A boat starts from rest at time $t = 0$ s and travels along a straight line. Figure 1 shows the velocity-time graph of the boat from $t = 0$ to 300 s.

*(a)* Describe the motion of the boat from $t = 0$ to 300 s. (5 marks)

(b) Find the acceleration of the boat in the first 50 s. (2 marks)

(c) In Figure 2, draw the acceleration-time graph of the boat from $t = 0$ to 300 s. (3 marks)

(d) Find the distance travelled by the boat in the first 50 s. (2 marks)

(e) A buoy is located 900 m ahead of the starting point of the boat. Explain whether the boat will pass the buoy during its motion as shown in Figure 1. (3 marks)
Two dippers \( S_1 \) and \( S_2 \) vibrate in phase producing identical circular water waves in a ripple tank. Figure 3 shows the wave pattern at a certain instant. (Note: The dark lines represent crests.) The distance between \( S_1 \) and \( S_2 \) is 0.06 m and it is known that the water waves travel with a speed of 0.4 m s\(^{-1}\).

(a) Find the wavelength and frequency of the water waves. (3 marks)

(b) The ripple tank has a spongy lining at its edges. Explain the function of the spongy lining. (2 marks)

(c) \( P \) and \( Q \) are two points at the water surface as shown in Figure 3. Find the path difference at

(i) point \( P \), and

(ii) point \( Q \)

from \( S_1 \) and \( S_2 \), giving the answers in terms of the wavelength \( \lambda \) of the water waves.

Hence state the types of interference occurring at \( P \) and \( Q \). (4 marks)

*(d)* How would the interference at \( Q \) be affected if the frequency of vibration of the two dippers is doubled? Explain your answer. (Note: You may assume that the speed of the water waves remains unchanged.) (4 marks)

(e) If only one dipper is available, suggest a method of producing an interference pattern in the ripple tank. Illustrate your answer with a diagram. (2 marks)
Figure 4 shows a trolley running down a friction compensated runway. The trolley is connected to a hanging weight by means of a light inelastic string. A card of width 0.03 m is attached to the trolley. Light sources $S$ and light detectors $D$ are fixed at two positions $A$ and $B$ along the runway. Each light detector is connected to a timer, which can measure the time taken by the card to pass the light detector.

(a) The timers record that it takes 0.050 s and 0.025 s for the 0.03 m card to pass the light detectors at $A$ and $B$ respectively.

(i) Calculate the average speed of the trolley as it passes

(1) position $A$, and

(2) position $B$. (3 marks)
(ii) If the mass of the trolley is 1.5 kg and the distance between A and B is 0.4 m, calculate

(1) the acceleration of the trolley,

(2) the tension in the string, and

(3) the gain in kinetic energy of the trolley as it travels from A to B. Where does this gain in kinetic energy come from?

(7 marks)

*(b)* Describe how you can use a ticker-tape timer to check whether the runway is friction compensated.

(4 marks)

(c) If the string suddenly breaks, describe the subsequent motion of the trolley along the runway.

(1 mark)
A student uses the apparatus shown in Figure 5 to perform an experiment to measure the specific latent heat of fusion of ice. He uses a joulemeter to measure the energy required to melt a certain amount of ice.

(a) Draw a diagram to show how the apparatus can be set up for the experiment.

(b) The following data are obtained in the experiment:

Initial joulemeter reading = 28 000 J
Final joulemeter reading = 40 400 J
Mass of water collected in the beaker = 0.045 kg.

Calculate the specific latent heat of fusion of ice.

(c) Why should the ice used in the experiment be crushed?
A teacher comments that the result of this experiment is not accurate. She points out that a control experiment is required in order to improve the accuracy of the experiment.

*(i)* Describe how the control experiment can be set up and explain its function.  

(ii) After setting up the control experiment, the student repeats the above experiment. Would you expect the specific latent heat of fusion obtained to be higher or lower than that obtained in (b) ? Explain your answer.
A student sets up a circuit as shown in Figure 6 to control the operation of an air-conditioner.

(a) Name the devices $X$, $Y$ and $Z$.

How does the resistance of $X$ change when its temperature is increased?

(4 marks)

(b) Construct a truth table for an AND gate.

(2 marks)

(c) Assume that the input $B$ is high when the temperature is higher than $T_0$ and becomes low when the temperature is lower than $T_0$. State whether the air-conditioner is on or off in each of the following cases:

<table>
<thead>
<tr>
<th>Case</th>
<th>Switch $S$</th>
<th>Temperature</th>
<th>Air-conditioner</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Closed</td>
<td>$&gt; T_0$</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Closed</td>
<td>$&lt; T_0$</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Open</td>
<td>$&gt; T_0$</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Open</td>
<td>$&lt; T_0$</td>
<td></td>
</tr>
</tbody>
</table>

Table 1

(2 marks)
(d) What is the function of the device $Y$ in the circuit? (2 marks)

(c) What is the advantage of using device $Z$ to control the operation of the air-conditioner? (2 marks)

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**Figure 7**

If a NOR gate is used to replace the AND gate in Figure 6, the student has to modify the circuit so that the operation of the air-conditioner remains unchanged as in Table 1. Figure 7 shows part of the modified circuit. Copy Figure 7 into your answer book and complete the circuit using the devices $R, S, X$ and $Y$. (3 marks)
Two metal plates are connected to a high voltage d.c. supply and a galvanometer as shown in Figure 8. When a radioactive source \( X \) emitting \( \alpha \) particles is placed very near the metal plates, the galvanometer shows that a current is flowing. When \( X \) is moved a small distance away from the two plates, the galvanometer reading quickly drops to zero.

*(a)* Explain why there is a current and why it is present only when \( X \) is very near the metal plates.

(4 marks)

(b) \(^{220}_{86} X\) decays by emitting an \( \alpha \) particle to form a stable nucleus \( Y \). Write down an equation for the decay. What is the neutron number of \( Y \)?

(3 marks)

(c) How would the galvanometer reading be affected if \( X \) is replaced by a \( \beta \) source? Explain briefly.

(2 marks)
(d)  $X$ is placed very near the metal plates and the galvanometer reading is recorded every 30 seconds. The results obtained are shown below:

<table>
<thead>
<tr>
<th>Time/s</th>
<th>0</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current/µA</td>
<td>72</td>
<td>48</td>
<td>32</td>
<td>22</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>

Plot a graph of current against time on graph paper.

Hence find the half-life of $X$. (Note: You may assume that the activity of the source is directly proportional to the current.)  

(5 marks)

(e)  Explain why $X$ is not suitable for use as tracers. 

(1 mark)
7. Two students suggest using a 24 V d.c. supply and a 24 V a.c. supply separately to operate a lamp $X$ of rating '6 V, 12 W'.

(a) 

![Circuit Diagram]

Figure 9

A student connects $X$ in series with a 24 V d.c. supply and a resistor $R$ (see Figure 9). If $X$ works at its rated value,

(i) find the current flowing through $X$,

(ii) find the voltage drop across $R$,

(iii) find the resistance of $R$,

(iv) what percentage of the electric power provided by the d.c. supply is dissipated in $R$?

(8 marks)

(b) The other student suggests that $X$ can also be made to work by using a 24 V a.c. supply together with a transformer.

(i) Draw a circuit diagram to show how $X$, the a.c. supply and the transformer are connected.

(2 marks)

(ii) What is the advantage of using this method over the one shown in Figure 9?

(1 mark)

(iii) Find the turns ratio (primary to secondary) of the transformer for $X$ to work at its rated value, and calculate the primary current if the transformer is 100% efficient.

(4 marks)

END OF PAPER