MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2020 SECOND SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	I
DATE:	14th December 2020
TIME:	4:00 p.m. to 7:05 p.m.

A list of useful formulae and equations is provided. Take the acceleration due to gravity $g = 9.81\ m\ s^{-2}$ 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. Kepler's third law of motion states that the periodic time T of the Earth's orbit obeys the relation

$$T^2 = kr^3$$

where r is the distance between the Sun and the Earth, and k is a proportionality constant.

i. Give **TWO** instances of how an equation can be incorrect. (2)

ii. If $T = 365.25$ days and $r = 1.496 \times 10^8$ km, find a value for k expressed in base units. (2)

b. A lifeguard jumps into the sea to save a person who is being dragged away by a $2.5\ m\ s^{-1}$ easterly sea current. The lifeguard needs to swim back to shore, located 15 m south, without being drifted further east.

i. Sketch a copy of Figure 1 and draw the velocity vector of the lifeguard. (2)

ii. Find the lifeguard's swimming velocity if the lifeguard takes 20 seconds to reach the shore. (4)

(Total: 10 marks)

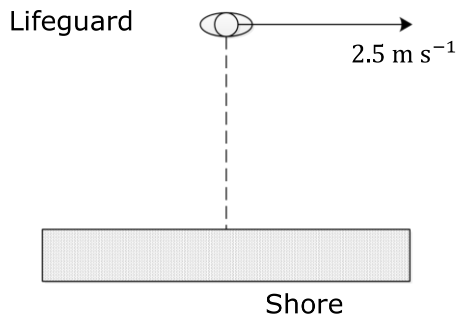

Figure 1

2. A uniform beam of length 2 m and mass 3 kg is attached to a hinge, as shown in Figure 2. At the end of the beam, a constant horizontal force F is applied which maintains the beam at an angle of 30° to the horizontal. The system is in static equilibrium.

a. State the **TWO** necessary conditions for a system to be in static equilibrium. (2)

b. Find the value of the force F. (3)

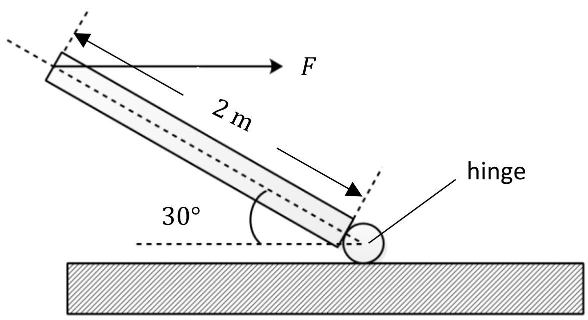

Figure 2

c. Obtain the direction and magnitude of the reaction force at the hinge. (4)

d. The beam is now lowered and maintained at some angle to the horizontal above the ground. If the system still remains in equilibrium, what happens to the magnitude of the force F? Explain your answer. (1)

(Total: 10 marks)

3. As part of a stunt, a motorcyclist plans to jump over a number of buses from an inclined $3.5\ \mathrm{m}$ high ramp at an angle of $30°$ to the horizontal. The motorcyclist needs to jump a distance of $140\ \mathrm{m}$ to land safely on a horizontal platform of the same height, as shown in Figure 3, and wants to know the minimum initial velocity required to just make it. Let the initial velocity of the motorcycle be v.

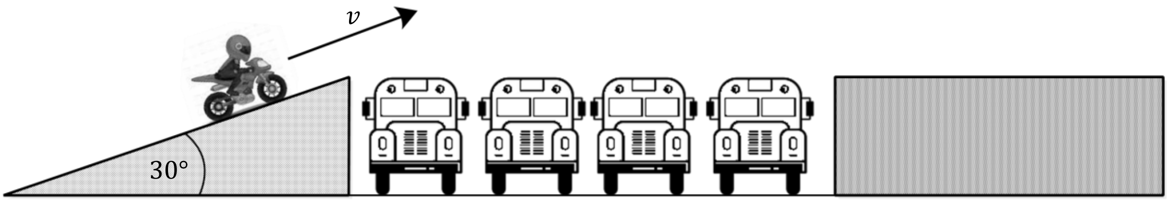

Figure 3

a. Obtain the time taken to reach the highest point during the jump in terms of v. (2)

b. Write the expression for the total time taken to travel the $140\ \mathrm{m}$. (1)

c. Hence, or otherwise, determine the initial velocity required to cover the whole distance. (4)

d. Determine the maximum height measured from the ground reached by the motorcyclist. (3)

(Total: 10 marks)

4. A child is playing with a spherical marble of radius $1.5\ \mathrm{cm}$ and mass $5\ \mathrm{g}$. He decides to push it at a constant speed of $0.7\ \mathrm{m\ s^{-1}}$ along a horizontal track. The marble then encounters a bump, of circular shape of radius $17\ \mathrm{cm}$, as shown in Figure 4.

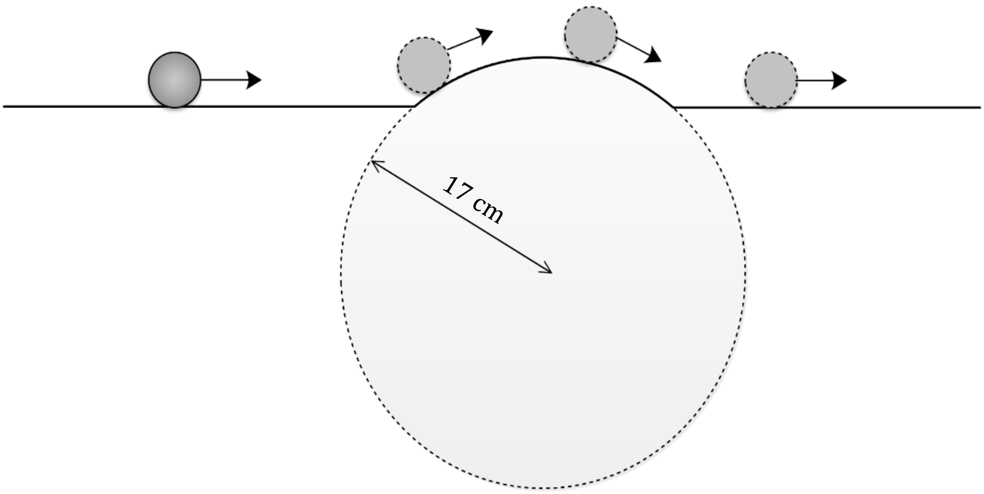

Figure 4

a. Determine the centripetal acceleration of the marble when it is on the bump. (3)

b. What is the total reaction force on the marble when it is at the highest point of the bump? (4)

c. Will the marble maintain contact with the ground? Explain. (1)

d. Further down the track, another bump of a larger radius is encountered. Assuming that the marble's speed remains constant, will the marble be in contact with the ground? Explain. (2)

(Total: 10 marks)

5. Consider two wires, one is a high carbon wire and the other is made of nichrome. The resistance of the wires at $0\,°\mathrm{C}$ are $R_{\mathrm{C},0}$ for carbon and $R_{\mathrm{N},0}$ for nichrome. The temperature coefficients of resistance are $-0.005\,\Omega\,°\mathrm{C}^{-1}$ for carbon and $0.004\,\Omega\,°\mathrm{C}^{-1}$ for nichrome.

a. Define what is meant by temperature coefficient of resistance. (2)

b. Explain what happens to the resistance of the carbon and nichrome wires if the temperature increases. (2)

c. The wires are now connected in series to create a resistor. If the temperature of each wire is t, show that the combined resistance R is

$$R = R_{\mathrm{C},0} + R_{\mathrm{N},0} + t\left(0.004R_{\mathrm{N},0} - 0.005R_{\mathrm{C},0}\right).$$ (4)

d. With $R_{\mathrm{N},0} < \frac{5}{4}R_{\mathrm{C},0}$, explain how R changes when the temperature increases. (2)

(Total: 10 marks)

6. Consider two ideal cells, each having an e.m.f. ε, connected to a filament lamp of resistance R. Assume that this resistance remains constant. When one cell is connected to the lamp, it shines brightly.

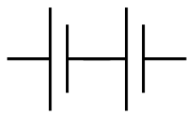

Figure 5

a. If the cells are connected in series as shown in Figure 5, what happens to the brightness of the lamp? Explain your reasoning. (4)

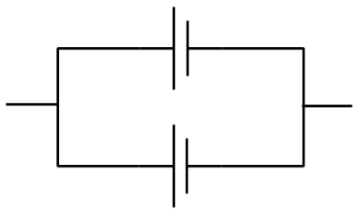

Figure 6

b. If the cells are now connected in parallel as shown in Figure 6, compare the resulting brightness to the one obtained in part (a) and the one cell case. Explain your reasoning. (3)

A student claims that connecting the cells in parallel makes the cells last longer than those connected in series.

c. Verify or discard this claim by comparing the power consumption by each cell when they are connected in series and in parallel. (3)

(Total: 10 marks)

Please turn the page.

7. A circuit was set up and a charge-time (Q vs t) graph, as illustrated in Figure 7, was obtained.

   a. Using the graph, explain how the current in each time interval can be determined. (1)

   b. Hence, obtain the current flowing through the circuit in each interval, AB, BC, CD and DE. (4)

   c. Using the results obtained in part (b), sketch a current-time graph clearly illustrating the given information. (3)

   d. Explain how the current-time graph, drawn in part (c), can be used to obtain the total charge which flowed through the circuit and calculate this total charge. (2)

(Total: 10 marks)

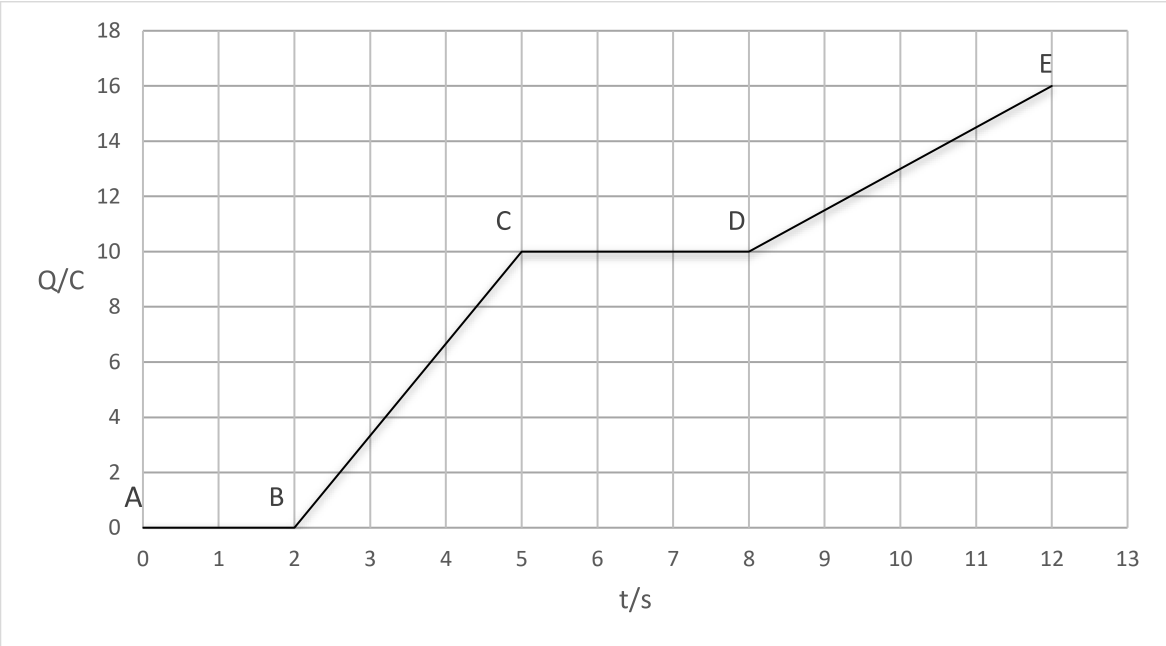

Figure 7

8. In the photoelectric effect experiment, incident light of a particular frequency is shone onto a cathode. The voltage between the cathode and anode is varied until the current flowing is zero. The voltage is then measured.

   a. As the light intensity is varied on the cathode, the maximum kinetic energy of the emitted electrons does not change. Explain this observation. (1)

   b. For a particular wavelength of $248\ \mathrm{nm}$, the stopping voltage is $0.5\ \mathrm{V}$. Determine the work function of the material. Give your answer in eV. (4)

   c. Determine the maximum velocity of the emitted electron. (2)

   d. Orbiting satellites can slowly lose surface electrons due to incident solar radiation caused by the photoelectric effect. This can be problematic for the satellite's electronics.
      i. Explain why it is ideal that the surface material of the satellite must have a very large work function. (1)
      ii. If most of the incident solar radiation is below a frequency of $1.2 \times 10^{15}\ \mathrm{Hz}$, determine the minimum work function, in Joules, required to minimise this effect. (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. A student wants to determine the spring constant of a spring.
i. Describe an experiment which the student can perform in order to determine this quantity. The description, should include:
- a list of the apparatus required; (2)
- a well labelled diagram of the setup; (2)
- the procedure of the steps taken; (2)
- a table illustrating the data recorded; (2)
- a sketch of the expected graph; (2)
- an explanation of how the graph is used to determine the spring constant. (2)

ii. State the condition that must be satisfied throughout the experiment in order to obtain a correct value for the spring constant. (2)

b. The student then decides to investigate the usage of springs as a stopping force for moving objects. The student sets up the springs attached in parallel as shown in Figure 8.

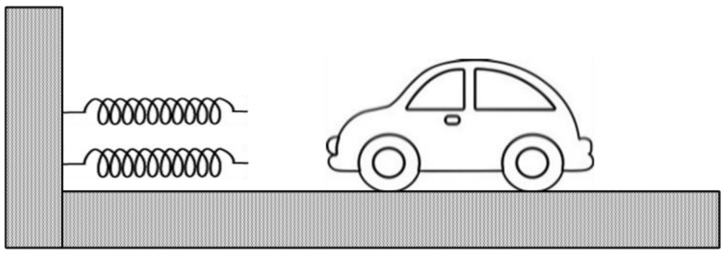

Figure 8

A toy car of mass $2\,\mathrm{kg}$ was then set in motion at a constant velocity of $0.5\,\mathrm{m\,s^{-1}}$. Both springs are hit at the same time by the front of the car. The spring constants of the spring used are $100\,\mathrm{N\,m^{-1}}$ and $150\,\mathrm{N\,m^{-1}}$.
i. Determine the compression in the springs when the toy car comes momentarily to rest. (4)
ii. If the system were to be replaced by a single spring, what would be its spring constant if the toy car is to stop within the same compressing distance? (2)

(Total: 20 marks)

10.
a. The circuit shown in Figure 9 can be used to determine the unknown emf of a battery. A wire of resistivity ρ and cross-sectional area A is stretched along a metre ruler. A jockey attached to a galvanometer can slide along the resistance wire. Assume that the batteries are ideal. Initially, the switch is open.

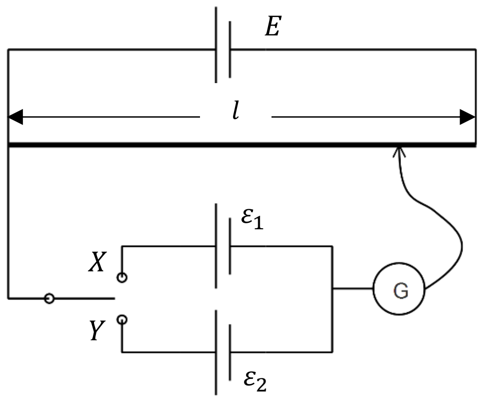

Figure 9

i. Obtain the magnitude of the current I in the resistance wire in terms of E, A, ρ and l. (2)

The switch is now closed at X. At a length l_1, the galvanometer gives no deflection.

ii. State Kirchhoff's laws. (4)

iii. Hence, or otherwise, show that the condition $\varepsilon_1 = \frac{El_1}{l}$ is satisfied. (3)

The switch is now closed at Y. The jockey is moved until at a length of l_2, the galvanometer gives no deflection.

iv. Show that the emfs of the two batteries are related by $\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$. (2)

v. If these two batteries were to be replaced with non-ideal batteries, will the relation obtained in part (a)(iv) remain the same or change? Explain your reasoning. (2)

b. Consider the circuit shown in Figure 10. Obtain the magnitude and direction of the current flowing through each resistor. (7)

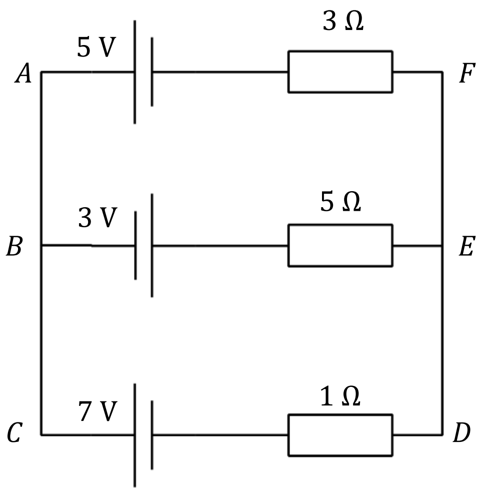

Figure 10

(Total: 20 marks)

11.

a. In an experiment, a fine mist of oil droplets is sprayed into the air. The oil droplets are so tiny that the drag acting on the droplets as they fall through the air soon cancels their weight and the droplets continue to drop through the air with terminal velocity. Air has a viscosity of 18.03×10^{-6} Pa s.

i. Distinguish between drag and viscosity and describe qualitatively the relationship between the two indicating clearly any other factors that affect drag. (4)

ii. State what is meant by terminal velocity and explain, by making reference to the relevant Newton's law of motion, how this is attained. (4)

iii. Sketch a speed-time graph that show how the speed of the droplet changes with time as it drops through the air. (3)

b. A spherically shaped balloon of radius $7.5\ \mathrm{cm}$ is attached to two strings as shown in Figure 11. The system is in equilibrium. The balloon is filled with helium which has a density of $0.180\ \mathrm{kg\,m^{-3}}$. The surrounding air has a density of $1.204\ \mathrm{kg\,m^{-3}}$.
   i. State Archimedes principle. (2)
   ii. Determine the magnitude of the buoyancy force. (2)
   iii. Hence, determine the tension in each string. (5)

(Total: 20 marks)

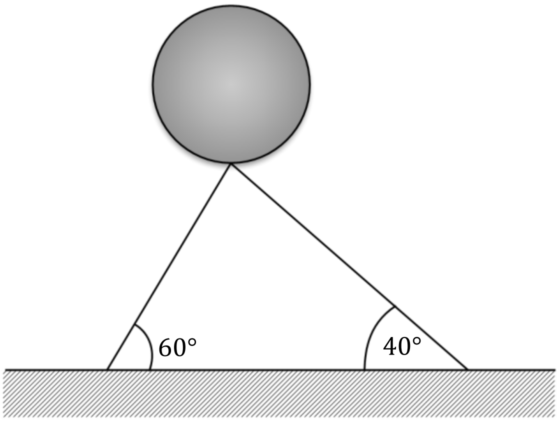

Figure 11

12.

a. Two wires A and B, having different material composition, of equal length L and cross-sectional area A, are connected in series. One of the wires is a conductor and the other wire is an intrinsic semiconductor, and both wires are at room temperature. The wires are then connected to a circuit and a current I flows through the wires.
   i. Derive the expression $I = nAve$ where n is the number of charge carriers per unit volume, v is the drift velocity and e is the charge of the carrier. (3)
   ii. Discuss how n can be used to distinguish between a conductor and a semiconductor. (2)
   iii. Show that $n_{\mathrm{A}}v_{\mathrm{A}} = n_{\mathrm{B}}v_{\mathrm{B}}$, where the subscripts refer to the wires A and B respectively. (2)
   iv. If $v_A = 10^9\ v_B$, determine which wire is the conductor and the semiconductor. (2)

   Consider the case when the temperature of the intrinsic semiconductor is increased.

   v. Discuss what happens to the electrons in the valence band as the temperature is increased. (2)
   vi. What happens to the conductivity of the wire? What can you say about the wire's resistance? (3)

b. Using band theory, discuss the difference between an insulator and a conductor, clearly making reference to:
   i. the width of the bands; (2)
   ii. the population in each band; (2)
   iii. the conduction of each material after an electric field is applied; (2)

(Total: 20 marks)

13. An experiment is devised to find the moment of inertia of a solid cylinder of radius R and mass M. The cylinder is wound up by a long string of length L with one end attached to a bar. The cylinder is then released from rest and the time, t, taken for the string to fully unwind is measured. A setup is shown in Figure 12. Let I be the moment of inertia of the cylinder.

a. By finding the torque on the cylinder, show that the angular acceleration α is given by $\alpha = \frac{TR}{I}$ where T is the tension in the string. (3)

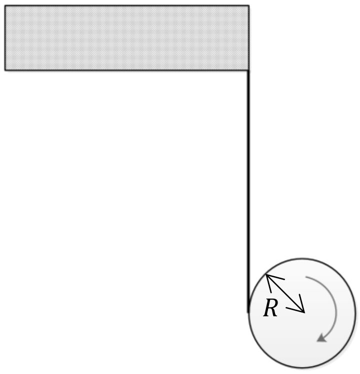

Figure 12

b. Show that the linear acceleration of the object, a, is given by $a = \frac{Mg-T}{M}$. (2)

c. Hence, or otherwise, show that the tension is $T = \frac{MgI}{I+MR^2}$ and use this to show that the linear acceleration can be expressed as $a = \frac{gMR^2}{I+MR^2}$. (5)

d. Show that the total time taken is $t = \sqrt{\frac{2L(I+MR^2)}{MgR^2}}$. (3)

e. Show that the angular velocity of the cylinder when the string becomes fully unwound is given by $\omega = \sqrt{\frac{2LMg}{I+MR^2}}$. (4)

f. The cylinder is now replaced by another one, having the same mass and radius, but a larger moment of inertia. Explain how this can be achieved, and whether the new cylinder will unwind faster or slower. (3)

(Total: 20 marks)

14. In Rutherford's alpha scattering experiment, a gold foil was bombarded by alpha particles.

a. During the experiment, it was observed that 1 out of 8000 alpha particles back scattered. Discuss **THREE** conclusions about the nucleus which can be inferred from this observation. (3)

b. Determine the distance of closest approach of the alpha particles to the gold nucleus if the kinetic energy of the alpha particles is 20 MeV. (5)

c. Is it possible to determine the radius of the nucleus using this method? Explain. (2)

The rest mass of gold $^{197}_{79}\mathrm{Au}$, protons and neutrons are given to be $196.967\ \mathrm{u}$, $1.007\ \mathrm{u}$ and $1.008\ \mathrm{u}$ respectively.

d. Explain what is meant by nuclear binding energy and find its value for the gold nucleus. Give your answer in eV. (5)

If one looks at the composition of protons, it is known that it is composed of quarks, namely 2 up quarks and 1 down quark. The charge of an up quark is $\frac{2}{3}e$.

e. Determine the charge of the down quark. (2)

f. Compare the overall charge and mass between the proton and the antiproton. (1)

g. Describe the internal quark composition of the antiproton. (1)

h. Explain why an electron is not a hadron. (1)

(Total: 20 marks)

15.

a. A small $100\ \mathrm{g}$ marble is released from the top of a $2\ \mathrm{m}$ high ramp along a track, consisting of a circular loop of radius $25\ \mathrm{cm}$, a $30\ \mathrm{cm}$ horizontal rough surface and a $1\ \mathrm{m}$ high ramp. Except for the rough patch, the rest of the track is smooth. The track is illustrated in Figure 13.

i. Determine the velocity of the marble at the top of the loop. (3)

ii. Hence, explain why the marble maintains contact with the track at the top of the loop. (4)

iii. Calculate the work done against friction as the marble passes over the rough surface if a constant frictional force of $5\ \mathrm{N}$ is present. (1)

iv. Hence, determine whether the marble is able to go up the final $1\ \mathrm{m}$ high ramp. (3)

v. Determine the net work done against gravity through the whole process. (2)

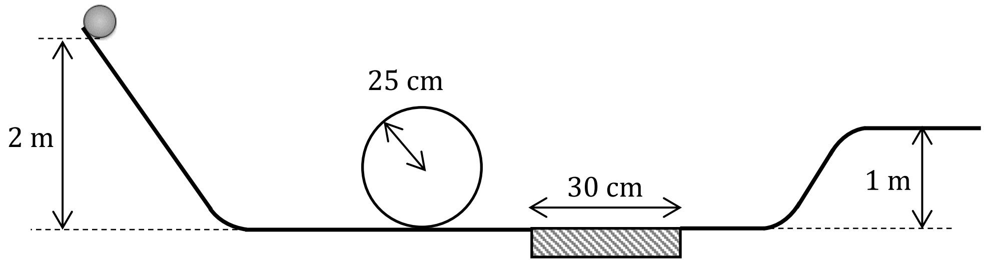

Figure 13

b. A small spring cannon is composed of a $15\ \mathrm{cm}$ long spring of spring constant $60\ \mathrm{N\ m^{-1}}$, which is inclined at an angle of $30°$ to the horizontal, as shown in Figure 14. The cannon is then loaded with a $50\ \mathrm{g}$ marble and the spring is compressed a distance of $8\ \mathrm{cm}$, and then released.

i. Determine the speed of the marble as soon as it leaves the cannon. (6)

ii. At what angle should the cannon be inclined for the marble to reach the maximum height? (1)

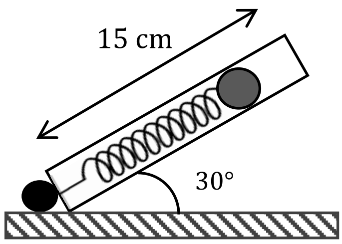

Figure 14

(Total: 20 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2020 SECOND SESSION

SUBJECT:	**Physics**
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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. A temperature scale can be set up using two fixed points. What is a fixed point? Give **TWO** examples of fixed points. (2)

   b. Name **TWO** thermometric properties. (2)

   c. Briefly describe how a Celsius scale can be set up using a thermometer with one of the thermometric properties mentioned in your answer to part (b). (3)

   d. The temperature of an object is measured using a platinum resistance thermometer and a liquid-in-glass thermometer. A resistance of $1.500\ \Omega$ was obtained when the object was at the ice point of water and $2.060\ \Omega$ when object was at the steam point of water. If the resistance of the thermometer when the object is placed in a thermostatic water bath at $50°C$ is $1.788\ \Omega$, calculate the difference in the temperatures measured by both thermometers? (3)

(Total: 10 marks)

2. Figure 1 shows two charged spheres on insulating rods. The left-hand sphere has a charge of $0.18\ \mu C$ and the right-hand sphere has a charge of $-0.18\ \mu C$.

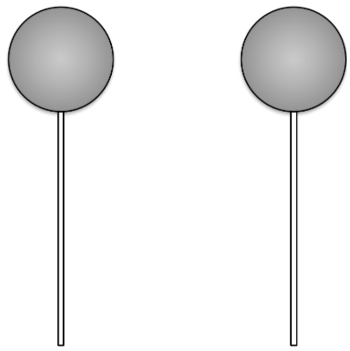

Figure 1

   a.
      i. What are equipotential lines? (2)
      ii. Copy the figure and draw equipotential lines between the two spheres. (2)

   b. The centres of the two spheres in Figure 1 are initially $8.0\ cm$ apart. An amount of work equal to $0.38\ mJ$ is done against the electric field to move the left-hand sphere further to the left.
      i. Calculate the new distance of the left-hand sphere from the other sphere. (4)
      ii. Calculate the magnitude of the force that acts between the two spheres when the left hand sphere is in this new position. (2)

(Total: 10 marks)

3.

a. A cyclist moves at a velocity of $7\ \mathrm{m\,s^{-1}}$ towards a stationary police car which has the siren on. State the effect, if any, on the frequency of the sound that is heard by the cyclist. Explain your answer. (2)

b. The same effect occurs not only with sound but also with light and this fact has been invaluable in astronomy. During the 1920s, the astronomer Edwin Hubble, together with other scientists, had noticed that the spectral lines of distant galaxies were red-shifted. Explain carefully what this means and the implications about how the Universe is behaving. (2)

c. A distant galaxy G is found to have a red-shift of 15%.

i. Is the galaxy moving away or towards Earth? (1)

ii. State Hubble's law and sketch a labelled graph to illustrate its meaning. (2)

iii. Calculate the velocity with which galaxy G is moving. (2)

iv. Using Hubble's law, can the age of the Universe be accurately calculated? Explain. (1)

(Total: 10 marks)

4. A surface water wave is an example of a transverse progressive wave. Sound is an example of a longitudinal progressive wave.

a. Distinguish between a transverse progressive and a longitudinal progressive wave. (2)

b. Figure 2 can be used to represent either the variation of displacement with time (x-axis in seconds) or the variation of displacement with distance (x-axis in cm) of a water wave. Find the velocity of the wave. (4)

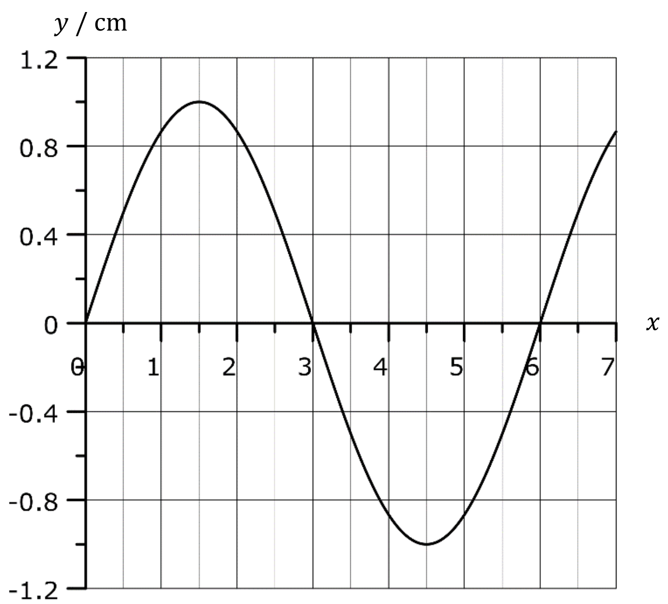

Figure 2

c. In a ripple tank experiment, plane water waves are produced by a straight wooden bar attached to an oscillating dc motor. The wooden bar moves in and out of the water. The waves produced are represented by the equation:

$$y = 0.005 \sin 2\pi(20t - 100x)$$

where y is the instantaneous displacement of a particle from the rest position at time t, when its distance is x from the origin. Both y and x are measured in metres. Find the value of the wavelength, frequency, velocity, and amplitude of the water waves. (4)

(Total: 10 marks)

5. Consider a p-n junction diode.
   a.
      i. Briefly explain the formation of the depletion region at a p-n junction. (3)

   b.
      i. Draw the I-V characteristics for a p-n junction diode. Label both axes. (2)
      ii. Describe how the resistance of a diode varies as the potential difference across it increases. Give a reason for your answer. (1)
      iii. A cell of e.m.f $1.5\ \mathrm{V}$ is connected across a parallel combination of a resistor R of resistance $50\ \Omega$ and a diode D in forward bias. Find the current through the cell when a current of $22\ \mathrm{mA}$ flows. (2)
      iv. The cell is replaced by an alternating current supply and the diode D is now connected in series with the resistor R. Draw a diagram to show the variation of the current through the resistor with time. (2)

(Total: 10 marks)

6.
   a. Briefly describe a simple experimental procedure used to estimate the value of the focal length of a converging lens. (4)

   b. A converging lens is placed at a distance of $0.3\ \mathrm{m}$ from an illuminated object. A clear image forms on a screen placed $0.6\ \mathrm{m}$ away from the lens. Then, without moving the object or image, the lens is moved towards the screen to a new position where a smaller clear image results on the screen. Calculate the distance, in metres, through which the lens has been moved such that the second image could have been formed. (3)

   c. Can the procedure described in part (b) be carried out successfully using a diverging lens? Explain your answer. (3)

(Total: 10 marks)

7. A satellite with a mass of $2200\ \mathrm{kg}$ is launched into a geostationary orbit. The orbit has a radius of $42{,}350\ \mathrm{km}$ from the centre of the Earth.

   a. What are the characteristics of a satellite that is following a geostationary orbit? (1)

   b. State and explain **TWO** conditions for a satellite to move in a geostationary orbit. (2)

   c. Calculate the speed that the satellite needs to travel at, in its orbit, to maintain an orbital radius of $42{,}350\ \mathrm{km}$. (2)

   d. As the satellite is launched from the Earth's surface into the synchronous orbit, it experiences a change in gravitational potential of $5.3 \times 10^{7}\ \mathrm{J\,kg^{-1}}$.
      i. Calculate the total energy required to put the satellite in orbit. (3)
      ii. Find the initial speed of the satellite at the launching stage, in order for it to reach the orbit and remain in a synchronous orbit around Earth. (2)

(Total: 10 marks)

8.

a. Figure 3 shows a lagged solid copper bar of uniform cross-section, which is insulated at both ends. One end is kept at a temperature θ_1 and the other end at a temperature θ_2.

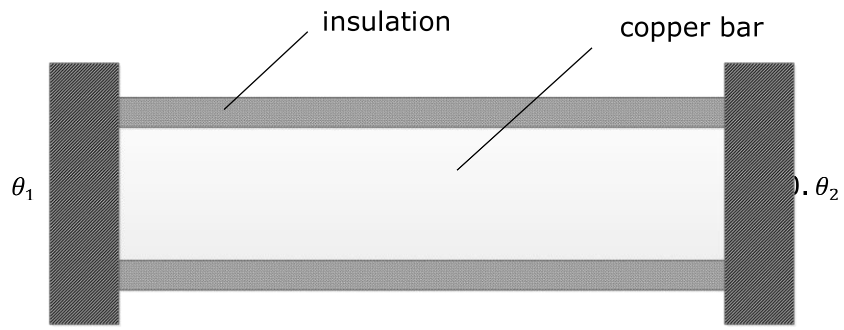

Figure 3

i. Copy the diagram and on it include heat flow lines that indicate how heat is conducted through the copper bar. (1)

ii. Beneath your diagram draw a corresponding temperature versus distance graph to show the corresponding variation of temperature along the copper bar. (2)

b. The lagging of the copper bar described in part (a) is now removed, but the end temperatures are still kept fixed at θ_1 and θ_2 respectively. Draw a diagram to show the heat flow lines in this new situation. (2)

c. The solid copper bar is now joined to an aluminium bar of the same length, L, forming a composite rod of uniform cross section. The composite rod is insulated, keeping the copper end at $100\,°\mathrm{C}$ and the aluminium end at $0\,°C$, as shown in Figure 4. Sketch a temperature versus distance graph to show the variation of temperature, θ, along the rod when conditions are steady. Explain the shape of the sketch. (2)

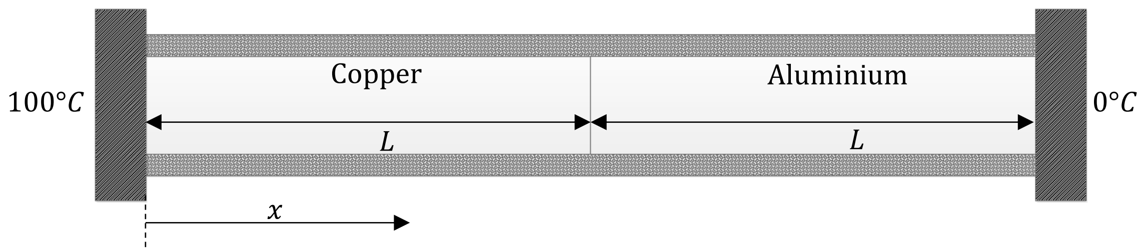

Figure 4

d. Use the data in part (c) to find the temperature at the junction between the rods.
($K_{copper} = 385.0\ \mathrm{W\,m^{-1}\,K^{-1}}$; $K_{aluminium} = 205.0\ \mathrm{W\,m^{-1}K^{-1}}$) (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. State the basic assumption of the kinetic theory of gases that leads to the conclusion that the potential energy between the atoms of an ideal gas is zero. (2)

b. Under what conditions can a real gas be assumed to behave like an ideal gas? Explain why. (2)

c. A student is examining the equation of state for one mole of a *real* gas. The equation that relates the pressure of the gas p with its volume V is given by:

$$\left(p + \frac{a}{V^2}\right)(V - b) = RT$$

where T is the absolute temperature of the gas and a and b are constants. Determine the units of a, b and R. (4)

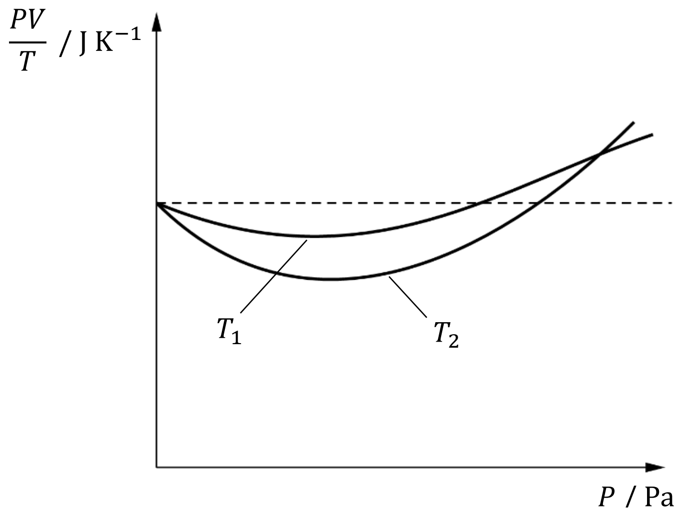

Figure 5

d. Figure 5 shows a plot of $\frac{PV}{T}$ against P for 1.00×10^{-3} kg of oxygen gas (O_2) at two temperatures, T_1 and T_2.

i. What does the dotted line signify? (2)

ii. Which is true, $T_1 > T_2$ or vice versa? Explain. (2)

iii. Calculate the value of $\frac{PV}{T}$ where the curves meet the y-axis. (3)

iv. If similar plots were to be obtained for 1.00×10^{-3} kg of hydrogen (H_2), why would the value of $\frac{PV}{T}$ at the point where the curves meet on the vertical axis not be the same? (2)

v. Determine the mass of hydrogen that would yield the same value of $\frac{PV}{T}$, that was determined in part (d)(iii). (3)
(Molecular mass of H_2 is 2.02 u while that of O_2 is 32.0 u)

(Total: 20 marks)

Please turn the page.

10.

a. Capacitance is measured in Farads. A student checks the information on a capacitor which reads $62\ \mathrm{pF}$. Explain what is meant by a capacitance of 1 Farad in relation to a capacitor device. (2)

b. Mention **THREE** factors which affect the capacitance of a parallel plate capacitor. What effect does a change in each factor have on the capacitance of the capacitor? (3)

c. Define the term time constant of a $C - R$ series circuit. (2)

d. State the S.I. unit of the time constant. (1)

e. On the same scale and axes, sketch **TWO** graphs showing the variation of the charge build up on a capacitor versus time, as the capacitor is charged using two different series circuits with a different time constant. Clearly indicate the graph with the larger time constant. (3)

f. A $3000\ \mu\mathrm{F}$ capacitor is charged through a $1.5\ \mathrm{k\Omega}$ resistor using a $6\ \mathrm{V}$ d.c. supply.
   i. Draw the circuit that is used to charge the capacitor. (3)
   ii. Calculate the charging current after $2.5\ \mathrm{s}$. (3)
   iii. Determine the charge on the plates after $2.5\ \mathrm{s}$. (3)

(Total: 20 marks)

11.

a. A mass spectrometer, like the one shown in Figure 6, is used to analyse ions from a sample of a material under investigation.
   i. What are ions? Give **ONE** example. (2)
   ii. The velocity selector is used to select ions that are moving with a specific velocity. It makes use of crossed electric and magnetic field. With the help of diagrams, explain how the velocity selector works. (4)
   iii. State **TWO** physical quantities which may be different for particles which have passed through the velocity selector region. (2)

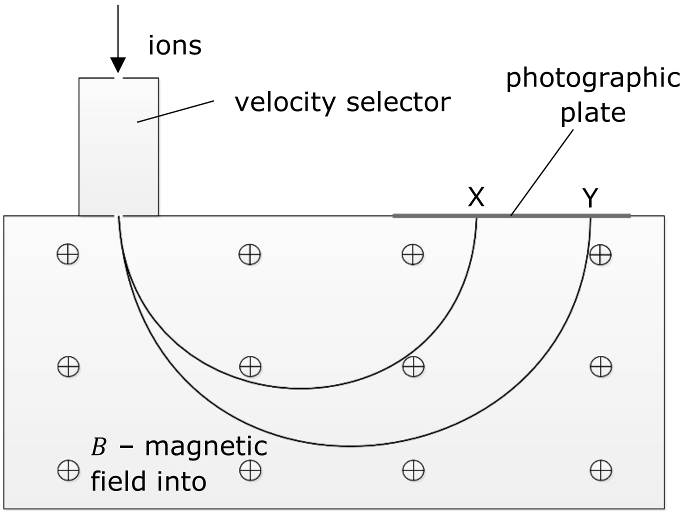

Figure 6

   iv. Derive an equation for the velocity of the ions which pass straight through the velocity selector, identifying all symbols used in your equation. (2)
   v. A beam of ions passes through a velocity selector. The electric and magnetic fields are of strengths $6.0 \times 10^{3}\ \mathrm{V\,m^{-1}}$ and $3.0 \times 10^{-3}\ \mathrm{T}$, respectively. Calculate the velocity, v, with which ions enter the region of the magnetic field. (2)
   vi. If the electric field, E, applied to the velocity selector, acts in the horizontal plane, state the direction of the magnetic field, B, such that the forces on the electrons due to E and B oppose each other. Give a reason for your answer. (2)

b. Ions from the velocity selector enter a region of uniform magnetic field B. Refer to Figure 6.

i. State the charge of the ions emerging from the selector. (1)

ii. Explain why the ions move in a circular path when in the B-field region. (2)

iii. Ions of two isotopes of an element of molar masses 3.5×10^{-2} kg and 3.7×10^{-2} kg leave the velocity selector with a velocity of $450\ \mathrm{m\,s^{-1}}$. Each of the ions carries a charge equal to 1.6×10^{-19} C and enters the magnetic field B of strength 1.8 mT. Find the linear separation XY of the isotopes as they hit the photographic plate. (3)

(Total: 20 marks)

12.

a.

i. Draw a well-labelled diagram of a step-up transformer, distinguishing between secondary and primary circuits. (2)

ii. State **TWO** properties of the transformer that can make it more efficient. (2)

iii. Figure 7 shows the primary solenoid of a transformer and the direction of an instantaneous current through the windings. The solenoid is wound on a solid iron core. On a copy of the diagram, include any resulting currents within the core, as a result of the changing current through the windings. (3)

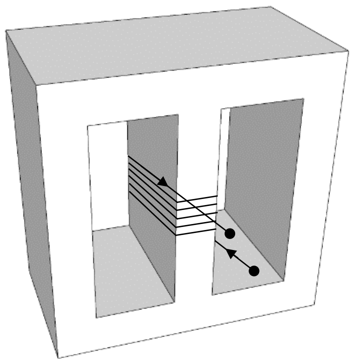

Figure 7

b. A circuit consists of an air-cored coil, a lamp and an a.c. source, as shown in Figure 8. A solid iron core is introduced into the coil.

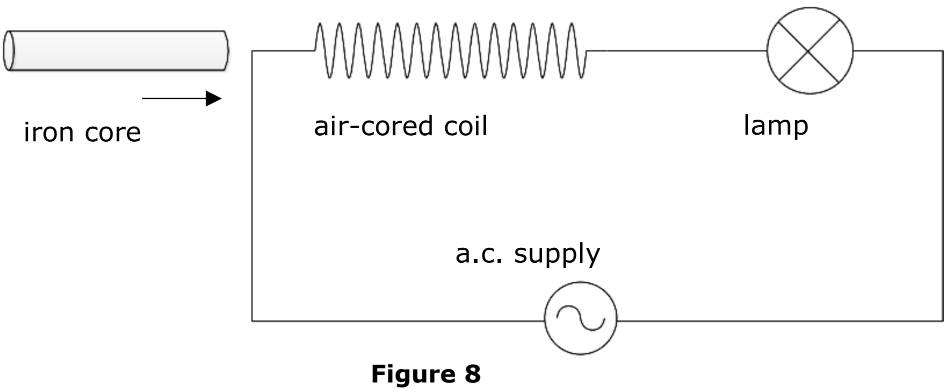

Figure 8

i. Explain why the lamp is dimmer after the core has been introduced. (2)

ii. State the reason(s) why the core becomes hot. (2)

iii. What will be the effect on the heating of the core if:

- it were laminated with the plane of the laminations parallel to the axis of the core? (1)
- it were laminated with the plane of laminations perpendicular to the axis of the core? (1)

c. A $2\ \mathrm{H}$ solenoid and a resistor are connected in series with a $2.0\ \mathrm{V}$ d.c. supply. The total resistance in the circuit is $0.8\ \Omega$.

i. What is the greatest value of the current in the circuit once the circuit is switched on? (2)

ii. What is the largest rate of change of current? (2)

iii. What is the rate of change of current with time when the current is $2.0\ \mathrm{A}$? (2)

iv. Explain why an e.m.f greatly in excess of $2.0\ \mathrm{V}$ will be produced when the current is switched off. (1)

(Total: 20 marks)

13. A student wants to investigate stationary waves on a string.

a.

i. Explain how stationary waves are formed. (2)

ii. Distinguish between nodes and antinodes. (2)

iii. State **TWO** differences between stationary and progressive waves. (2)

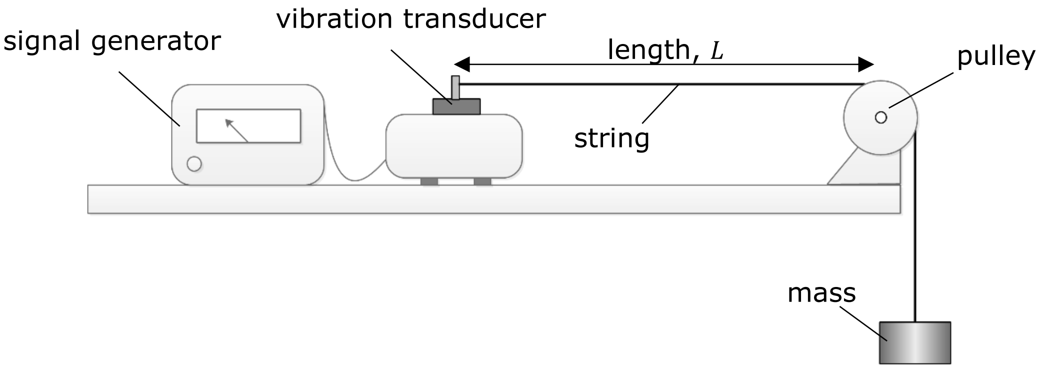

Figure 9

b.

i. Briefly describe how the student could use the apparatus shown in Figure 9 to obtain accurate measurements of the frequency of the fundamental mode, as the string's length is varied. (4)

ii. Describe how the values obtained in part b(i) can be used to find μ, the mass per unit length of string. Include a labelled sketch of the graph required and a description of how to find μ from the graph. (3)

iii. Identify a control variable in the experiment indicated above, apart from μ. (1)

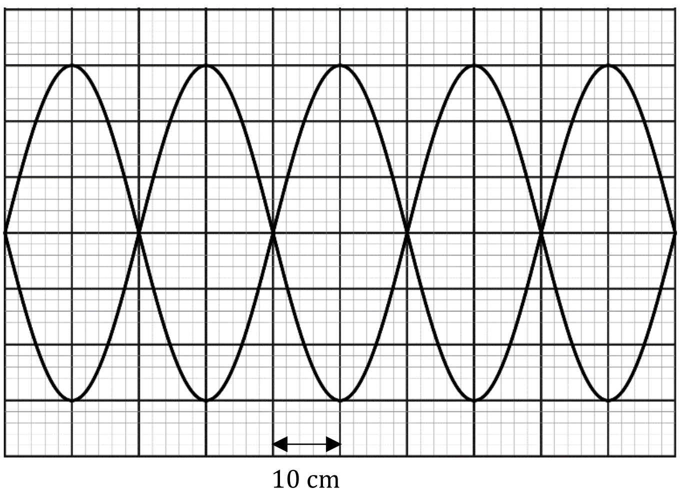

Figure 10

c. Figure 10 shows a stationary wave obtained during Melde's experiment of Figure 9. The scale is marked on the diagram and is the same for both axes.
   i. Use the diagram to find the wavelength of the stationary wave. (1)
   ii. Given that the frequency of the vibrator is $400\ \mathrm{Hz}$, calculate the wave speed. (2)
   iii. Calculate the fundamental frequency of the cord when supported in this manner. (3)

(Total: 20 marks)

14.
a.
   i. State the second law of thermodynamics as applied to a heat engine. (2)
   ii. Draw a well labelled diagram that shows how a heat engine works in principle. (2)
   iii. Comment on how the second law of thermodynamics impacts on the efficiency of a heat engine. (2)

b. A Carnot engine uses $0.200\ \mathrm{mol}$ of an ideal gas $(\gamma = 1.40)$ which undergoes a cycle between two isotherms at temperatures of $227\ °\mathrm{C}$ and $27\ °\mathrm{C}$. The initial pressure at point A is $10.0 \times 10^5\ \mathrm{Pa}$ and during the isothermal expansion at the higher temperature, the volume doubles, as shown in Figure 11.

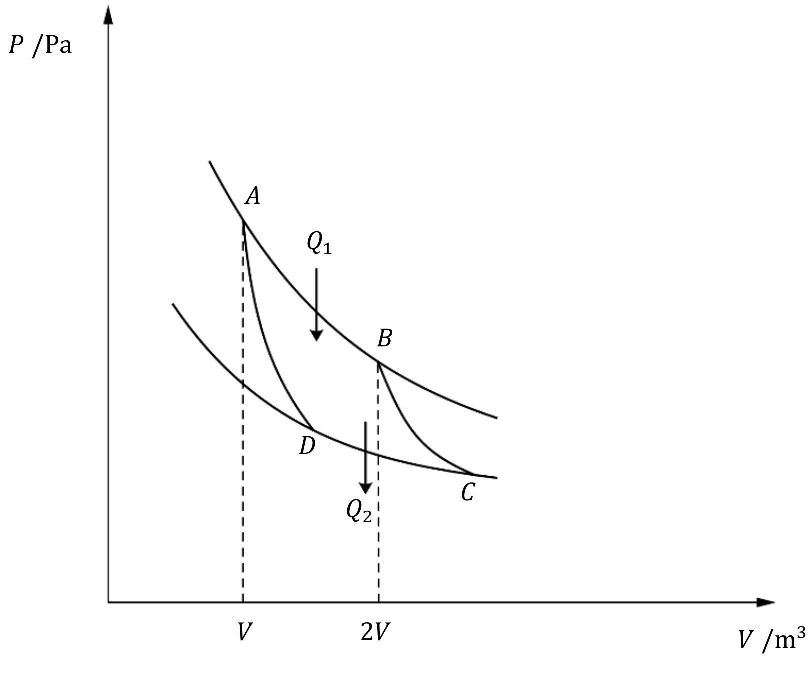

Figure 11

   i. Find the pressure and volume at each of the points A, B and C. (8)
   ii. What is the heat transfer Q_{BC} during the expansion of the gas from B to C? Give a reason for your answer. (2)
   iii. Use the First Law of Thermodynamics to express the work done W_{BC} in terms of the internal energy of the gas for the process BC. (2)
   iv. Given that the molar heat capacity for an ideal diatomic gas, C_V, is equal to $20.8\ \mathrm{J\ mol^{-1}\ K^{-1}}$, calculate the change in internal energy ΔU in the process BC. (2)

(Total: 20 marks)

Please turn the page.

15.

a. Define specific latent heat of vaporisation of a liquid. (1)

b.

i. Describe an experiment used to find the specific latent heat of vaporisation of water, L, using the electrical heating method. The description, should include:
- a list of the apparatus required; (2)
- a well labelled diagram of the setup; (2)
- the procedure of the steps taken including particular reference to energy conservation; (2)
- the calculations necessary to determine L. (2)

ii. Mention the main source of experimental error in this experiment. (1)

c. The heater in an electric kettle has a power of $2.40\ \mathrm{kW}$. When the water is boiling at a steady rate, the mass of water evaporated in 2.0 minutes is $106\ \mathrm{g}$. The specific latent heat of vaporisation of water is $2260\ \mathrm{J\,g^{-1}}$. Calculate the rate of loss of thermal energy to the surroundings of the kettle during the boiling process. (3)

d. Figure 12 shows a graph of temperature in $°\mathrm{C}$ plotted against the total internal energy in Joules for $1.0\ \mathrm{kg}$ of pure water as it is heated.

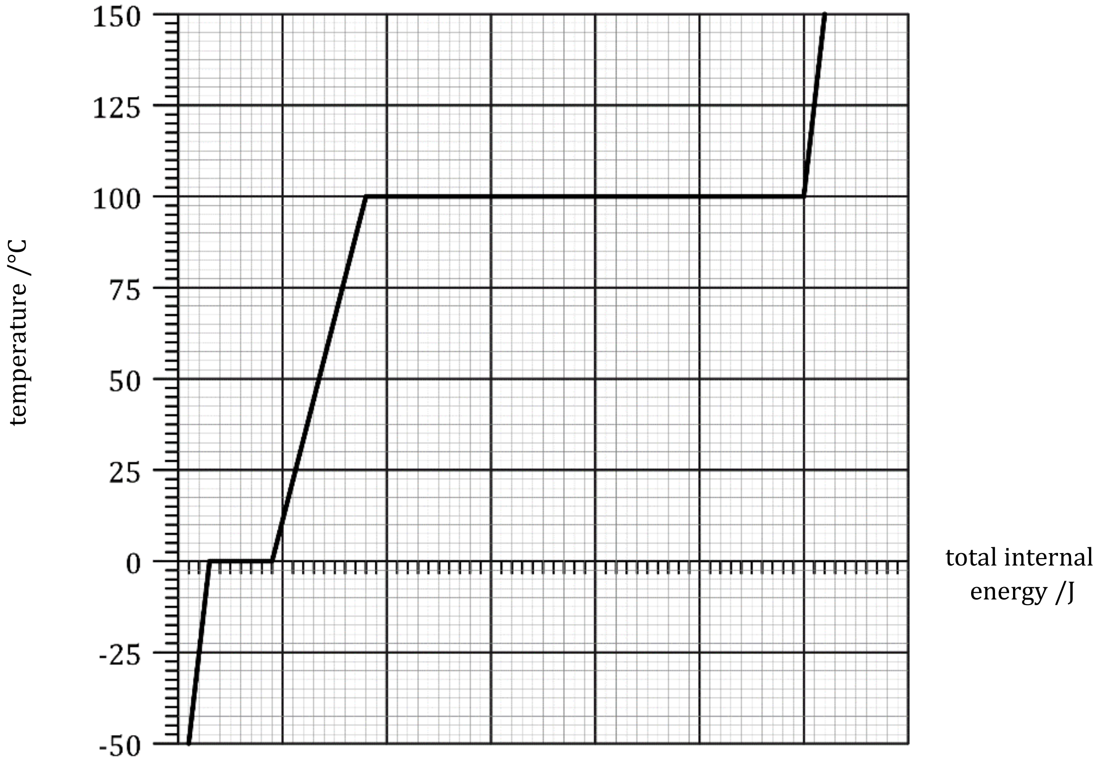

Figure 12

i. Explain the increase in internal energy of the water at $100°\mathrm{C}$, and calculate this increase. The specific latent heat of vaporisation for water is $2.3 \times 10^6\ \mathrm{J\,kg^{-1}}$. (3)

ii. Hence, calculate the increase in internal energy at $0°\mathrm{C}$, and the specific latent heat of fusion of water. (2)

iii. Using data from the graph, identify which of water's three states has the greatest specific heat capacity. Explain your answer. (2)

(Total: 20 marks)