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 8 questions in this section. This section carries 50% of the total mark for this paper.

1. A block is hung to the ceiling using two ropes tied to an eye bolt which is installed in the block as shown in Figure 1. The block is stationary.
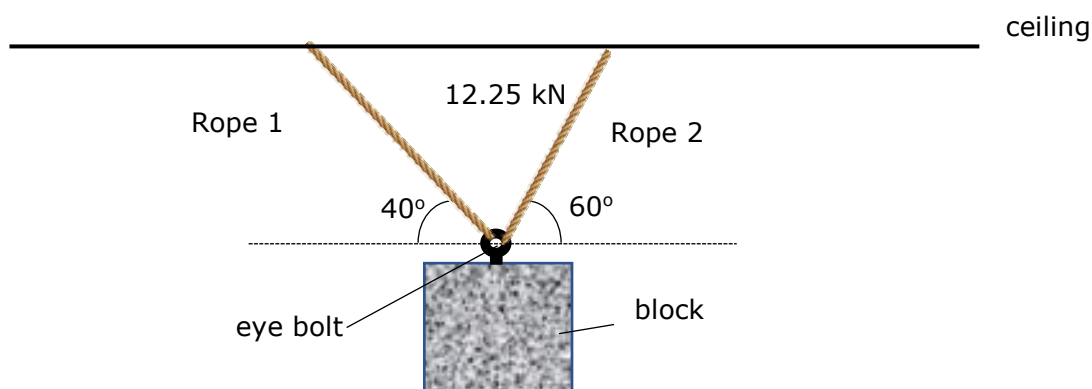

Figure 1

a. Comment on the forces acting on the block and state the relevant law. (2)

b. Determine the magnitude of the force being exerted by Rope 1. (3)

c. Calculate the mass of the block. (2)

(Total: 7 marks)

2. A copper wire connects one of the navigation bulbs found at the front of a yacht. The wire is 4.2 m long, has a cross sectional area of 0.75 mm^2 and carries a current of 1.2 A.

a. Calculate the average drift velocity of electron flow in the wire if $n_{copper} = 8.47 \times 10^{28}$ m^{-3}. (2)

b. The owner of the yacht wanted to move the bulb elsewhere and extended the wire with a thinner copper wire. How is the drift velocity of the electrons expected to change? Explain. (2)

(Total: 4 marks)

3. Estelle was taking part in a sports event. In one of the games she had to run across the ground holding a tennis ball, throw it in a container and run back to the starting line. Figure 2 shows the velocity-time graph representing her run where **q** is Estelle's maximum velocity.
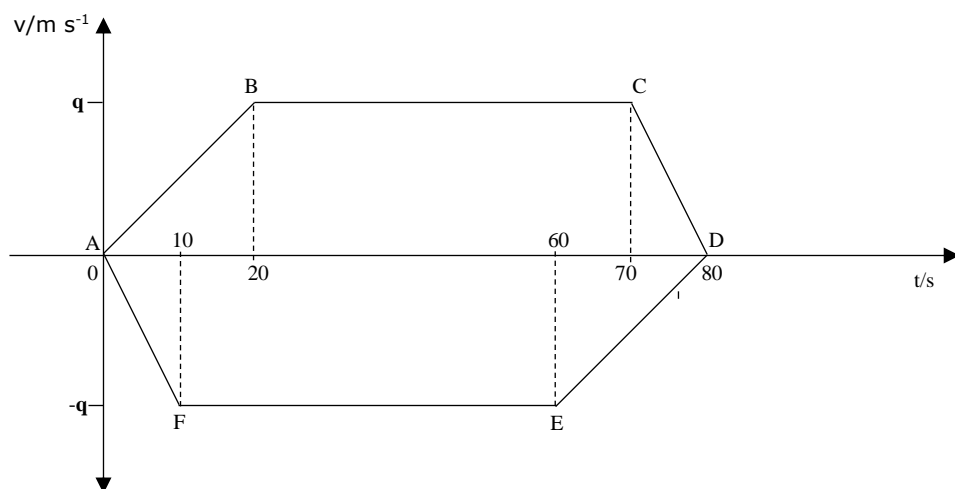

Figure 2

a. Which part/s of the graph represent the motion of Estelle while she was:
   i. accelerating; (1)
   ii. decelerating. (1)

b. Show that the distance she ran to the container holding the tennis ball is equal to 65**q** m. (2)

c. If Estelle's average speed for the whole run was 4.26 ms^{-1}, find **q**. (2)

(Total: 6 marks)

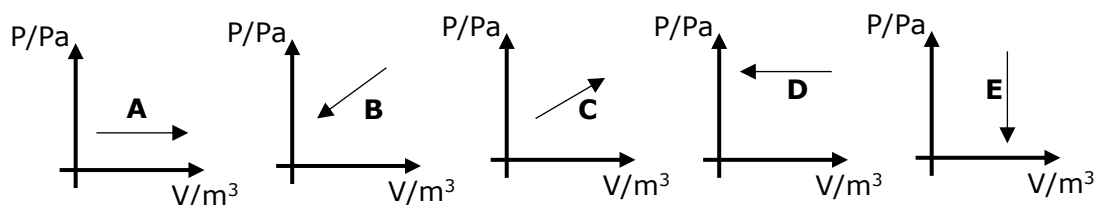4. a. Consider the following P-V diagrams for an ideal gas.

Figure 3

State which graph (or graphs) shown above represent:
   i.   an isobaric process; (1)
   ii. an isochoric process; (1)
   iii. work done by the system. (1)
   iv. work done on the system. (1)

b. A gas is contained in a cylinder with a heavy moveable piston of mass 4.2 kg. The internal energy of the gas increases by 720 J and the piston rises by 64 mm when X Joules of heat flow into the gas.
   i. Find X. (3)
   ii. State the law used to determine X. (1)

(Total: 8 marks)

5. Figure 4 shows two parallel metal plates M and N which are 0.20 m away from each other. Plate M is at a potential of +120 V while plate N is at 0 V. A charge of +3 C is placed near plate M and it accelerates towards plate N.

   a. Calculate the electric potential energy lost by the +3 C charge. (2)

   b. Calculate the force acting on the +3 C charge when it leaves plate M. (2)

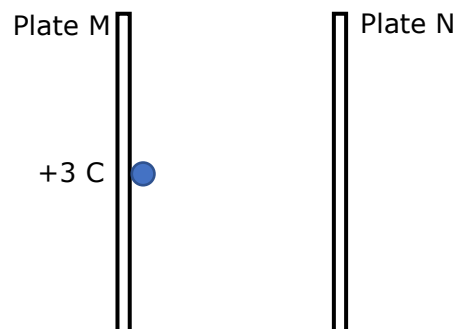   c. What is the value of the force when the +3 C charge is close to plate N? (1)

Plate M   Plate N

+3 C

Figure 4

(Total: 5 marks)

6. a. Define simple harmonic motion. (2)

   b. The bob of a simple pendulum is displaced by 2 cm to the right from its equilibrium position. When released it oscillates with a period of 1.2 s.
      i. Sketch the displacement-time and velocity-time graphs of the pendulum over 2 complete cycles. (2)
      ii. What is the acceleration of the pendulum after 0.3 s? (1)
      iii. State **ONE** instance at which the pendulum has maximum kinetic energy. (1)
      (Total: 6 marks)

7. a. Explain, with the aid of diagrams, how an electromotive force (e.m.f.) is induced in a simple alternating current generator. (3)

   b. An alternating current generator is producing a current which has a peak value of ±2.2 A.
      i. Sketch a graph of the current induced against time. (2)
      ii. Calculate the root mean square value of current generated. (2)
      (Total: 7 marks)

8. a. Define decay constant. (1)

   b. The half-life of Radon-222 is 3.8 days.
      i. Determine the decay constant of Radon-222. (2)
      ii. A sample of Radon-222 initially contains 6880 nuclei. How many will remain after 15.2 days? (2)

   c. Radon-222 is a colourless, odourless gas which can be found in background radiation. Give **TWO** sources of background radiation. (2)
   (Total: 7 marks)

Please turn the page.

SECTION B
This question carries 14% of the total mark of this paper and must be attempted.

9. Students set up the circuit shown in Figure 5. A battery of e.m.f. *E* and internal resistance *r* is connected to a variable resistor *R*. A voltmeter measures the voltage, *V*, across the variable resistor.

    The variable resistor was initially set at a maximum value. The resistance of the variable resistor was reduced and each time readings of *V* and *I* were noted and tabulated in the table below. The p.d. across the variable resistor, *V*, is related to the current, *I*, by
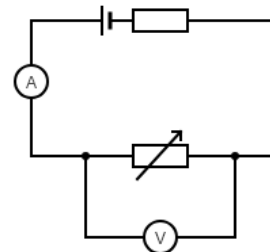 $$V = E - Ir.$$

Figure 5

Voltage, *V*/V	1.34	1.32	1.31	1.30	1.29	1.28	1.27	1.26	1.25
Current, *I*/mA	40	45	50	55	59	63	67	73	78

   a. Plot a graph of *V*/V on the y-axis against *I*/mA on the x-axis. (5)

   b. Use the graph to determine the value of *E* and r. (4)

   c. Explain the role of the variable resistor in this experiment. (2)

   d. Name **ONE** precaution that could be taken to minimise errors. (1)

   e. Explain how to maximise the current flowing through the circuit and determine this maximum value of the current. (2)

   (Total: 14 marks)

SECTION C
Answer any TWO questions from this section. Each question carries 18 marks. This section carries 36% of the total mark for this paper.

10. a. State Newton's law of Universal Gravitation. (2)

    b. i. Define gravitational field strength and draw the gravitational field lines, including direction, around the Earth. (2)
       ii. Sketch a graph to show how the gravitational field strength varies with distance from the Earth's centre. Comment on the shape of the graph. (3)

    c. Derive the equation $v^2 = \frac{GM}{r}$ for a satellite travelling with a linear velocity *v* in a circular radius *r* around the Earth of mass *M*. (3)

d. A satellite of mass 4.0×10^4 kg is in orbit at a distance of 200 km from the surface of the Earth. Calculate:
   i. the gravitational force between the Earth and the satellite;   (2)
   ii. the linear orbital velocity of the satellite;   (1)
   iii. the periodic time of the satellite.   (2)

e. Another satellite is orbiting around the Earth at a height where the gravitational field strength is 7.97 N kg^{-1}. Work out the orbital height from the Earth's surface.   (3)
   (Mass of Earth = 5.97×10^{24} kg; Radius of Earth = 6370 km)
                                                                          (Total: 18 marks)

11. a. Figure 6 shows the Force-extension graph of a spring.
    i. Define the spring constant and give its units.   (2)
    ii. Copy the graph and on the same axis, sketch a graph for a stiffer spring. Explain.   (3)
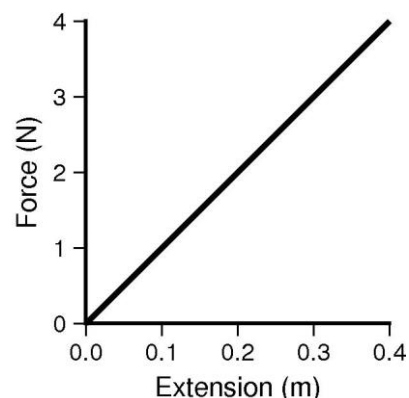

Figure 6

b. A 6 kg mass is hung on a 2.0 m length of copper wire of diameter 0.4 mm. The Young's modulus for copper is 1.2×10^{11} Pa.
   i. State the relationship between the Young's Modulus and the stress and strain of the loaded copper wire.   (1)
   ii. Hence derive an expression for the Young's Modulus in terms of the weight of the load, the original length, the extension and the cross-sectional area of the wire. (1)
   iii. Calculate the resulting extension of the copper wire.   (2)

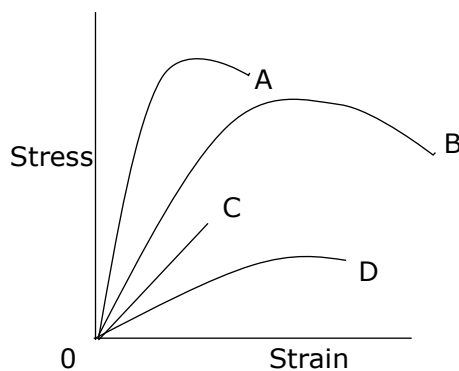c. Figure 7 shows the stress-strain graphs of four different materials, A, B, C and D, up till breaking point.

Figure 7

   i. Which material is the most ductile?   (1)
   ii. Which material has the highest Young's modulus? Explain.   (2)
   iii. Which material is the easiest to break?   (1)
   iv. Which material is most brittle?   (1)

d. By means of an appropriate graph, describe the hysteresis behaviour of rubber and discuss **ONE** situation where this behaviour is useful.   (4)
                                                                          (Total: 18 marks)
                                                                          Please turn the page.

12. a. Electromagnetic waves from coherent light sources can interfere and produce a fringe pattern.
    i. Using a diagram, illustrate how light emanating from a light source can interfere to produce a fringe pattern. (2)
    ii. Explain coherent source. (2)
    iii. By means of a wave diagram, illustrate how destructive interference occurs. (1)
    iv. Give **TWO** other conditions necessary for total destructive interference to occur. (2)
    v. Yellow light with a wavelength of 5.40×10^{-7} m from a sodium lamp falls on two slits that are 0.01 mm apart. If the screen is place 2 m away from the slits, calculate the distance between the zero order and the first order fringe. (2)

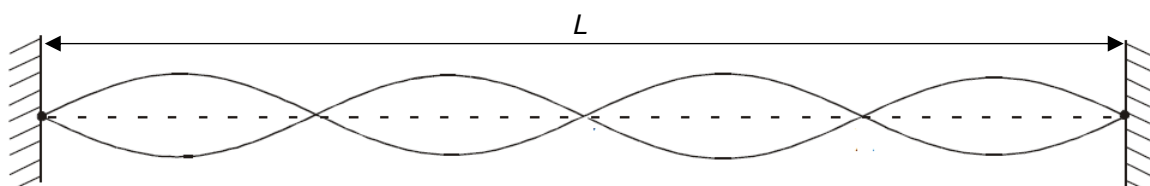 b. Figure 8 shows a stationary wave (standing wave) on a vibrating stretched string.

Figure 8

    i. Explain how a stationary wave is created. (2)
    ii. How many wavelengths are there in the distance marked L? (1)
    iii. Apart from the length of the string, state **TWO** other factors that affect frequency of the harmonics of a stretched string. (2)
    iv. If distance L is 2.8 m, calculate the frequency of the note emitted by the string if the speed of sound in air is 340 ms^{-1}. (2)

  c. Explain resonance and discuss by giving an example where such phenomenon is dangerous. (2)

(Total: 18 marks)

13. a. Magnetic flux density is measured in Tesla (T). Define magnetic flux density and Tesla. (2)

3.20 T

  b. A copper wire of length 60 cm is placed in a uniform magnetic field of density 3.20 T at right angles to the field as shown in Figure 9. The wire carries a current of 12.0 A.
    i. Calculate the force acting on the wire. (2)
    ii. State the direction of the force. (1)
    iii. State the rule which was used to determine the direction in part (b)(ii) above. (1)

  c. State the magnitude and direction (if applicable) of the force acting on the wire, if the wire is:
    i. rotated by 90º in the anti-clockwise direction; (1)
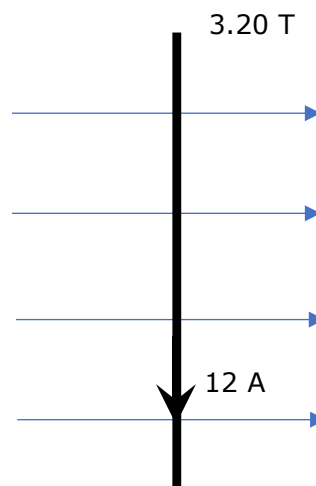   ii. rotated by 180º. (1)

12 A

Figure 9

d. Derive the equation, $F = Bev$, where F is the force acting on an electron moving with velocity v in a magnetic field of flux density B. (3)

e. A negatively charged particle P moves in the plane of the paper and enters a region of uniform magnetic field of flux density B of 5 T. The magnetic field acts perpendicularly into the paper, as shown in Figure 10.
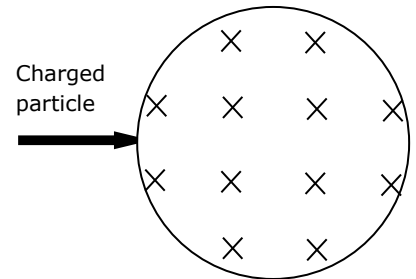

Figure 10

   i. Copy the diagram in Figure 10 and draw the path taken by particle P in the magnetic field. (2)
   ii. Another equally charged negative particle Q moves at the same speed through the same magnetic field. Particle Q has a larger mass than particle P. On the same diagram, draw and label the path of particle Q. (1)
   iii. What is the name given to this magnetic force? (1)
   iv. State what happens to the path taken by the particles if the magnetic flux density is increased. (1)
   v. Another particle R is at rest in the same region, in the same magnetic field. State the magnitude of the force experienced by R. Explain your answer. (2)

(Total: 18 marks)