L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2020 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	I
DATE:	19th September 2020
TIME:	9:00 a.m. to 12:05 p.m.

A list of useful formulae and equations is provided. Take the acceleration due to gravity $g = 9.81\ m\ s^{-2}$ unless otherwise stated.

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

1.

a. Newton's law of friction for a fluid is stated to be $F = \mu A \frac{u}{y}$, where F is the force, μ is the viscosity, A is the area, u is the fluid velocity and y is the displacement.

  i. Express the units of force in terms of base units. (1)

  ii. Hence, determine the base units of viscosity. (3)

b. Two people are pulling a crate using two inextensible ropes in the directions X and Y as shown in Figure 1. The crate is moving at a constant velocity along the dotted line and a frictional force of $500\ N$ acts in the opposite direction to the movement of the crate.

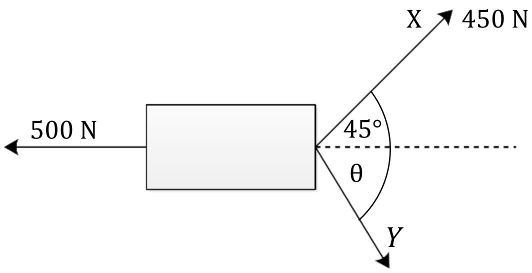


Figure 1

  i. Determine the magnitude of the force along the Y direction and the angle θ. (4)

  ii. If the magnitude of the force X is increased, will the velocity remain constant? Explain. (2)

(Total: 10 marks)

2. A person is using a $2.5\ m$ long uniform ladder AB of mass $11.5\ kg$ by resting it against a frictionless wall as shown in Figure 2. The person is at a point C and weighs $60\ kg$. The ground is rough and a frictional force F is present between the ladder and the ground. The system is in equilibrium.

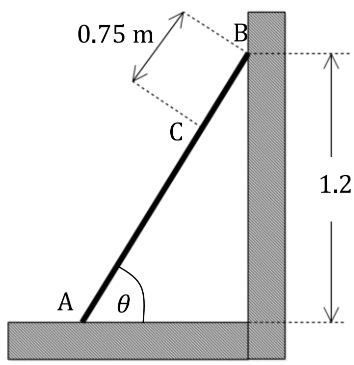


Figure 2

a. Determine the magnitude of the reaction force at point A. (2)

b. Determine the angle of the ladder with the ground. (1)

c. Using point B as the fulcrum, obtain:

  i. the total clockwise moment in $N\ m$; (2)

  ii. the total anticlockwise moment in terms of F. (4)

d. Hence, determine the magnitude of the frictional force F. (1)

(Total: 10 marks)

3. In a $100\,\mathrm{m}$ sprint competition, the velocity of an athlete during their sprint, race and their continuation beyond the finish line was monitored. A graph of the athlete's velocity as it changes with time is shown in Figure 3.

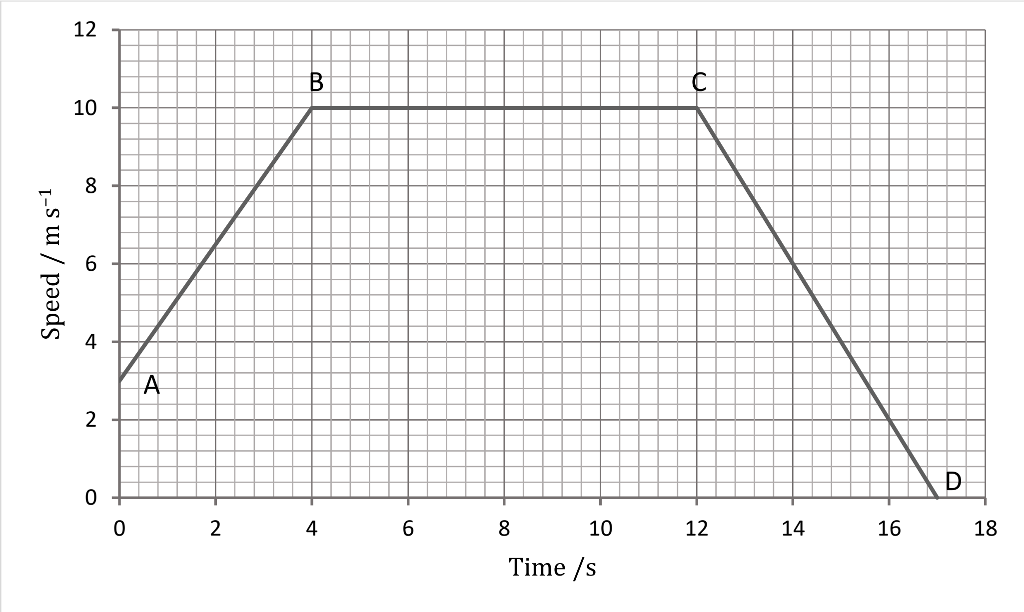


Figure 3

a. Determine the total distance travelled. (4)

b. Using the information provided by the graph, determine the time taken for the athlete to complete the 100 m sprint, that is up to the finish line. (4)

c. Calculate the athlete's deceleration during section CD. (2)

(Total: 10 marks)

4. A student is investigating the resistance properties of a rectangular conductor of dimensions $2x$ by $0.5x$ by x and resistivity ρ, as shown in Figure 4. The conductor is connected to a circuit and a potential difference of $5\,\mathrm{V}$ is maintained across it.

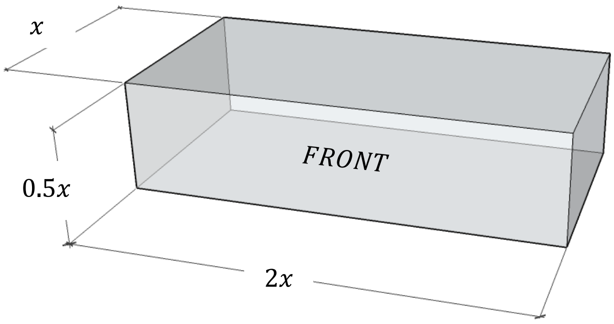


Figure 4

To study its properties, the student connects the conductor into three different configurations: (A) between the front and back faces; (B) between the side faces, and; (C) between the top and bottom faces.

a. Determine which **one** of these configurations (A, B or C) gives the largest resistance. (4)

b. Which one of these configurations (A, B or C) gives the largest current? (2)

c. In all three configurations, what happens to the resistance of the conductor if:
   i. the value x increases? (2)
   ii. the conductivity of the material increases? (2)

(Total: 10 marks)

5. The drum of a washing machine, which is a cylinder of radius $26\ \mathrm{cm}$, rotates at a speed of 900 revolutions per minute as illustrated in Figure 5. A sock of $20\ \mathrm{g}$ is rotating in the drum without slipping or overturning.

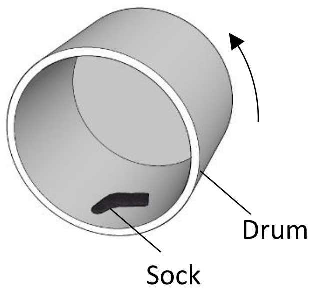


Figure 5

a. Find the angular speed of the drum. (1)

b. Determine the centripetal force experienced by the sock. (1)

c. Will the sock remain in contact with the drum as it rotates? Explain your answer. (3)

d. Determine the minimal angular speed required for the sock to remain in contact with the drum. (3)

e. If the sock is replaced by another heavier piece of clothing, will this remain in contact as the drum rotates? Explain. (2)

(Total: 10 marks)

6. Consider two batteries connected in series to an external resistor of resistance R, as shown in Figure 6. Battery A has an e.m.f of $12\ \mathrm{V}$ and internal resistance of $1\ \Omega$ and battery B has an e.m.f of $9\ \mathrm{V}$ and internal resistance of $2\ \Omega$.

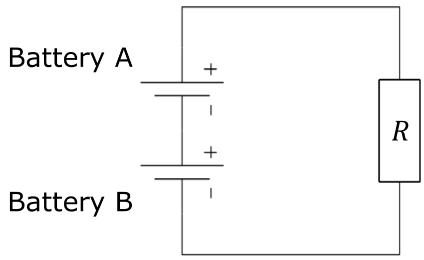


Figure 6

a. Distinguish between electromotive force (e.m.f) and potential difference (p.d). (2)

b. Determine the current flowing through the circuit in terms of R. (3)

c. Determine the potential difference across battery A in terms of R. (2)

d. Determine whether it is possible to have an external resistance R which causes the terminal potential difference across battery A to be zero. (3)

(Total: 10 marks)

7. A cylindrical $2\ \mathrm{m}$ long copper wire of radius $2\ \mathrm{mm}$ is being tested for its resistance properties. The number of charge carriers per unit volume of copper is $8.5 \times 10^{28}\ \mathrm{m^{-3}}$ and its resistivity is $1.7 \times 10^{-8}\ \Omega\ \mathrm{m}$. A potential difference of $1\ \mathrm{V}$ is applied across the length of the wire.

a. Obtain the resistance of the wire. (2)

b. Explain what is meant by drift velocity and obtain its value. (4)

c. If the length of the wire is changed to $3\ \mathrm{m}$, will the drift velocity of the charge carriers change? (1)

Another wire is designed to be in a shape as shown in Figure 7. The cross-sectional areas A_1 and A_2 of the endpoints are such that A_1 is smaller than A_2.

d. Explain why the drift velocity across the length of the wire changes. (1)

e. Determine whether the drift velocity increases or decreases with length along the direction of current flow. (2)

(Total: 10 marks)

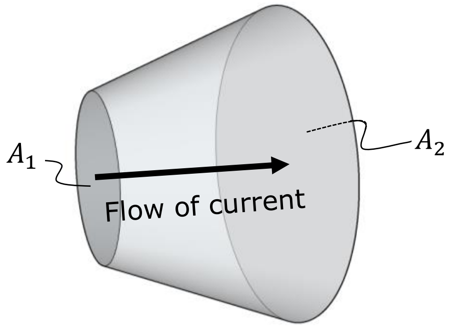


Figure 7

8. An experiment is devised to illustrate the wave behaviour of electrons. The setup consists of a source of electrons, which are targeted on a graphite crystal and controlled by a voltage V as shown in Figure 8. This leads to an image on a photographic film or fluorescent screen.

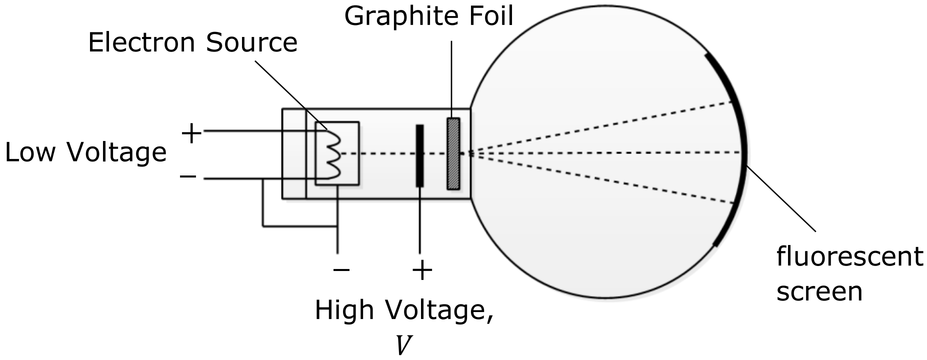


Figure 8

a. Describe the resulting observed image on the fluorescent screen and how it is related to the probability of finding an electron. (3)

b. Show that the de Broglie wavelength, λ, of the electron is given by $\lambda = \frac{h}{\sqrt{2eVm}}$, where m is the electron mass. (4)

c. State what happens to the observed image when the voltage V is decreased. (1)

d. If the de Broglie wavelength of the electron is given to be $7.8\,\mathrm{pm}$, obtain the value of voltage V. (2)

(Total: 10 marks)

SECTION B

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

9.

a.

i. Describe an experiment which can be used to determine the acceleration of free fall. Your description should include:

- the list of the apparatus required; (2)
- a well labelled diagram of the setup; (2)
- the procedure to be followed; (2)
- a table illustrating the data that needs to be recorded; (2)

- a sketch of the expected graph; (2)
- an explanation of how the graph is used to determine this acceleration. (2)

b. In a car crash testing site, a $50\ \text{kg}$ dummy is placed on the front seat of a car of mass $9500\ \text{kg}$ and moving at a constant speed of $90\ \text{km hr}^{-1}$. The car crashes into a wall and comes to a complete stop. Assume the seat to be frictionless.

i. If the car takes $0.1\ \text{s}$ to come to rest, determine the average force exerted by the wall on the car and state any of Newton's laws of motion that you refer to. (5)

ii. Using Newton's laws of motion, explain the resulting motion of the crash test dummy if it is not wearing a seatbelt. (2)

iii. If a seatbelt is worn, the impact occurs over a longer time period. Explain how this difference reduces the force felt on the dummy. (1)

(Total: 20 marks)

10.

a. Two uniform disks are rotating about a vertical rod which passes through their centre. The top disk, having moment of inertia $0.9\ \text{kg m}^2$, is rotating at an angular speed of $200\ \text{rad s}^{-1}$ while the bottom disk with a moment of inertia of $1.5\ \text{kg m}^2$ is rotating at an angular speed of $300\ \text{rad s}^{-1}$. After some time, the top disk falls and hits the bottom disk causing both disks to rotate at a common angular velocity ω. Assume that there is no slipping between the disks as they come in contact.

i. Explain what conservation of angular momentum is. (2)

ii. Determine the resulting magnitude and direction of the angular velocity ω if the top disk was rotating in a clockwise direction and the bottom disk in an anticlockwise direction. (3)

iii. Determine the required magnitude and direction of the angular velocity of the top disk if both disks are to stop rotating when they make contact. (3)

b. A $1\ \text{kg}$ block, initially at rest, is released from the top of a frictionless ramp and slides downhill. Its centre of mass drops a height of $0.75\ \text{m}$. It then hits a uniform $5\ \text{kg}$ rod of length $1.5\ \text{m}$ which is attached to a frictionless pivot at the point X.

The block undergoes a perfectly elastic collision with the bottom tip of the rod. The moment of inertia of the rod about X is $I = \frac{1}{3}MR^2$ where M is the mass and R is the length of the rod. The system is illustrated in Figure 9.

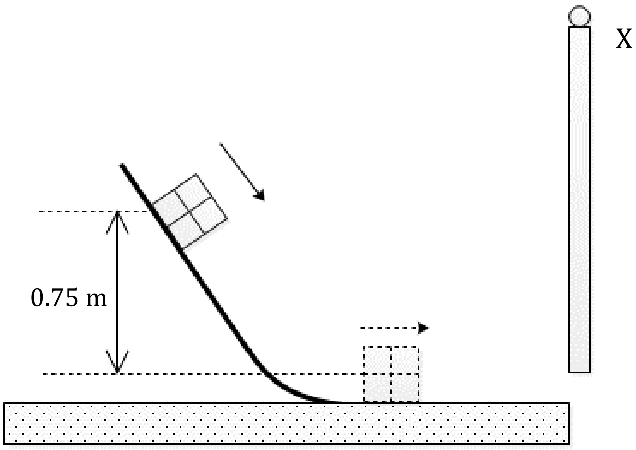


Figure 9

i. Determine the velocity of the block as it reaches the bottom of the ramp just before hitting the rod. (3)

ii. Given that the collision is perfectly elastic and that the block after collision moves in the opposite direction with one fourth (¼) the magnitude of the velocity before collision, use the principle of conservation of energy to determine the angular velocity with which the rod rotates. (5)

iii. Hence, or otherwise, show that the angular momentum is also conserved. (4)

(Total: 20 marks)

11.

a. A steel wire of length $3\ \mathrm{m}$ and cross-sectional area $2.8 \times 10^{-7}\ \mathrm{m}^2$ was tested in a lab to examine its stress-strain properties. This was carried out by applying loads while extension measurements were taken during loading and unloading. The resulting graph is shown in Figure 10.

i. Describe how the value for the Young's modulus can be determined from the graph and find its value. (2)

ii. If the wire is loaded up to B and then unloaded again, the wire returns back to its original state. Explain what the point B represents and therefore explain this observed behaviour. (2)

iii. Determine the resulting permanent extension in the wire. (3)

iv. Use the graph to determine the force required for the wire to have an extension of $12\ \mathrm{mm}$ during unloading. (3)

v. Explain why:

- a very long wire was used during the experiment; (1)
- diameter readings along the length of wire were necessary to determine the cross-sectional area. (1)

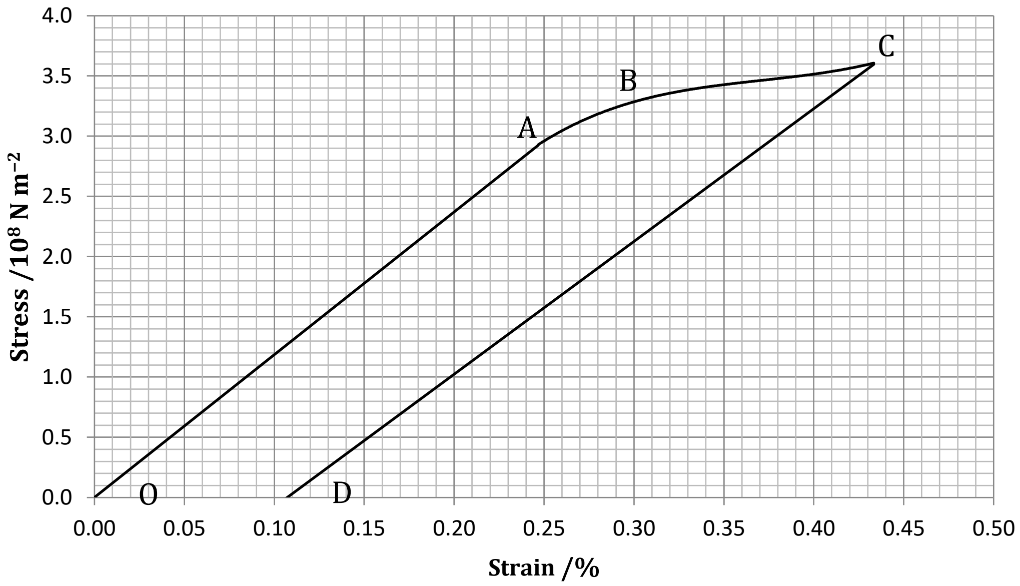


Figure 10

b. A structural engineer is in charge of a project to build a tunnel between two cities, as shown in Figure 11. The engineer is planning to use concrete columns $5\ \mathrm{m}$ high each having a cross-sectional area of $7\ \mathrm{m}^2$ distributed along the tunnel. The tunnel is situated $100\ \mathrm{m}$ underground. The total weight of the ground which is resting on the columns is $2.83 \times 10^9\ \mathrm{N}$. Let y be the number of concrete columns required to hold the structure.

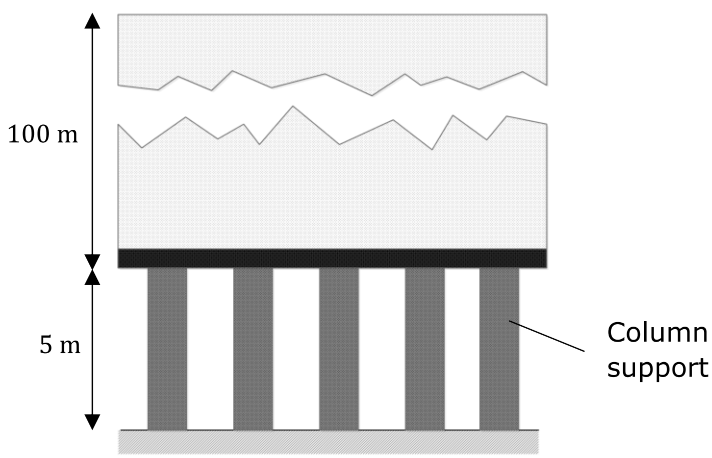


Figure 11

i. Determine the force exerted on **each** column in terms of y. (2)

ii. If the Young's modulus of concrete is 2.1×10^{10} Pa and the maximum allowed strain on each column is $0.2\,\%$, determine the minimum number of concrete columns required to hold the tunnel. (4)

iii. If the area of the columns is increased, determine whether the number of columns required is bigger, smaller or the same when compared to that obtained in part (b)(ii). (2)

(Total: 20 marks)

12.

a. Consider the circuit shown in Figure 12 with the switch open. The cell has an internal resistance of $1\,\Omega$ and an e.m.f of $9\,\text{V}$. A voltmeter of resistance $250\,\Omega$ and an ammeter of resistance $4\,\Omega$ were used.

i. Determine the readings of the voltmeter and ammeter. (3)

The switch is now closed.

ii. If the ammeter reads $0.5\,\text{A}$, determine the value of the unknown resistance R. (4)

iii. If only the voltmeter is replaced by an ideal one, obtain the new readings read by the ideal voltmeter and the ammeter. (2)

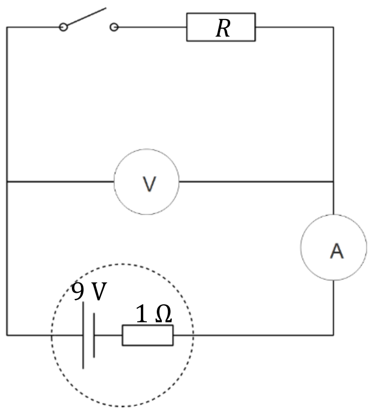


Figure 12

b. A potential divider is constructed as shown in Figure 13. The thermistor has a negative temperature coefficient and the LDR is initially exposed to light.

i. Show that the output voltage, V_{out}, across the resistor is given by $V_{out} = \frac{\varepsilon R}{R+R_L+R_T}$ where R is the resistance of the resistor, R_T is the resistance of the thermistor and R_L is the resistance of the LDR. (3)

ii. State what happens to this voltage V_{out} when:

- the temperature of the thermistor increases; (2)
- the LDR is covered. (2)

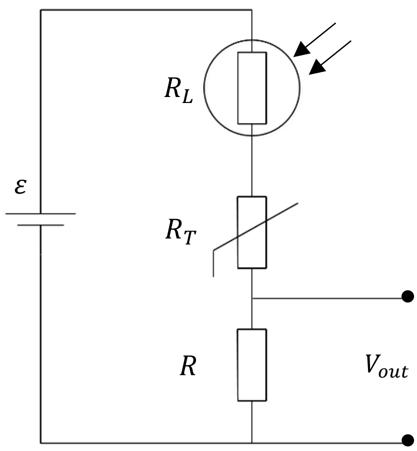


Figure 13

c. A potential difference of $12\,\text{V}$ is applied across a coil of wire. The resistance of the wire at $0°\text{C}$ is $3.0\,\Omega$ and the wire has a temperature coefficient of resistance α equal to $4 \times 10^{-3}\,\text{K}^{-1}$. Determine the ratio of the power output as heat from the coil at $0°\text{C}$ and $100°\text{C}$. (4)

(Total: 20 marks)

13. Pure silicon is a crystal which can be used for different uses. In its atomic structure it has 14 electrons, 4 of which lie in the outermost shell. The latter are called valence electrons and pure silicon is said to have valence 4.

a. Discuss the difference between an intrinsic and extrinsic semiconductor. (2)

The silicon can be doped using impurities having valence 3 (trivalent) or valence 5 (pentavalent).

b. Explain the importance of doping in silicon making particular reference to the effect on conductivity. (2)

c. Explain what a hole is. (2)

d. By sketching a diagram of the resulting crystal structures, discuss how the number of holes and electrons change with each type of impurity. Clearly indicate the majority and minority carriers in each case. (3, 3)

e. Determine which impurity is a p-type semiconductor and an n-type semiconductor. (2)

f. Using band theory, explain the differences between a p-type and an n-type semiconductor. In your description, include:
   i. a clear diagram showing **all** bands; (3)
   ii. an explanation as to what happens when an electric field is applied. (3)

(Total: 20 marks)

14.

a. An oscillating pendulum as shown in Figure 14 is considered. The mass of the bob is $1\,\mathrm{kg}$ and the length of the string is $2\,\mathrm{m}$. The pendulum reaches a maximum angle of $75°$ to the vertical.
   i. Determine the maximum height reached by the bob as measured from the lowest point. (2)
   ii. Calculate the velocity of the bob as it passes through the lowest point. (2)
   iii. Determine the angle the string makes with the vertical when the velocity of the bob is $2.7\,\mathrm{m\,s^{-1}}$. (5)
   iv. By time, the pendulum is observed to slow down and eventually come to rest. Explain briefly why this occurs by making reference to the interchange of energy of the system. (2)
   v. It is desired that the maximum possible velocity achieved by the bob at its lowest point is increased while still released from the same initial angle of $75°$. Using the results obtained in parts (a)(ii) and (a)(iii), or otherwise, suggest **ONE** simple change to achieve this. (2)

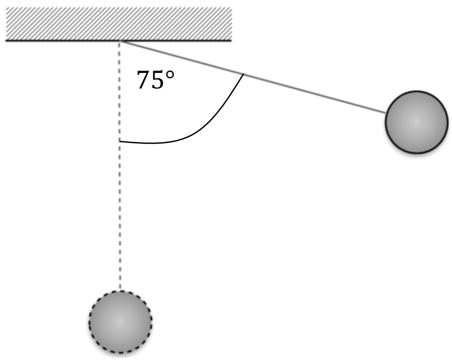


Figure 14

b. A $9\,\mathrm{V}$ battery is used to switch on a light bulb. The bulb is left on for 1 hour and a current of $5\,\mathrm{A}$ is maintained.
   i. Explain, in detail, the energy transfers throughout the whole process, clearly accounting for **all** energies used and lost during the process. (3)
   ii. If the efficiency of the bulb is $10\,\%$, determine the amount of useful energy used during this time. (4)

(Total: 20 marks)

15.

a. A particular sample of radon is being studied to determine its half-life.
   i. Describe an experiment which could be used to determine the half-life of radon. Your description should include:
      - the list of the apparatus required; (2)
      - a well labelled diagram of the setup; (2)
      - the procedure to be followed; (2)

- a table illustrating the data that needs to be recorded; (2)
- a sketch of the expected graph; (2)
- an explanation of how the graph is used to determine the half-life. (2)

ii. When the radon element is removed, the Geiger-Müller counter still reads a non-zero value. Explain this observation. (1)

b. Rubidium is an example of an element which is used to date rocks. An isotope of rubidium, $^{87}_{37}\mathrm{Rb}$, decays according to the following nuclear equation:

$$^{87}_{37}\mathrm{Rb} \rightarrow \, ^{87}_{38}\mathrm{Sr} + \, ^{0}_{-1}\beta$$

where $^{87}_{38}\mathrm{Sr}$ is an isotope of strontium. The rest mass of $^{87}_{38}\mathrm{Sr}$ is $86.9089\ \mathrm{u}$ and the energy of β is $272\ \mathrm{keV}$.

i. Determine the rest mass of $^{87}_{37}\mathrm{Rb}$ in terms of the unified atomic mass unit u. Assume that there is no other energy released. (4)

ii. It is known that the half-life of $^{87}_{37}\mathrm{Rb}$ is 4.75×10^{10} years. Determine the remaining mass of Rubidium if $20\ \mathrm{mg}$ of $^{87}_{37}\mathrm{Rb}$ is left to decay for 5×10^{9} years. (3)

(Total: 20 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

L-Università ta' Malta

ADVANCED MATRICULATION LEVEL
2020 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	II
DATE:	19th September 2020
TIME:	16:00 p.m. to 19:05 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 perfect black body radiator emits radiation as shown in Figure 1.

   a. Explain a perfect black body radiator. (2)

   b. Draw a well-labelled diagram to explain how a black body radiator can be approximated in practice. (3)

   c. Use Figure 1 to explain why the colour of a red-hot body changes to white-hot, when its temperature is increased. (3)

   d. How is the area under the graphs in Figure 1 changing with temperature increase? What does this signify? (2)

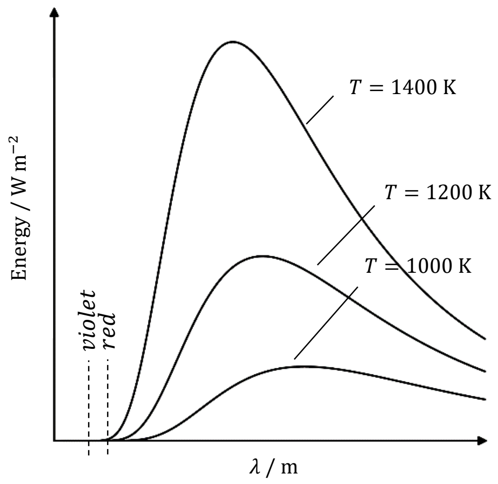


Figure 1

(Total: 10 marks)

2. A resistor R of $100\ \Omega$ is connected to a variable frequency sinusoidal voltage supply, from a signal generator with negligible resistance in its output circuit. The peak voltage of the supply is constant. The resistor is then replaced by a pure inductor, L, of 0.10 H. Graphs A and B, drawn in Figure 2, show how the peak value of the current through each of the devices changes with frequency.

   a. Which graph corresponds to R and which one to L? Give valid reasons for your answer. (2)

   b. Using the appropriate graph, calculate the peak voltage of the signal generator. (3)

   c. Explain the term 'pure' in relation to the inductor. (1)

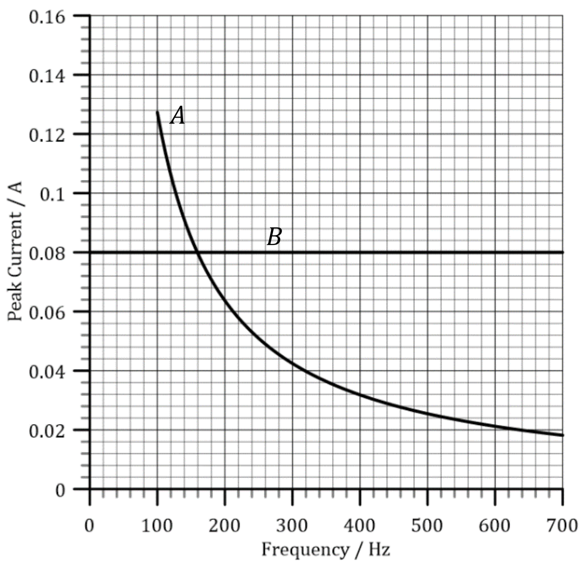


Figure 2

d. Use **THREE** points from the curve to show that the current in the device is inversely proportional to the frequency. (3)

e. If R and L were to be connected in series with the same signal generator, what would be the phase difference of the current in L when compared with the current in R? (1)

(Total: 10 marks)

3.

a. State **TWO** conditions necessary for the motion of an oscillating body to be simple harmonic. (2)

b. Give **ONE** reason why the vertical oscillations of a large body M attached to a spring may not satisfy the conditions for simple harmonic motion. (1)

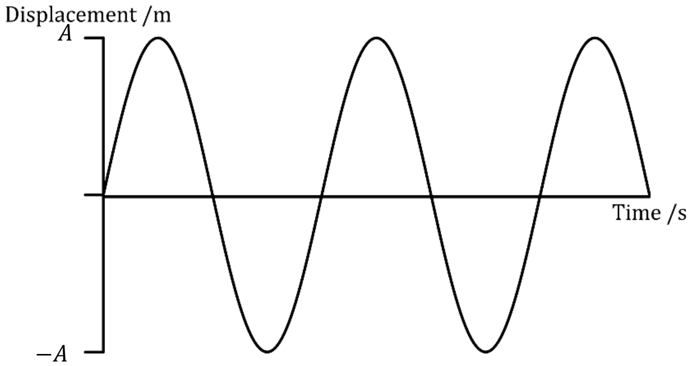


Figure 3

c. Figure 3 shows the variation of the displacement from the mean position with time for a body attached to a spring and undergoing simple harmonic oscillations.

i. Copy the diagram in Figure 3 and on it sketch another graph that shows the respective variation of the acceleration of the oscillating body with time. (1)

ii. Sketch a graph to show how the acceleration of the body varies with displacement. Explain the shape of the graph drawn. (3)

d. A light spring is loaded with a $200\ \mathrm{g}$ mass and is made to oscillate horizontally on a friction-free table. The graph of restoring force versus extension is a straight line passing through the origin. The slope of the graph is $30\ \mathrm{N\ m^{-1}}$. Calculate the period of the oscillations of the $200\ \mathrm{g}$ mass. (3)

(Total: 10 marks)

4.

a. A ray of light passes through the boundary between two media of different density. Use a well labelled diagram to explain what is meant by critical angle. Indicate clearly the dense and denser media. (3)

b. Figure 4 shows a glass prism in air. The prism has a refractive index of 1.66 and angles A are $25°$ each. Two parallel light rays, m and n, are directed towards the prism and enter it.

i. What is the angle between the two rays after they emerge from the prism? (6)

ii. Calculate the critical angle for the prism. (1)

(Total: 10 marks)

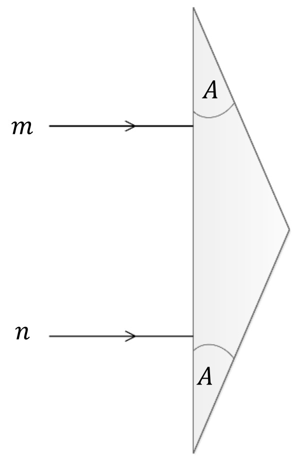


Figure 4

5.

a. Light of wavelength $659.6\ \text{nm}$ is emitted by a star in a galaxy in the Pandora's cluster. The wavelength of this light as measured on Earth is $661.1\ \text{nm}$.

i. Briefly distinguish between planets, stars and galaxies. (4)

ii. Determine the relative velocity of the star with respect to Earth. (2)

iii. Is it moving toward Earth or away from it? Explain your answer in terms of the Doppler Effect. (2)

b. State what type of star an astronomer is examining if both red and blue shifts are observed. Explain your answer, giving reasons. (2)

(Total: 10 marks)

6.

a. Internal energy, work done and heat energy are all measured in Joules. Distinguish between these three forms of energy. (1, 1, 1)

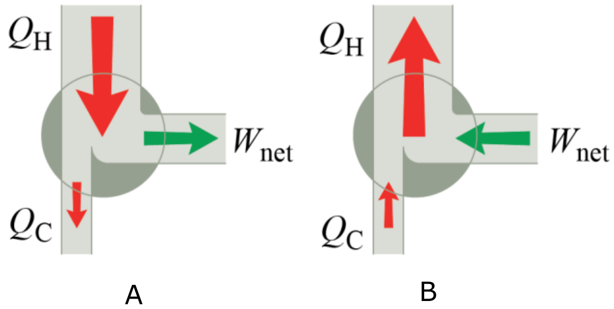


Figure 5

b. Figure 5 shows two energy flow diagrams for a heat engine and a heat pump.

i. State the second law of thermodynamics in terms of a heat pump and of a heat engine. (2)

ii. Hence or otherwise, indicate which of the energy flow diagrams, A or B, represents the energy transfer in a heat pump. Explain your choice. (2)

iii. In an oil-burning electric power plant, steam from the boilers at a temperature of $873\ \text{K}$ is used to drive a turbine. Steam leaves the turbine at a temperature of $373\ \text{K}$ Calculate the theoretical maximum efficiency of the engine and state **ONE** way in which this maximum efficiency of the engine can be increased. (3)

(Total: 10 marks)

7. Eris is a dwarf planet on our solar system. The mass of Eris was determined by examining the orbit of its moon, Dysnomia. The orbit of Dysnomia about Eris can be assumed circular.

a.

i. Write an equation relating the centripetal force experienced by Dysnomia to the orbital radius, r, as it moves in a circular path around Eris. (2)

ii. What is the origin of this centripetal force? (1)

iii. Hence, prove that the speed of Dysnomia is inversely proportional to the square root of the radius of its orbit. (3)

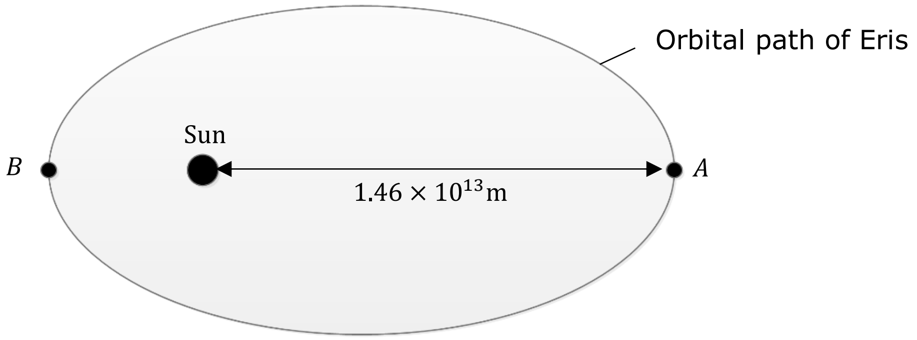


Figure 6

b. Figure 6 shows the orbital path of Eris about the Sun. Points A and B are positions of Eris when this is at a maximum distance and a minimum distance respectively away from the Sun. If the difference in the gravitational potential between A and B is 1.38×10^{7} J kg^{-1}, calculate the distance between the centre of Eris and the centre of the Sun when Eris is at point B. Take the mass of the Sun to be 1.99×10^{30} kg. (4)

(Total: 10 marks)

8. Figure 7 shows a top view of two charged plates which form part of a particle detector. A voltmeter is connected across the plates and is used to monitor the potential difference between them. When a charged particle collides with a plate, this creates a fluctuation on the voltmeter reading. A radioactive isotope is placed as shown in the diagram and is a source of charged particles which pass between the plates. Assume that all charged particles are emitted at the same speed.

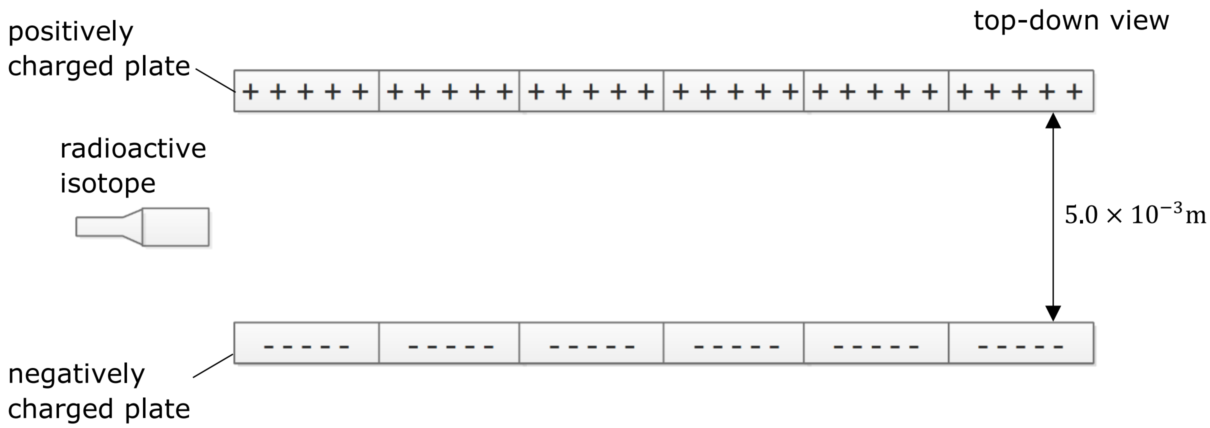


Figure 7

a.

i. Sketch a diagram to show the path taken by an alpha particle as it passes through the detector. (2)

ii. Is the path taken by the alpha particle described as parabolic or circular? Give a reason for your answer. (2)

b. Explain why, using this detector, a scientist will **not** be able to distinguish between an electron and a positron. (3)

c. The plates are now rotated such that the negative plates are vertically above the positively charged plates. The distance between the plates is kept the same. Calculate the potential difference between the charged plates that would be needed such that a positron passes between the plates without being deflected. (3)

(Total: 10 marks)

SECTION B

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

9.

a. Explain what is a thermometric property. (1)

b. State **TWO** qualities that make a thermometric property suitable for use in a practical thermometer. (2)

c. A Celsius temperature scale may be defined in terms of a thermometric property X by the following equation:

$$\theta = \frac{X - X_0}{X_{100} - X_0} \times 100\ ^\circ\mathrm{C}$$

i. Name **ONE** thermometric property that X could represent in this equation. (1)

ii. Give the meaning of X_0 and X_{100}, naming relevant fixed points in your explanations. (2)

iii. Referring to the equation, sketch a graph showing how the thermometric property X varies with temperature θ /°C as measured on the X scale, indicating X_0 and X_{100} clearly on your sketch. (3)

d. A copper rod of radius of cross-section $0.50\ \mathrm{mm}$, a length of $10\ \mathrm{cm}$ and a thermal conductivity of $401\ \mathrm{W\,m^{-1}K^{-1}}$ has one of its ends in contact with a hot reservoir at a temperature of 104°C. The other end is in contact with a cold reservoir at a temperature of 24°C.

i. Calculate the temperature gradient along the bar when it reaches a steady state. (2)

ii. Calculate the rate of heat conduction along the bar. (3)

iii. If two such rods were placed in parallel (side by side) with the ends in the same temperature baths, what would the total rate of heat conduction be? (2)

iv. If two such rods were placed in series, calculate the temperature at the junction where the rods are in contact. (4)

(Total: 20 marks)

10.

a. The first law of thermodynamics may be written as: $\Delta U = \Delta Q + \Delta W$. State what the terms used in the equation stand for and explain the meaning of this equation as applied to the heating of a gas. (5)

b. Use the given equation to justify that the molar heat capacity of a gas at constant pressure is greater than the molar heat capacity at constant volume. (4)

c. A mass of gas is expanded isothermally and then compressed adiabatically to its original volume. The gas is then allowed to return to its original pressure at constant volume.

i. Explain the terms 'isothermal change' and 'adiabatic change'. (2)

ii. Sketch a p-V graph to show the changes made to the gas, clearly distinguishing the isothermal and adiabatic change. (3)

iii. What does the enclosed area of the graph represent? (1)

d. An ideal gas at an initial temperature of $15\ ^\circ\mathrm{C}$ and a pressure of $1.1 \times 10^5\ \mathrm{Pa}$ is compressed adiabatically to one quarter of its original volume. What will be its final pressure and temperature? Take the ratio of the principal specific heat capacities of the gas to be 1.4. (5)

(Total: 20 marks)

11.

a. One mole of ideal gas at pressure p and Celsius temperature θ occupies a volume V.

i. Sketch a graph showing how the product pV varies with θ. (3)

ii. What valid information can be obtained from the gradient of the graph and the intercept on the temperature axis? (3)

b. How would the graph in part (a)(i) change if:

i. a second mole of the same gas is added to the first? (1)

ii. the original gas were replaced by one mole of another ideal gas having twice the relative molecular mass of the first? (1)

c. State Boyle's Law and write down its mathematical representation. (2)

d. Describe a simple experimental procedure for investigating how the pressure of a known mass of air varies as its volume changes at room temperature. Your description should include:

i. the list of the apparatus required; (1)

ii. a well labelled diagram of the setup; (2)

iii. the procedure to be followed; (2)

iv. the data that needs to be recorded; (1)

v. an explanation of how you would use the results to investigate the relationship between the density of air and its pressure, sketching the appropriate graph. (4)

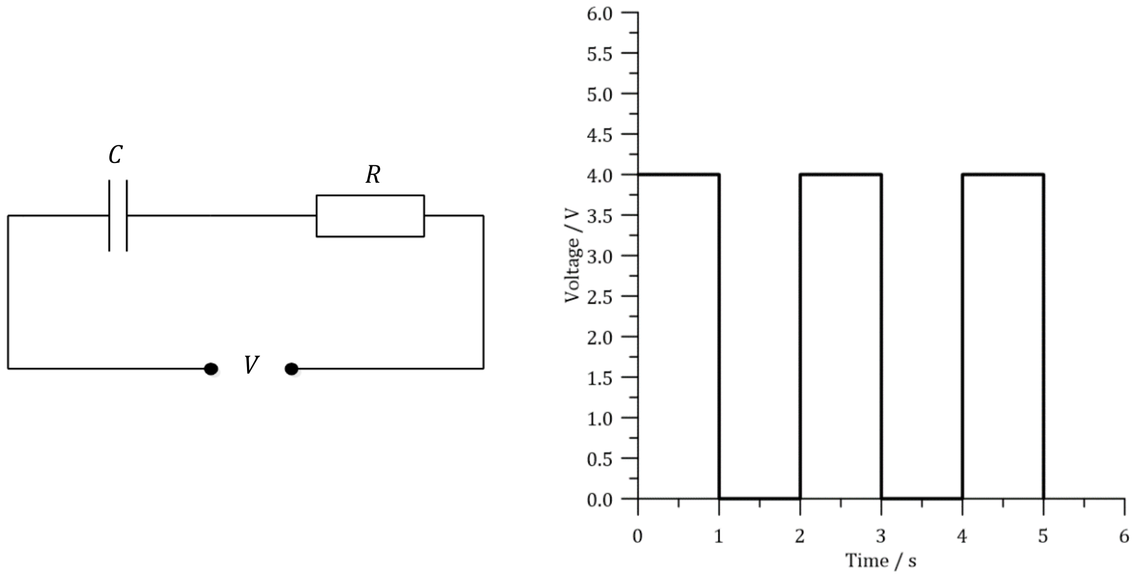
(Total: 20 marks)

12.

a. Define capacitance. (2)

b. Sketch a well labelled diagram of the structure of an electrolytic capacitor and qualitatively describe the formation of the dielectric. (3)

c. Give **ONE** practical advantage of electrostatic capacitors. (1)



(i) (ii)

Figure 8

d. The circuit in Figure 8 (i) shows a capacitor C and a resistor R connected in series. The applied voltage V varies with time as shown in the Figure 8(ii). The product CR is of the order 1 s.

i. Explain what the product CR measures. (1)

ii. On a copy of the graph in Figure 8(ii), add **TWO** separate graphs that show how the voltage V_C across C and the voltage V_R across R change across the time interval of $4\ \text{s}$. (4)

iii. If the product CR were made considerably smaller than $1\ \text{s}$, describe what would be the effect on the graphs drawn in part d(ii)? (2)

iv. Derive an equation, in terms of V, C and R that can be used to determine the current flowing through the resistor at any point in time during the charging phase. (2)

e. A camera flash-lamp uses a $5000\ \mu\text{F}$ capacitor which is charged by a $9\ \text{V}$ battery. The capacitor is then disconnected from the battery.

i. Assuming that there are no charge losses, calculate the energy transferred from the capacitor while it is discharged through the flash-lamp to a point where the final potential difference across its plates is $6.0\ \text{V}$. (3)

ii. The capacitor is now disconnected from the lamp and charged again using the $9\ \text{V}$ battery. It is then disconnected from the battery and connected to a $4000\ \mu\text{F}$ capacitor which is initially uncharged. Calculate the final voltage across each capacitor. (2)

(Total: 20 marks)

13. A cyclotron is used to bombard a sample of material with high speed charged particles to get information on the atomic structure of the sample.

a. Briefly explain what a cyclotron is and, in your explanation, clearly indicate which of the fields, electric or magnetic fields, is responsible for the increase in the kinetic energy of the particle. (2)

b. Derive the non-relativistic expression for the cyclotron supply frequency ν. Assume that a particle of mass m having charge q is being accelerated in the cyclotron and define any other symbols used in the derivation. (5)

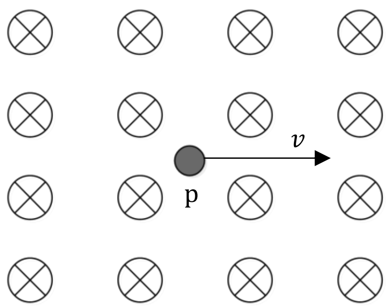


Figure 9

c. Figure 9 shows a proton, p, moving inside the cyclotron where there is a magnetic field. The magnetic flux density is $0.38\ \text{T}$ and the proton travels at a speed of $1.2 \times 10^7\ \text{m s}^{-1}$.

i. Draw the direction of the force acting on the proton at this instant in time, due to the magnetic field, stating the rule used to come to your conclusion. (2, 1)

ii. Describe the path taken by the proton when travelling inside the magnetic field region. Explain. (2)

iii. Calculate the force acting on the proton. (2)

iv. Calculate the magnitude of the proton's acceleration. (2)

v. Assuming that the proton leaves the cyclotron when its radius of orbit has become $1.5\ \text{m}$, determine the kinetic energy of the proton when it leaves the cyclotron. (4)

(Total: 20 marks)

14.

a. State Lenz's law of electromagnetic induction. (1)

b. Describe an experimental set up which may be used to prove Lenz's law. Your description should include:

i. the list of the apparatus required; (1)

ii. a well labelled diagram of the setup; (2)

iii. the procedure to be followed; (2)

iv. the interpretation of experimental observations obtained. (2)

c. A copper rod XY of mass $0.020\ \mathrm{kg}$, a length of $1.20\ \mathrm{m}$ and negligible resistance, is free to slide between two frictionless vertical rails, as shown in Figure 10. The conducting rails are connected by means of wires to a $6.0\ \Omega$ resistor. A uniform magnetic field of $0.50\ \mathrm{T}$, into the plane of the paper, is acting on the entire system. When the rod is released it accelerates downwards until it reaches terminal velocity v. Ignore the effect of air resistance.

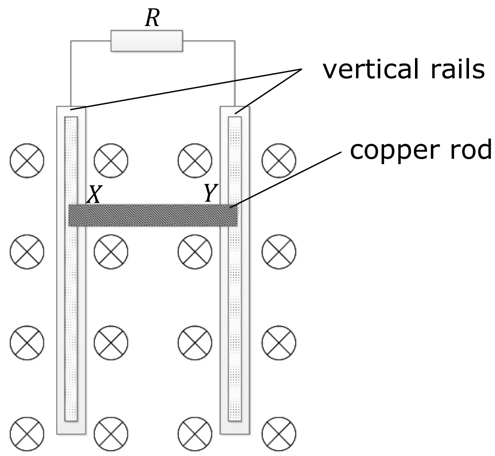


Figure 10

i. Explain why the copper rod reaches terminal velocity as it is sliding down. (2)

ii. Calculate the force that is initially pulling the copper rod downwards. (1)

iii. Hence, calculate the terminal velocity v. (5)

iv. At this terminal velocity, the rod is losing gravitational potential energy. What other energy change is taking place in the circuit, and what can you say about its magnitude? (2)

v. If the direction of the magnetic field is reversed, will this affect the movement of the rod? Explain your answer. (2)

(Total: 20 marks)

15.

a. A student is investigating interference between sound waves using the apparatus shown in Figure 11. Two speakers are attached to a signal generator so that they produce coherent sound waves.

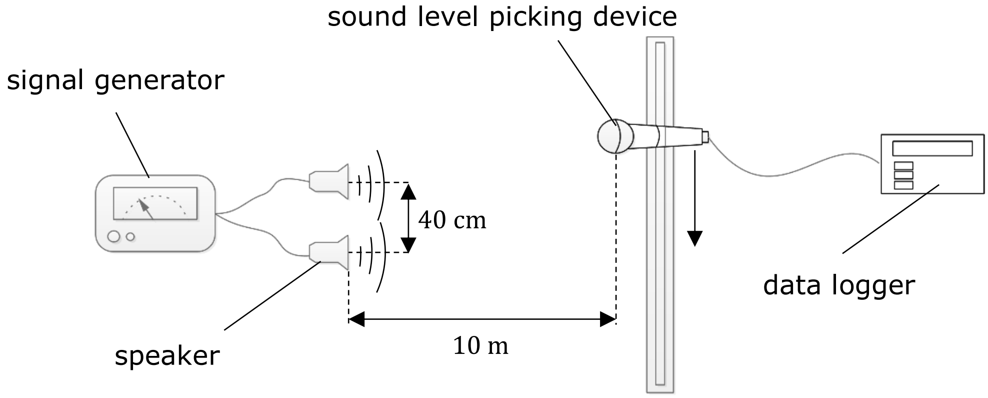


Figure 11

The frequency of the waves is $13.5\ \mathrm{kHz}$ and the speakers are separated by a distance of $40\ \mathrm{cm}$. A sound level meter is moved at a speed of $0.25\ \mathrm{m\,s^{-1}}$ along a track which is positioned at a distance of $10\ \mathrm{m}$ from the speakers. The meter is linked to a data logger and the sound pressure levels resulting from the interference of the sound waves can thus be measured.

i. Give the meaning of the term 'coherent' and state how coherency is being achieved in this case. (2)

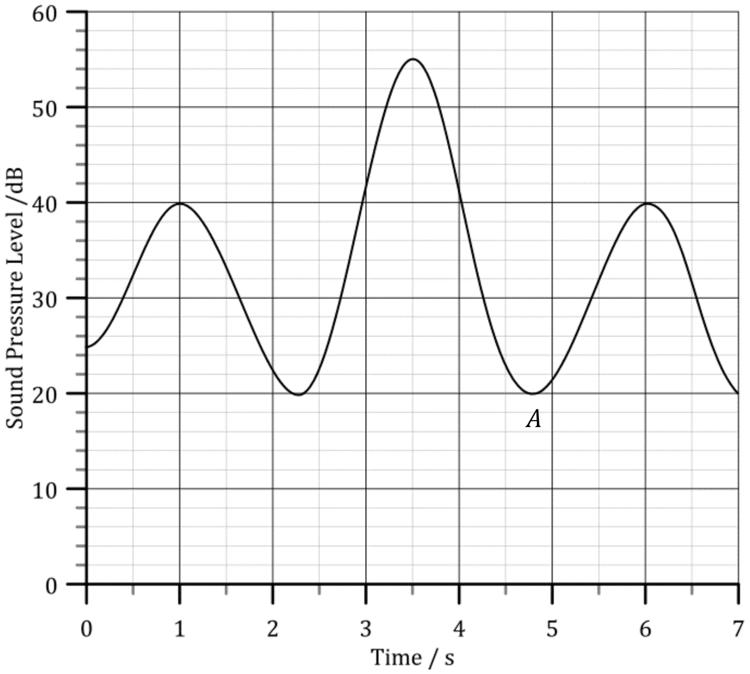


Figure 12

The graph in Figure 12 shows the sound pressure levels measured by the sound pressure level meter as it moves along the track.

ii. State the phase difference, in terms of wavelengths, between the sound waves at point A. (1)

iii. Using Figure 12 calculate the fringe spacing. (2)

iv. Use relevant data provided to measure the wavelength of sound. (2)

v. Hence calculate the speed of the sound waves. (1)

b. Interference patterns can also be observed with light.

i. Draw a labelled diagram showing the apparatus required to determine the wavelength of red light using a pair of slits. Indicate approximate values for the dimensions of the slit, slit separation and distance of slits from screen. (3, 3)

ii. How would you use the measured values of the dimensions indicated in part (b)(i) to estimate the separation of the fringes produced by light of wavelength $500\ \mathrm{nm}$? (2)

iii. Describe the changes, if any, in the formation of fringes that would be observed when the pair of slits are now replaced by a diffraction grating, keeping the same light source:

- if the grating spacing is the same as the slit separation; (2)
- if the grating spacing is much smaller than the slit separation. (2)

(Total: 20 marks)