MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2021 SECOND SESSION

SUBJECT:	**Physics**
DATE:	11th October 2021
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 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 hose directs a horizontal jet of water, moving with velocity v, onto a vertical wall. The cross-sectional area of the jet is A. The density of water is represented by ρ and the water exerts a force F on the wall.

   a. State the SI units of ρ, v and F. (3)
   b. The force exerted on the wall is given by the equation $F = \rho A v^2$. By using base units, show that this equation is homogeneous. (2)

(Total: 5 marks)

2. In a shooting range, a 30 g bullet is fired horizontally and moves at 120 ms^{-1} until it hits a wooden block of mass 2 kg. The bullet becomes embedded in the block. The wooden block is suspended by light vertical strings of length 1 m, as shown in Figure 1.

   a. Is this collision elastic or inelastic? Explain. (1)
   b. Find the maximum rise in vertical height of the block and bullet after collision. (3)
   c. Hence, calculate the maximum angle of inclination that the strings make with the vertical. (2)

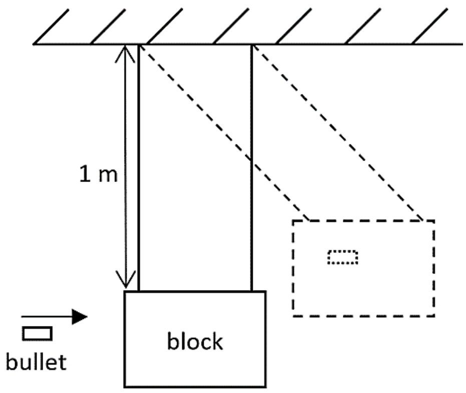

Figure 1

(Total: 6 marks)

3. The current flowing in a current carrying conductor is expressed by the equation $I=n A v q$.

   a. In the above equation, what do the letters n and v represent? (2)
   b. Explain the differences between conductors and semi-conductors in terms of n and v, as used in the given equation. (2)
   c. Briefly explain what causes a current to flow in a complete electric circuit. (1)
   d. Briefly explain why insulators do **not** allow current flow at room temperature. (1)

(Total: 6 marks)

4. a. (i) Explain why a body moving in circular motion must necessarily be acted upon by a force, even if the speed of the body remains unchanged. (1)

(ii) In which direction does this force act and what is it called? (1)

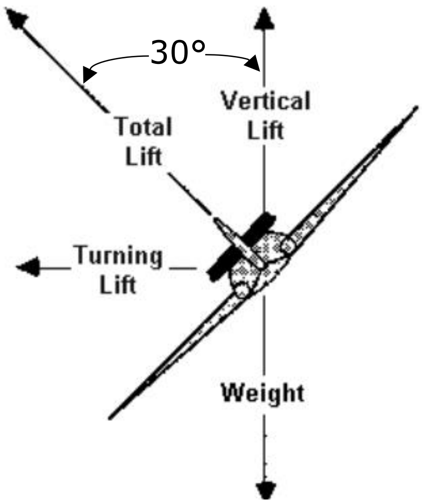

Figure 2

b. An aircraft of mass 60,000 kg has a cruising speed of 240 ms^{-1}. At a point along its path, it starts moving in a circle of radius r, as it banks at an angle of $30°$ to the vertical, as shown in Figure 2. Assuming that the aircraft stays at the same altitude:

(i) find the total lift during banking. (2)

(ii) find the radius, r, of the circular path. (2)

(Total: 6 marks)

5. A cosmic rock is at a point between the Earth and the Moon, such that the Earth exerts the same pull on it as the Moon. The distance from the surface of the Earth to the cosmic rock is 8 times as large as the distance of the rock from the surface of the Moon.

a. Express the mass of the Earth (m_E) as a multiple of the mass of the Moon (m_M). (2)

b. The gravitational field strength increases as the cosmic rock approaches the planet Earth. Define gravitational field strength. (1)

c. Sketch a graph to show the variation of the gravitational field strength with distance, from the surface of the Earth. (1)

d. When the cosmic rock reaches an altitude of 10 x 10^6 m above the Earth's surface, it starts to orbit the Earth. Find the velocity of the cosmic rock at this altitude. (2)

$[\mathrm{m_E} = 6.0 \times 10^{24}\ \mathrm{kg};\ \ r_E = 6380\ \mathrm{km}]$

(Total: 6 marks)

6. Figure 3 shows the sinusoidal variation of voltage, V / V, with time, t /s.

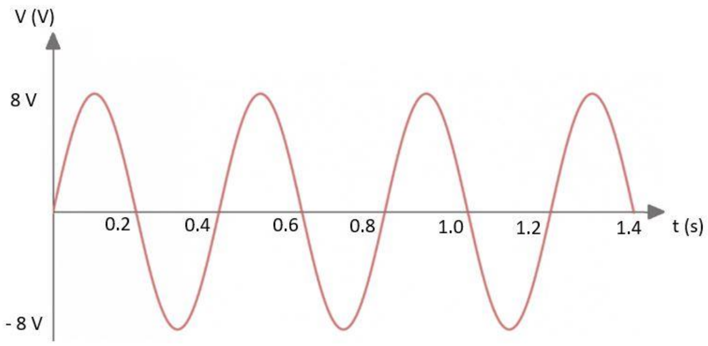

Figure 3

a. Determine the peak value of V. (1)
b. Calculate the frequency of the waveform. (1)
c. Find the average value of V over 2 cycles. (1)
d. Calculate the root mean square value of V. (2)

(Total: 5 marks)

7. A meter ruler is held firmly from one end, over the edge of a table. A force is applied momentarily to the free end of the ruler and then let go, causing this end of the ruler to start oscillating freely.

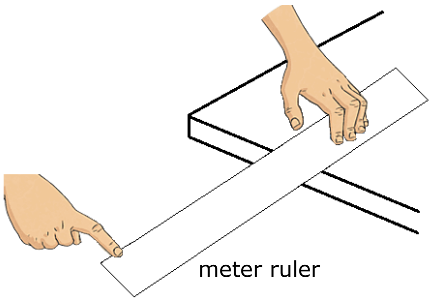

Figure 4

a. Explain in terms of forces, why the ruler oscillates back and forth. (1)
b. On the same set of axes, sketch a velocity-time graph and an acceleration-time graph that describe the oscillation of the end of the ruler. Distinguish between the graphs, by labelling them. (2)
c. State the phase difference between the graphs drawn in part (b), in terms of the periodic time. (2)
d. For a system oscillating in simple harmonic motion, using the same scale and axes, sketch graphs to show how the kinetic energy, potential energy and related total energy of the oscillating system vary as a function of position. Distinguish between the graphs. (3)

(Total: 8 marks)

Questions continue on next page.

8. Uranium-235 is a radioactive element and undergoes fission. The reaction below shows the fission products. The respective masses of reactants and products are also indicated.

$${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3{}^{1}_{0}\mathrm{n}$$

$$235.0439\mathrm{u} + 1.008665\mathrm{u} \rightarrow 140.9143\mathrm{u} + 91.9263\mathrm{u} + 3(1.008665)\mathrm{u}$$

a. What is the name given to the unit u and what does it represent? (2)
b. Give the meaning of '*mass defect*'. (1)
c. Calculate the mass defect for the reaction indicated above. (1)
d. Calculate the energy being released during the reaction shown above. Give your answer in Joules. (2)
e. Sketch a graph to show how the number of parent Uranium nuclides changes with time during fission. Label this as Sketch A. On the same set of axes, show what happens to the number of daughter nuclides as the Uranium decay proceeds. Label this as Sketch B. (2)

(Total: 8 marks)

SECTION B
This question carries 14% od the total marks of his paper and must be attempted.

9. A student sets up the apparatus shown in Figure 5.

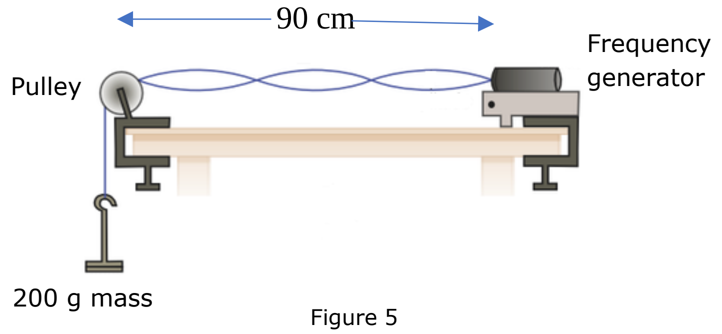

Figure 5

A 200 g mass hangs at one end of a stretched string which passes over a pulley and is connected at the other end to a frequency generator. The part of the string from the pulley to the frequency generator measures 90 cm. The frequency generator is initially set to a minimum value and the power supply is switched on. The frequency is then increased slowly, until it reaches 98 Hz, as different standing waves are observed on the string. The diagram indicates the 3rd standing wave observed by the student.

The following is a general equation for the frequency of standing waves in the string:

$$f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$$

where f_n is the frequency of the n^{th} harmonic, L is the length of the string that is free to vibrate, T is the tension in the string and μ is the mass per unit length of the string.

The student takes several readings of the frequency for different standing wave formations on the string. The results are shown in Table 1.

Table 1

f_n / Hz	$f_n{}^2$ / Hz^2	n	n ^{2}
20.0		1	
36.0		2	
63.2		3	
83.7		4	
98.0		5	

a. Copy Table 1 and fill in the missing values. (2)
b. Plot a graph of n^2 on the y-axis against $f_n{}^2$ / Hz^2 on the x-axis. (5)
c. Square the given equation and then write it in the form $y = mx + c$, clearly indicating the quantities representing the gradient and the y-intercept. (2)
d. Use the graph to find a value for μ. State the units of μ. (2)
e. State **ONE** precaution that should be taken during this experiment, to make the results more reliable. (1)
f. Sketch the standing wave that the student obtained for n=1 (the first harmonic). (1)
g. How would the value of the frequency, for different standing wave formations, differ if a larger mass had been attached to the end of the string? Explain. (1)

(Total: 14 marks)

SECTION C

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

10. a. A constant mass of gas is contained in a cylinder at an initial temperature of 314 K. The volume of the gas is kept constant, as its pressure is increased by heating the gas, supplying it with 91 J of energy. The gas reaches a final temperature of 790 K.
   (i) How much work is done on the gas? Explain. (2)
   (ii) Using the first law of thermodynamics, find the change in internal energy of the gas. (2)
   (iii) Draw a p-V diagram that shows the changes made to the gas, as described above, clearly indicating the points on the graph where the gas temperatures were 314 K and 790 K respectively. (2)
   (iv) Is the process described above isochoric or isobaric? Explain. (2)

   b. A copper calorimeter of mass 90 g contains 380 g of a liquid at 12°C. A 20 W heater is immersed in the liquid and is switched on for 3 minutes, raising the temperature of both the liquid and the calorimeter to 17°C. The calorimeter has a specific heat capacity of 390 J kg^{-1} K^{-1}.
   (i) Calculate the heat energy supplied by the heater. (1)
   (ii) What is the amount of heat supplied to the calorimeter alone? (2)
   (iii) Assuming no heat losses, find the specific heat capacity of the liquid. (3)

Questions continue on next page.

c. A liquid, initially at room temperature, partly fills a closed container. The liquid is put in a freezer where the temperature of the liquid drops below its freezing point, finally reaching -18°C.

(i) Sketch a temperature versus time graph to show how the temperature of the liquid falls from room temperature to -18°C, clearly indicating the room temperature and the freezing point. (3)

(ii) What happens to the internal energy of the liquid as the temperature decreases? (1)

(Total: 18 marks)

11. A student investigates the circuit shown in Figure 6.

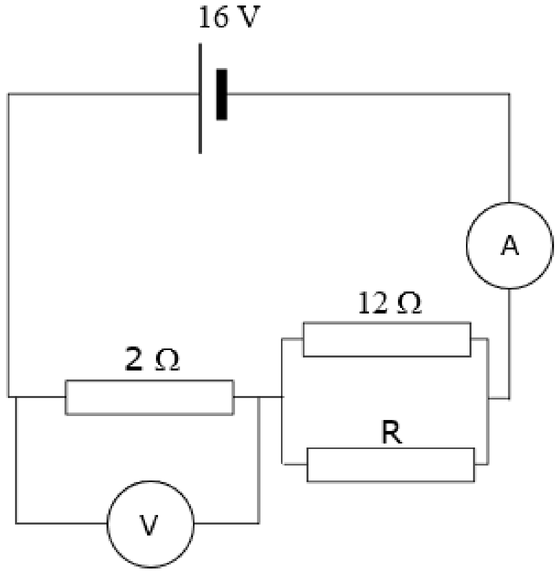

Figure 6

a. Define the electrical potential difference between two points in a circuit, in terms of energy. (2)

b. Define electrical resistance. (2)

c. Assuming that the ammeter and the voltmeter in the above circuit are ideal and that the ammeter measures a current of 2 A, calculate:

(i) the voltage across the 2 Ω resistor; (1)

(ii) the current passing through the 12 Ω resistor; (2)

(iii) the resistance R; (2)

(iv) the total resistance in the circuit; (2)

(v) the power supplied by the battery. (1)

d. If the student uses a non-ideal voltmeter instead of the ideal one, but still connects it in parallel to the 2 Ω resistor, in what way would this affect the ammeter reading? Explain. (2)

e. In 50 kg of typical household waste, 40 kg can be burned as fuel to generate electricity at a power plant. A tonne (1000 kg) of household waste generates about 500 kWh of electricity.

(i) Estimate the energy generated, in kWh, from 50 kg of typical household waste. (1)

(ii) Calculate the energy in Joules used by a 100 W light bulb in 1 hour. (1)

(iii) A 100 W light bulb is switched on for 5 hours a day for a whole week (7 days). What is the weekly cost, given that 1 kilowatt hour costs 10 cents? (2)

(Total: 18 marks)

12. a. A capacitor is connected as shown in Figure 7. A two way switch is used. When switch A is closed, the capacitor is charged. With switch B closed, the capacitor discharges through the 2200 Ω resistor.

(i) Draw **TWO** separate graphs to show how the charge stored on the capacitor changes with time, when:
- switch A is closed;
- switch B is closed. (4)

(ii) Define the time constant for the discharge circuit. (2)

(iii) Explain how the time constant of the circuit can be determined by using the graph for the discharging capacitor. Include a sketch to support your answer. (3)

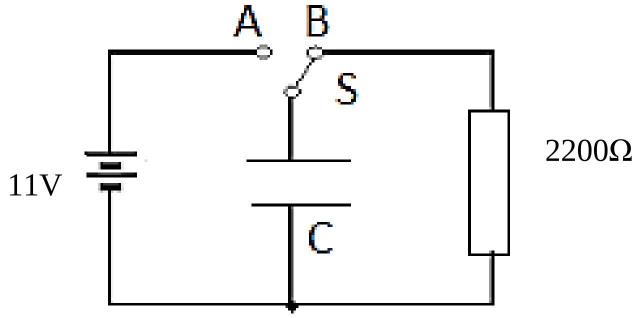

Figure 7

(iv) The capacitor C has a capacitance of 0.47 μF. Find the time constant of the discharging circuit. (2)

b. A student conducts an experiment using a capacitor having parallel circular plates, as shown in Figure 8.

(i) The metallic plates of the capacitor each have a radius R, equal to 40 mm. The plate separation is 5 mm. The capacitor is connected to a 12 V d.c. supply. Calculate the capacitance of the capacitor. (4)

(ii) State **THREE** changes that can be made during the construction of a capacitor, in order to increase its capacitance. (3)

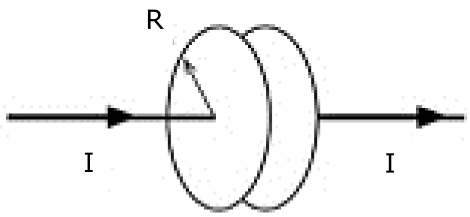

Figure 8

(Total: 18 marks)

13. a. (i) What is a virtual image? (1)

(ii) Draw a ray diagram to show the formation of a virtual image of an object which is under water and which is being viewed from directly above the water surface. (2)

(iii) An observer looks at a water tank which is partially filled with water. According to him water fills half the tank. The height of the tank is 190 cm. Find the real depth of the water in the tank (refractive index of water = 1.33). (3)

(iv) Explain why a ray of light is refracted when passing from one medium to another. (2)

(v) When does a ray of light pass from one medium to another without being deviated? (1)

b. Give a detailed description of an experiment used to determine the focal length of a thin converging lens. The description should include a diagram of the setup, the data that would need to be recorded, the equation to use, the graph that would be plotted and how to use the latter to find the focal length of the lens. (5)

c. A convex lens has a focal length, *f*, equal to 40 mm. An object is placed 25 mm away from the lens.

(i) Draw a ray diagram to show the image formation. (2)

(ii) Calculate the magnification. (2)

(Total: 18 marks)