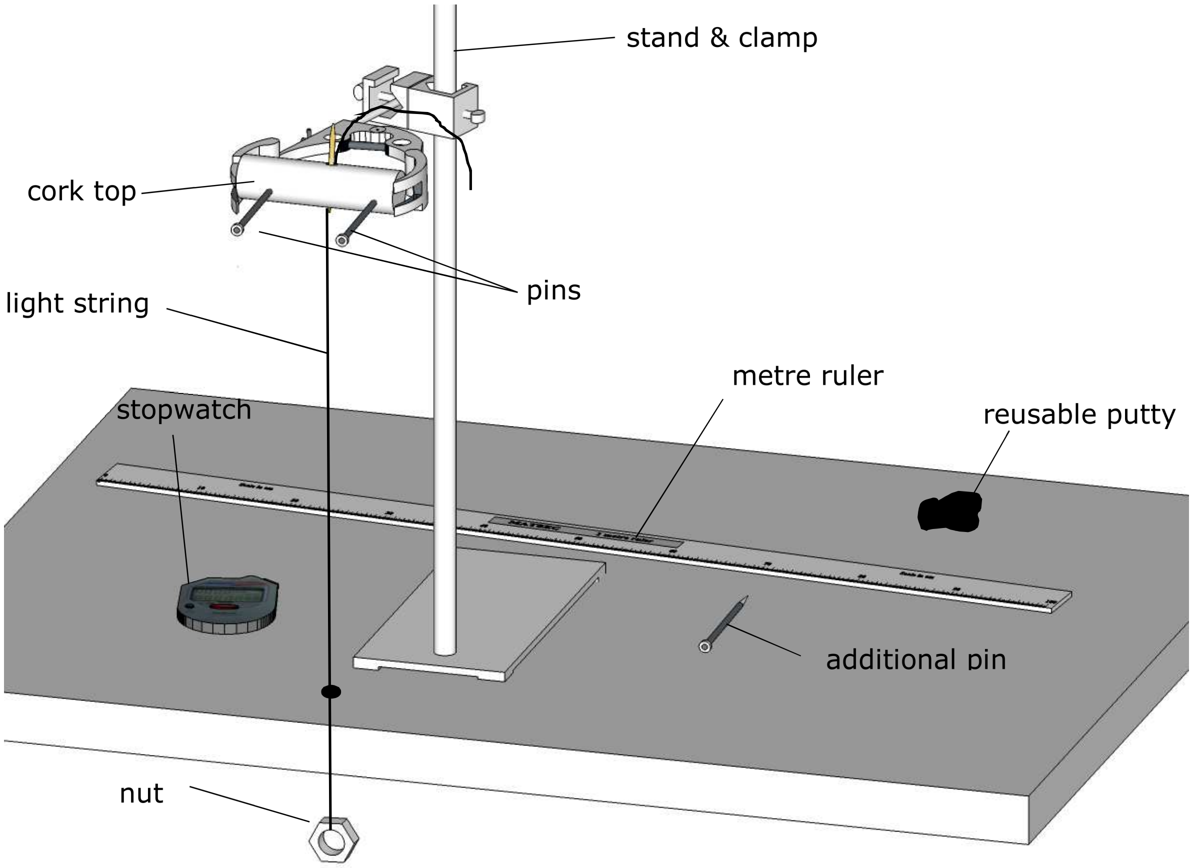


Figure 1 The experimental setup

Method – Part A:

1. The apparatus is set up for you. Make sure that you have all the apparatus shown in Figure 1.
2. You will now carry out the simple pendulum experiment.
3. The light string provided has one end tied to a nut while the other end passes through a hole in the cork top. A toothpick inserted in the hole provides the necessary friction to keep the string from sliding.

4. To change the length of the pendulum, remove the toothpick, adjust the length and re-insert the toothpick in its place.

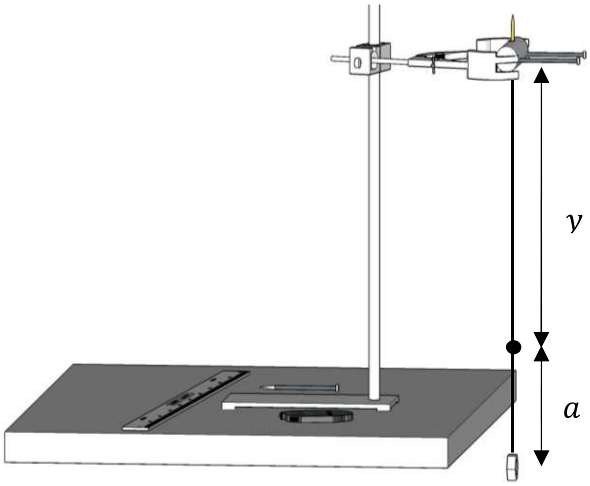


Figure 2

5. The string has a knot tied at a distance a from the centre of the nut. The length from the knot to the bottom of the cork top is y. Refer to Figure 2.
6. Set the length of the pendulum so that y is about $0.80\ \mathrm{m}$.
7. Displace the pendulum bob by a few centimetres to one side and release it so that the pendulum performs small planar oscillations.
8. Measure the time, T_{20} in seconds, for the pendulum to perform 20 small planar oscillations. (1)
9. Record all your measurements in Table 1 and take three repeated readings. (2)
10. Repeat for 6 different lengths y that span a range between approximately $0.20\ \mathrm{m}$ and $0.80\ \mathrm{m}$. (18)

Table 1

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

11. $\overline{(T_{20})}$ is the mean value of the repeated readings taken. Complete Table 1 by filling in the missing data. (7)

12. The period of a simple pendulum is given by $T = 2\pi\sqrt{\frac{L}{g}}$ where L is the length of the pendulum.

13. Show that the equation for the periodic time T in terms of a, y and g can be expressed by $T^2 = \frac{4\pi^2}{g}(a + y)$.

(3)

14. Plot a graph of $T^2\ /s^2$ on the y-axis against $y\ /\mathrm{m}$ on the x-axis. (10)

15. From the graph obtain a value for g and a value for a.

(6)

16. Measure the distance a from the knot to the centre of the nut and comment on how this value compares with the value of a obtained through experiment.

(3)

Method – Part B:

17. 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.
18. There are two pins inserted horizontally in the cork top. These will serve as a points of support for the oscillations of the metre ruler.
19. Use the reusable putty to fix the additional pin that was provided onto the metre ruler, on the $60\,\text{cm}$ mark as shown in Figure 3. Make sure that it is fixed well to the ruler.

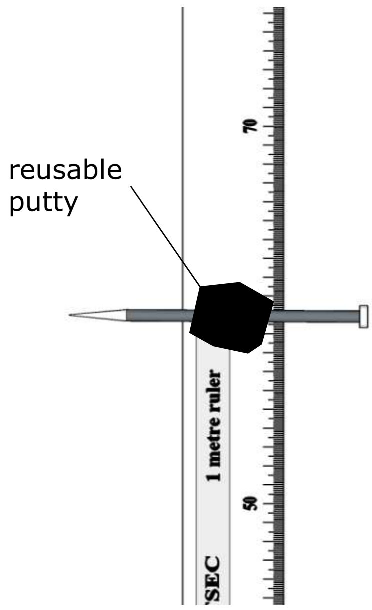
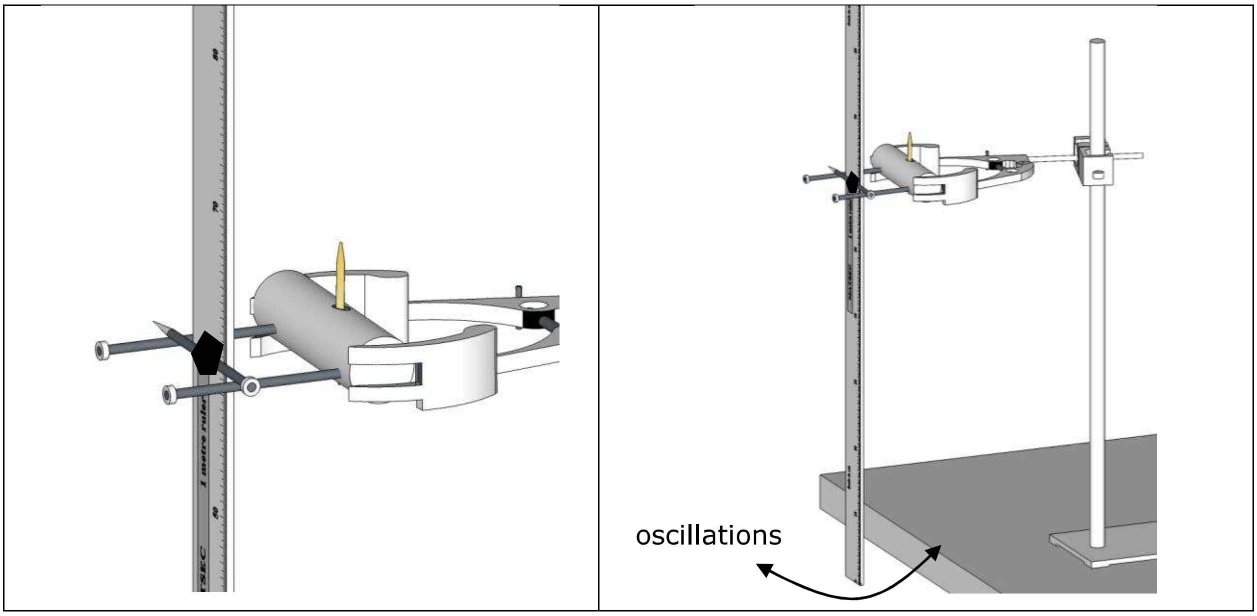


Figure 3

20. Hang the ruler with the zero at the bottom such that the pin attached to the ruler is supported on the two pins in the cork. Make sure that the ruler is able to oscillate freely without touching the cork top or pins. Refer to Figure 4 (a) and (b).



(a) (b)

Figure 4

21. With the pin on the 60 cm (0.60 m) mark, record the time T_{10} in seconds for 10 oscillations of the ruler as it swings with small amplitude in a vertical plane. Record this in the row for $x = 0.60\text{ m}$ in Table 2. (1)
22. Take repeated readings. (2)

23. Remove the pin and reusable putty and move it on the ruler marks indicated in Table 2, each time recording the time for 10 oscillations. (12)

Table 2

x / m	$d = (x - 0.5)$/m	d^2/m^2	T_{10} /s	T_{10} /s	T_{10} /s	$\overline{T_{10}}$ /s	T /s	T^2d/ m s^2
0.60								
0.65								
0.70								
0.75								
0.80								

24. $\overline{(T_{10})}$ is the mean value of the repeated readings taken and d is the distance of the pivot from the centre of mass of the ruler. Complete Table 2 by working out the missing values for d, d^2, $\overline{(T_{10})}$, T and T^2d. (15)

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

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

$$T^2d = \frac{4\pi^2d^2}{g} + \frac{\pi^2L^2}{3g}$$

where L is the length of the ruler in metres.

27. Use the graph to obtain a value for g and a value for the length L of the ruler.

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(6)

Questions continue on page 8

28. State **TWO** sources of error and **TWO** corresponding precautions undertaken during the experiment of part B.

(4)