A car moves along a straight road. Figure 1 shows the variation of the displacement $x$ of the car from a certain point on the road with time $t$.

(a) Describe the motion of the car from $t = 0$ to $40$ s. (3 marks)

(b) Find the average velocity of the car from $t = 0$ to $40$ s. (2 marks)
Kenneth, of mass 60 kg, falls vertically from rest from a 10 m platform into a swimming pool (see Figure 2). In the following calculations, you may neglect the size of Kenneth.

(a) Find the potential energy of Kenneth when he stands on the platform, taking potential energy at the water surface as zero.

(1 mark)

(b) Find the speed of Kenneth at the instant he reaches the water surface.

(2 marks)

(c) If Kenneth reaches a maximum depth of 3 m in the water, estimate the average resistive force exerted by the water on Kenneth.

(3 marks)
3. William makes a glass of hot tea (see Figure 3). After a while, he adds some ice cubes into the tea. William uses a temperature sensor to measure the temperature of the tea. Figure 4 shows the temperature-time graph obtained.

![Figure 3](image)

**Figure 3**

**Figure 4**

(a) William stirs the tea throughout the experiment. Why does he need to do this? (1 mark)

(b) $P$, $Q$, $R$ and $S$ are four points on the graph. State the point which corresponds to each of the following:

(i) The instant at which the ice cubes are added. (1 mark)

(ii) The instant at which all the ice cubes melt. (1 mark)

(c) Explain why the temperature of the tea increases from $R$ to $S$. (2 marks)

(d) Estimate the temperature of the surroundings. (1 mark)
Figure 5 shows a paper with some letters 'J' printed on it. The paper is placed behind a glass filled with water. Figure 6 shows the image of the letters formed by the glass of water.

(a) State the nature of the image formed (erect or inverted, magnified or diminished, real or virtual). (2 marks)

(b) Jason holds a lens in front of the paper in Figure 5 and finds that the image formed is of the same nature as that formed by the glass of water.

(i) What kind of lens is held by Jason? (1 mark)

(ii) Sketch a ray diagram to show how the image of the letters is formed by the lens. (3 marks)
Figure 7 shows a ripple tank with a deep region $P$ and a shallow region $Q$.

(a) Suppose that two obstacles are added in the ripple tank as shown in Figure 7.
   
   (i) Name two wave phenomena that may occur if water waves travel from $P$ to $Q$. 
   (2 marks)

   

(ii) Figure 8 shows the wave pattern observed when straight water waves are generated in $P$. Compare the wavelength and speed of the waves travelling in $Q$ with those in $P$. 
   (2 marks)

   

(b) Figure 9

Suggest one method of obtaining the wave pattern in $Q$ as shown in Figure 9. Illustrate your answer by completing Figure 9.

   (2 marks)
*6. You are provided with the apparatus shown in Figure 10.

![Diagram of signal generator and two identical loudspeakers]

Figure 10

Describe how you should use the apparatus to conduct an experiment to demonstrate the interference of sound waves. You may use additional apparatus if necessary.

(5 marks)
7. Read the following passage about Iodine-131 therapy and answer the questions that follow.

Iodine-131 is a radioisotope which emits β and γ radiation. It can be used for thyroid cancer treatment.

A patient suffering from thyroid cancer will first undergo an operation to have the thyroid gland removed. However, some thyroid tissue may remain in the neck of the patient or may be carried in the bloodstream to other parts of the body. Iodine-131 is then used to trace and get rid of the remaining thyroid tissue in the body.

Iodine-131 therapy consists of two stages. In Stage 1, the patient will take a low dose of Iodine-131 to trace the remaining thyroid tissue. A detector is placed near the patient to monitor the activity of the radiation coming from the patient.

In case any remaining thyroid tissue is spotted in Stage 1, the patient will then take a higher dose of Iodine-131 in Stage 2. The iodine will be absorbed by the thyroid tissue and the radiation emitted can kill the cancer cells.

Special hospital rooms are designed for patients who receive Stage 2 of the therapy. The rooms have metallic shielding in the doors and reinforced walls. Inside the rooms, there are plastic covers on the furniture, doors, handles and switches.

Source: *Iodine-131 Therapy*, The Ohio State University Medical Center, 2003.

(a) Explain why, in Stage 1, β radiation from the patient cannot be detected by the detector. (1 mark)

(b) In Stage 2, which kind of radiation is more effective in killing cancer cells? Explain your answer. (2 marks)

(c) State one special feature of the hospital rooms designed for patients receiving Stage 2 of the therapy and explain its function. (2 marks)
8. Carol performs an experiment to measure the half-life of a radioactive source. She places a Geiger-Muller tube in front of the source and the following results are obtained:

<table>
<thead>
<tr>
<th>Time ( t ) / hour</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count rate / counts per minute</td>
<td>400</td>
<td>225</td>
<td>154</td>
<td>119</td>
<td>107</td>
<td>105</td>
<td>100</td>
<td>102</td>
</tr>
</tbody>
</table>

**Table 1**

(a) Plot a graph of the count rate against time in Figure 11.  

(b) Estimate the background count rate.  

(c) Estimate the corrected count rate at \( t = 0 \).

Hence, or otherwise, estimate the half-life of the source.
Iris uses the apparatus shown in Figure 12 to study the lifetime of AA-size cells for lighting up a bulb. She connects a cell and a switch to the bulb and uses a voltage sensor to measure the voltage across the bulb.

(a) Draw a circuit diagram to illustrate how the apparatus is connected. Use the symbol $\mathbf{V}$ to denote the voltage sensor. (3 marks)

(b) Iris conducts the experiment for a zinc-carbon cell, an alkaline cell and a lithium cell separately. Figure 13 shows the variation of the voltage across the bulb with time for the cells. The bulb will light up as long as the voltage across it is above 0.6 V.
(b) (continued)

(i) A salesman claims that the lifetime of a lithium cell for lighting up the bulb is five times that of an alkaline cell. Determine whether the claim is correct or not. 

(ii) The prices of the three types of cells are shown in Table 2.

<table>
<thead>
<tr>
<th>Type of cells</th>
<th>Price per cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>zinc-carbon</td>
<td>$1.5</td>
</tr>
<tr>
<td>alkaline</td>
<td>$3.8</td>
</tr>
<tr>
<td>lithium</td>
<td>$25.0</td>
</tr>
</tbody>
</table>

Table 2

Which type of cells is the best buy, in terms of the cost per hour for lighting up the bulb? Show your calculations.
10. Optical fibres are widely used in telephone communication. The voice signals are transmitted in the form of light through optical fibres.

   (a) Figure 14 shows a light ray travelling towards an optical fibre.

      (i) In Figure 14, sketch the subsequent path of the ray.

      ![Figure 14](image)

      (2 marks)

     (ii) Name the wave phenomenon that occurs as the ray travels inside the fibre.

      (1 mark)

   *(b)* Before being transmitted to a telephone, the light signals are converted to electrical signals. Figure 15 shows the main structure of the earpiece of a telephone, which converts electrical signals into sound. Describe the working principle of the earpiece.

   ![Figure 15](image)

   (4 marks)

   (c) State two advantages of using optical fibres over copper wires in telephone communication.

      (2 marks)
Figure 16 shows a simple hairdryer designed by Joseph. He makes use of a motor-driven fan and a heating element to generate warm air. Figure 17 shows the circuit diagram of the dryer. The motor and the heating element are connected to the 220 V mains. The switch S can be connected to either contact P or Q.

(a) Carmen uses the dryer to dry her wet hair. Explain, in terms of molecular motion, how the dryer can speed up the rate of evaporation of water from wet hair. (2 marks)

(b) Switch S is connected to contact P and the following data are given:

- Resistance of the heating element = 50 Ω
- Rate of air flowing through the dryer = 0.05 kg s⁻¹
- Temperature of air flowing into the dryer = 20°C
- Specific heat capacity of air = 1000 J kg⁻¹ °C⁻¹

Estimate the temperature of the air flowing out of the dryer, and state one assumption in your calculation. (4 marks)

*(c) If switch S is connected to contact Q instead, explain whether the temperature of the air flowing out of the dryer would be higher than when S is connected to contact P. (4 marks)
Josephine conducts an investigation on transformers. She sets up a circuit as shown in Figure 18.

(a) Josephine varies the input voltage $V_1$ to the transformer and records the corresponding output voltage $V_2$. The results are shown in Table 3. In Figure 19, plot a graph of $V_2$ against $V_1$.

Hence draw a conclusion for this investigation.

<table>
<thead>
<tr>
<th>$V_1 / \text{V}$</th>
<th>$V_2 / \text{V}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.7</td>
</tr>
<tr>
<td>2.0</td>
<td>3.3</td>
</tr>
<tr>
<td>3.0</td>
<td>5.1</td>
</tr>
<tr>
<td>4.0</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Table 3

![Graph showing $V_2$ vs $V_1$](image)

(b) Josephine wants to study the relationship between the output voltage and the number of turns in the secondary coil of the transformer. Describe how she can conduct the experiment.

(c) Josephine adds a bulb to the circuit as shown in Figure 20. Suggest a method that Josephine can use to estimate the efficiency of the transformer. Additional apparatus may be used if necessary.
Read the following descriptions about ejection seats and answer the questions that follow.

Ejection seats (see Figure 21) are important safety devices in military planes. The pilot, together with the seat, are ejected out of the plane in an emergency. Figure 22 shows a test of the ejection process. A dummy pilot sitting on the ejection seat is initially placed on the ground. The ejection process can be divided into two phases:

Phase 1: At time $t = 0$, a rocket installed under the seat is ignited. From $t = 0$ to $0.5$ s, the seat accelerates upwards.

Phase 2: At $t = 0.5$ s, the rocket exhausts its fuel. After a while, the seat reaches its maximum height. The seat is then detached from the dummy and a parachute carried by the dummy is opened. The dummy eventually reaches the ground.

Figure 23 shows the velocity-time graph of the dummy during the ejection process. Assume that the motion of the dummy is vertical throughout the process, and the effect of air resistance is negligible before the parachute is opened.

(a) In Figure 23, label the point on the graph which corresponds to the instant when the dummy reaches the maximum height. (Note: Use $P$ to denote the point.)  

(b) Find the maximum height above the ground reached by the dummy.  

(c) The mass of the dummy is 80 kg. Find the force exerted by the ejection seat on the dummy in Phase 1.  

(d) By considering the forces acting on the dummy, explain the following motion of the dummy in Phase 2:  

After the parachute has been opened, the dummy accelerates downwards at first and then falls with a uniform velocity (see Figure 23).  

It is known that the force exerted by the parachute on the dummy increases with its speed.