1. 1990/I/4

Figure 5 shows the cooling curves of a substance changing from liquid to solid state.
(a) Given a boiling tube half filled with this substance in its solid state, describe, with the help of a diagram, and experiment to obtain the cooling curve of the substance. (5 marks)
(b) Read from the above cooling curve the melting point of the substance. (1 mark)
(c) Explain why the temperature remains constant as the substance solidifies at its melting point, even though heat is lost to the surroundings. (2 marks)
(d) If the mass of substance used is 0.05 kg and the rate of heat loss to the surroundings at its melting point is 25 W, find the specific latent heat of fusion of the substance. (3 marks)
(e) Describe the arrangement and motion of the molecules of the substance in the
   (i) solid state, and
   (ii) liquid state. (4 marks)

2. 1992/I/4

A student uses the experimental set-up shown in Figure 6 to find the specific heat capacity of a metal. The cylindrical metal block is heated by an immersion heater of unknown power. The following results are obtained:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of metal block</td>
<td>1 kg</td>
</tr>
<tr>
<td>Initial temperature of metal block</td>
<td>29°C</td>
</tr>
<tr>
<td>Final temperature of metal block</td>
<td>41°C</td>
</tr>
<tr>
<td>Energy supplied by the heater</td>
<td>12300 J</td>
</tr>
</tbody>
</table>

(a) Describe, with the help of a diagram, a method to measure the energy supplied by the heater. (4 marks)
(b) Calculate the specific heat capacity of the metal. (2 marks)

(c) The value obtained in (b) is found to be higher than the actual specific heat capacity of the metal. Suggest a reason for this and explain your answer briefly. (3 marks)

(d) Suggest TWO improvements on the set-up to increase the accuracy of the experiment. (3 marks)

(e) Is the above method suitable for finding the specific heat capacity of wood? Explain briefly. (3 marks)

3. 1993/I/4

A student performs an experiment to find the specific latent heat of vaporization of water. A beaker containing water is placed on an electronic balance. The water is heated by a 100 W immersion heater, which is immersed in the water such that it does not touch the beaker, as shown in Figure 5.

(a) It is found that there is a slight decrease in the mass of water in the beaker before the water boils. Explain briefly in terms of molecular motion. (3 marks)

(b) When the water boils, the reading of the balance is taken. After 240 s, the reading of the balance is taken again. The following results are obtained:

- Initial reading of the balance = 525.4 g
- Final reading of the balance = 515.2 g

Calculate (i) the energy supplied by the heater in 240 s,
(ii) the specific latent heat of vaporization of water. (4 marks)

(c) The value obtained in (b) (ii) is found to be higher than the actual specific latent heat of vaporization of water. Suggest a reason for this and explain briefly. (3 marks)

(d) If the student covers the beaker with a lid, how would the result of the experiment be affected? Explain briefly. (3 marks)

(e) Suggest TWO improvements on the set-up to increase the accuracy of the experiment. (2 marks)
4. 1997/I/4

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. (3 marks)

(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. (3 marks)

(c) Why should the ice used in the experiment be crushed? (2 marks)

(d) 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. (5 marks)
   *(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. (2 marks)

5. 1999/I/2

0.1 kg of melting ice is added to 0.5 kg of water at 30 °C in a foam cup. Find the final temperature of the mixture.

(Given: Specific heat capacity of water = 4200 J kg\(^{-1}\) K\(^{-1}\), Specific latent heat of fusion of ice = 3.4 x 105 J kg\(^{-1}\).) (4 marks)
6. 2000/I/8

An electric heater has two settings: ‘Low’ and ‘High’. The power output of the heater is 1400 W at the ‘Low’ setting and 2200 W at the ‘High’ setting. The heater is used to cook an egg. The egg is first put into a pot containing 1 kg of water and the heater is operated at the ‘High’ setting. (See Figure 9.) The temperature of the water is recorded every 30 s and the following results are obtained:

<table>
<thead>
<tr>
<th>Time t/s</th>
<th>0</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
<th>150</th>
<th>180</th>
<th>210</th>
<th>240</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature θ°C</td>
<td>27</td>
<td>32</td>
<td>44</td>
<td>57</td>
<td>69</td>
<td>81</td>
<td>92</td>
<td>98</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2

(a) Using a scale of 1 cm to 5°C and 1 cm to 15 s, plot a graph of θ against t on graph paper. (4 marks)

(b) (i) Find the energy supplied by the heater from $t = 0$ to $t = 240$ s. (2 marks)

(ii) Find the energy absorbed by the water from $t = 0$ to $t = 240$ s.

(Note: Specific heat capacity of water = 4200 J kg$^{-1}$ K$^{-1}$.) (2 marks)

(iii) State two reasons to account for the difference between your answers in (i) and (ii). (2 marks)

7. 2001/I/6c

Explain the following phenomena:

(c) Steam at 100°C causes more severe burns to human skin than boiling water. (2 marks)

8. 2001/I/9a

Mary wants to estimate the efficiency of an electric water heater in her kitchen. She uses a container to collect the water and a thermometer to measure the temperature (see Figure 9). She finds that when the heater is switched on, 1.6 kg of water at 23°C is heated to 67°C in one minute. The rating of the heater is ‘220 V, 6000 W’ and the specific heat capacity of water is 4200 J kg$^{-1}$ K$^{-1}$.

(i) Find the energy absorbed by the 1.6 kg of water in one minute. (2 marks)
(ii) Estimate the efficiency of the heater. (3 marks)

(iii) State one reason to explain why the efficiency found in (ii) is less than 100%. (1 mark)

9. 2002/I/9

Yunnan Guoqiao-mixian (雲南過橋米線) is a famous Chinese food. In preparing the food, the first step is to cook a pot of chicken soup: A pot of water containing chickens is heated over a high flame until it boils. A low flame is then used to keep the soup boiling for 3 hours.

(a) Explain why the temperature of the boiling soup remains unchanged, even though it is being heated. (2 marks)

(b) (i) The power output of the low flame is 300 W. If 70% of the energy supplied is lost to the surroundings, calculate the mass of soup that would be vaporized after being heated for 3 hours. Assume the specific latent heat of vaporization of the soup is $2.26 \times 10^6$ J kg$^{-1}$. (3 marks)

(ii) Explain why it is undesirable to use a high flame to keep the soup boiling. (1 mark)

(c) Customers ordering the food are served with the following:

- a bowl of hot soup with a layer of oil on the surface,
- a dish of thin slices of raw meat,
- a bowl of pre-cooked mixian (noodles) (see Figure 14).

10. 2004/I/8

Figure 12 shows an microwave oven. Mary wants to conduct an experiment to estimate the useful output power of the oven. She is provided with the apparatus and material shown in Figure 13.
(a) Describe how Mary should conduct the experiment. Specify all measurements Mary has to take and write down an equation for calculating the useful output power. (5 marks)

(b) The value obtained by Mary is found to be smaller than the rated power of the oven. Suggest one possible reason to account for this difference. (1 mark)

(c) Mary suggests that the following measures would improve the accuracy of the experiment:
   1. Replacing the beaker with a container with a smaller heat capacity.
   2. Increasing the mass of water used in the experiment.

Explain whether each of the above measures would work. (3 marks)

(d) Mary uses the oven to defrost a piece of meat of mass 0.2 kg. The meat is taken from a freezer, the temperature of which is maintained at –20°C. Assume that 70% of the mass of the meat is made up of water.

Given:
- specific heat capacity of the frozen meat = 1700 J kg\(^{-1}\) °C\(^{-1}\).
- specific latent heat of fusion of ice = 3.34 \times 10^5 J kg\(^{-1}\).

(i) Find
   (1) the energy required to raise the temperature of the meat from –20°C to 0°C, and
   (2) the energy required to change the ice in the meat at 0°C to water. (4 marks)

(ii) Sketch a graph to show the variation of the temperature of the meat with time during the defrosting process. (2 marks)
11. 2005/I/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.

(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)

12. 2006/I/6a-bi

Figure 12 shows the energy label of a water heater from which some information is listed in Table 2.
Given: mass of 1 litre of water = 1 kg,
   specific heat capacity of water = \(4200 \text{ J kg}^{-1} \text{ C}^{-1}\).

(a) The heating element of a water heater is usually installed on the lower position of the water tank. Suggest one reason for this design. (1 mark)
(b) Using the information in Table 2,
   (i) estimate the energy required to heat a full tank of water from 15°C to 65°C. (2 marks)

13. 2006/I/10
Dehumidifiers (see Figure 20) are used to lower the humidity of air. Wet air flows into Part A of the dehumidifier and dry air flows out from Part B of the dehumidifier as shown in Figure 21. A liquid called the refrigerant circulates through the coiled tube. The refrigerant absorbs heat from the wet air and evaporates inside the coiled tube in Part A. The vapour of the refrigerant is then pumped to the coiled tube in Part B where it is compressed and condenses into a liquid. The liquid refrigerant then passes back to the coiled tube in Part A and the process is repeated.

(a) In terms of molecular motion, explain why the temperature of the refrigerant drops when it evaporates inside the coiled tube in Part A. (2 marks)
(b) Explain why the coiled tube in Part A is designed in a coiled shape. (2 marks)
(c) In the coiled tube in Part B, the vapour of the refrigerant is compressed and condenses into liquid. State the change of the average potential energy of the refrigerant molecules during this process of changing state. (1 mark)
(d) When the dehumidifier is in operation, the coiled tube in Part B gives out heat. State and explain two designs that could prevent the dehumidifier from overheating. (2 marks)
(e) The dehumidifier is turned on for a few hours in a closed room. Water vapour in the incoming wet air condenses and 1.5 kg of water is collected in the water tank (see Figure 21).
   (i) Estimate the total energy released by the water vapour. The specific latent heat of vaporization of water is $2.26 \times 10^6$ J kg$^{-1}$. (2 marks)
   (ii) Using the data and the formula in Table 5, estimate the increase in temperature of the air in the room, assuming that all the energy released in Part B is used to raise the temperature of the air inside the room. (3 marks)

| Volume of the air in the room = 400 m$^3$ |
| Density of the air = 1.3 kg m$^{-3}$ |
| Specific heat capacity of the air = 1030 J kg$^{-1}$ oC$^{-1}$ |
| Mass = density x volume |

Table 5
14. 2007/I/3

Read the following passage about thermal flasks and answer the questions that follow.

**Working principles of thermal flasks**

Thermal flasks are used to store hot liquids and can keep them warm for a period of time. Insulating by foam and insulating by vacuum are two common ways of making thermal flasks.

For a thermal flask applying insulation by foam, a layer of foam is used to wrap the container (see Figure 4). Both the foam and the air trapped inside the foam are poor conductors of heat. Also, the air inside the foam is broken into many tiny bubbles, which reduce convection of air inside the foam. Heat transfer through foam is therefore pretty slow.

For a thermal flask applying insulation by vacuum, there is a vacuum between the double glass walls of the container (see Figure 5). The heat insulation of vacuum is better than that of foam. Furthermore, the inner surface of walls of the glass container is painted silvery to reduce heat transfer. As glass is fragile, the glass container is protected by an outer case with an insulated support.

(a) Explain how the foam reduces heat transfer by conduction and convection.  
(b) Explain why the heat insulation of vacuum between the double glass walls is better than that of foam. 
(c) State ONE design in the vacuum flask shown in Figure 5 that helps to reduce heat loss by radiation. 
(d) Can a thermal flask also store cold liquids and keep them cold for a period of time? Explain your answer.
Karen puts 0.12 kg of water at room temperature $T_1$ into the freezer of a refrigerator to make ice cubes. The cooling curve of the water is shown in Figure 6.

Given: specific latent heat of fusion of ice $= 3.34 \times 10^5$ J kg$^{-1}$

(a) State the physical meaning of temperature $T_2$.  
(b) Find the latent heat released in the above process. 
(c) If an ice cube from the freezer is placed at room temperature $T_1$, sketch a graph to show the expected change in temperature of the ice cube in Figure 7.
A student performs an experiment with the setup in Figure 5 to measure the specific heat capacity of a liquid X. The joulemeter in the figure is used to measure the energy consumed by the immersion heater.

The increase in the reading of the joulemeter (E) for an increase of temperature of 10°C for different mass (m) of liquid X is recorded in Table 1.

<table>
<thead>
<tr>
<th>E / kJ</th>
<th>1.6</th>
<th>2.9</th>
<th>4.1</th>
<th>5.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>m / kg</td>
<td>0.05</td>
<td>0.10</td>
<td>0.15</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Table 1

(a) State the importance of using a "well insulated" container in the experiment. (1 mark)

(b) (i) Plot a graph of E against m in Figure 6. A scale of 1 cm to 0.5 kJ and 0.025 kg is used. (4 marks)
(ii) Using the graph plotted in (b)(i), find the specific heat capacity of liquid X. (3 marks)

(iii) Estimate the heat absorbed by the apparatus. (1 mark)

(iv) If the experiment is repeated with liquid Y with a smaller specific heat capacity than liquid X and the increase in temperature is also 10°C, sketch a graph of $E$ against $m$ you would expect to obtain in Figure 6, and label it as $L$. (2 marks)
1. 1990/I/1

Figure 1 shows a trolley of length 0.25 m resting on a horizontal runway. An elastic string of unscratched length 0.15 m is tied to the trolley. The trolley is pulled along the runway by stretching the elastic string. By keeping the length of the stretched string equal to the length of the trolley, a constant force $f_1 \text{N}$ is applied to pull the trolley.

(a) The force-extension characteristic of the elastic string is shown in Figure 2. What is the value of $f_1$?

(b) Describe a method to determine the acceleration of the trolley along the runway.

(c) The same experiment is repeated in turn with two, three and four identical strings in parallel. The following results are obtained:

<table>
<thead>
<tr>
<th>Number of elastic strings</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force on trolley $F/N$</td>
<td>$f_1$</td>
<td>$f_2$</td>
<td>$f_3$</td>
<td>$f_4$</td>
</tr>
<tr>
<td>Acceleration $a/\text{ms}^2$</td>
<td>0.15</td>
<td>0.75</td>
<td>1.35</td>
<td>1.95</td>
</tr>
</tbody>
</table>

(i) Find the values of $f_2$, $f_3$ and $f_4$.

(ii) Using a scale that 4 cm represents 0.5 N and 4 cm represents 0.5 ms$^{-2}$, plot a graph of $F$ against $a$.

(iii) Find the equation relating $F$ and $a$ from the graph in (ii).

(iv) Comment on the physical meaning of $f_0$, the intercept on the $F$ axis, when $a$ equals zero.
2. 1990/I/2

Figure 3 shows part of the route of a roller-coaster in an amusement park. A cart full of passengers with total mass 1200 kg runs down from rest at the starting point $H$ to the terminal platform. $H$ is 30 m above the terminal platform. The track provides an average frictional force of 300 N throughout the journey.

(a) The cart travels a distance of 150 m to reach the highest point $A$ of the vertical loop, which is 20 m above the terminal platform.

(i) In moving from $H$ to $A$, calculate

1. the loss in potential energy,
2. the work done against friction, and
3. the gain in kinetic energy of the cart.

(ii) Find the speed of the cart at $A$. (7 marks)

(b) The cart reaches the terminal platform at a speed of 10 ms$^{-1}$. A braking device at the platform stops the cart in 2 seconds. Find the average force on the cart exerted by the device. (3 marks)

(c) Suggest one safety device for passengers riding on the roller-coaster and briefly explain its function. (2 marks)

(d) In the design of the roller-coaster do you think the summit $B$ can be higher than point $A$? Explain briefly. (3 marks)

3. 1991/I/2

Figure 3 shows a simplified lift system. The lift consists of a car connected to a counterweight over a drum. The weights of the car and the counterweight are 6500 N and 6000 N respectively. A motor connected to the
A car is traveling at a uniform speed of 10 m s\(^{-1}\). The driver sees a warning signal and applies the brakes to bring the car to rest with uniform deceleration. Figure 1 shows the speed-time graph of the car, starting from the instant the driver first sees the signal.

(a) Write down the reaction time of the driver, i.e. the time lapse between seeing the signal and starting to apply the brakes. (1 mark)

(b) Find the area under the graph in Figure 1. State its physical meaning. (4 marks)

(c) If there is an obstacle 20 m ahead when the driver first sees the signal, would the car hit the obstacle? Explain your answer. (2 marks)

(d) Assume that the reaction time of the driver and the deceleration of the car remain unchanged.

(i) In Figure 1, draw a speed-time graph for the car if it is initially traveling at 20 m s\(^{-1}\). (2 marks)

(ii) A student says ‘if the initial speed of the car is doubled, the stopping distance of the car would be doubled. ‘ State whether his statement is true or false and explain briefly. (6 marks)

(e) Suggest TWO factors that would affect the deceleration of a car. (2 marks)
5. 1992/I/2

(a) Figure 2 shows an inclined plane of length 5 m. A block of weight 800 N is pushed up the plane slowly from the ground to a height of 2 m by a force parallel to the inclined plane. The frictional force between the block and the inclined plane is 80 N.

(i) Find the potential energy gained by the block.
(ii) Find the work done against friction.
(iii) Find total energy supplied by the force; assume that there is no energy loss other than that in (ii)
(iv) Find the efficiency of the inclined plane.

(b) The process in (a) is repeated by using a longer inclined plane. (See Figure 3.) Assume that the frictional force between the block and the inclined plane remains unchanged. How would the efficiency of the inclined plane be affected? Explain your answer briefly

(c) A student says that the force required to push the block in (b) is smaller than that in (a). State whether he is right or wrong and explain briefly.

6. 1993/I/1

A helicopter of mass 1500 kg is initially at rest at a certain level above the ground. It accelerates uniformly and vertically upwards for 75 m and reaches a speed 15 m s$^{-1}$. Assume the air resistance is negligible.

(a) Calculate

(i) The acceleration of the helicopter,
(ii) The uplifting force acting on the helicopter.

(b) At this moment, an object is released from the helicopter. The object reaches the ground after 6 s. Figure 1 shows the velocity-time graph of the object; starting from the instant the object is released.

(i) Write down the velocity of the object when it reaches the ground.
(ii) State the physical meaning of the velocity of the object when it reaches the ground.
(iii) Using Figure 1, or otherwise, find the height of the object above the ground when it is released.
(iv) Comment on the following two statements:

Statement 1: At time \( t = 1.5 \) s, the acceleration of the object is zero.

Statement 2: If the object is replaced by a heavier one, it would take the same time to reach the ground.  

(10 marks)

7. 1993/I/2

Figure 2 shows a horizontal runway \( ABC \) consisting of two parts, a smooth portion \( AB \) and a rough portion \( BC \). A block \( P \) of mass 0.8 kg undergoes the following motion;

Step (1): \( P \) is pressed against a spring at \( A \) and then released. After \( 0.05 \) s, \( P \) loses contact with the spring and moves with a speed \( 1.8 \) m s\(^{-1} \).

Step (2): When \( P \) moves along \( AB \), a lump of plasticine is dropped from a height slightly above \( P \) and sticks to it. The speed of \( P \) is reduced to \( 1.6 \) m s\(^{-1} \).

Step (3): \( P \) enters the rough portion and stops at point \( D \).
(a) Calculate
   (i) The average force acting on the block by the spring in step (1),
   (ii) The mass of the plasticine,
   (iii) The distance \( BD \), given that the frictional force between \( P \) and the rough portion is 3 N.

(b) Describe the energy change in Step (1).

(c) Is kinetic energy conserved in Step (2)? Explain briefly.

(d)

The above process is repeated with the rough portion \( BC \) inclined at angle 15° to the horizontal. (See Figure 3). If the frictional force is still 3 N, what happens to \( P \) after it reaches the highest point? Explain your answer.

8. 1994/I/1

A block is placed on a rough plane inclined at an angle \( \theta \) to the horizontal. A force \( P \) parallel to the inclined plane is applied to the block so that it moves up the plane at a constant speed. (See Figure 1)

(a) Draw a diagram to show all the forces acting on the block. Label the forces.

(b) Describe briefly a method to check whether the speed of the block remains constant.

(c) A student performs an experiment to find the relationship between \( P \) and \( \theta \). Different values of \( \theta \) are used and the corresponding values of \( P \) are measured. The results are plotted is a graph \( P \) against \( \sin \theta \) as shown in Figure 2. Assume that the frictional force between the block and the inclined plane remain unchanged.
   (i) Find the intercept of the graph on the P-axis and the slope of the graph. Hence write down the equation relating \( P \) and \( \sin \theta \).
   (ii) State the physical meanings of the intercept and the slope found in (i).

(d) The following are two methods of raising the block from the ground to a certain height:
   Method (1): Pulling the block up the inclined plane as shown in Figure 1.
   Method (2): Lifting the block vertically upwards.
(i) What is the advantage of method (1) over method (2)?
(ii) Which method has a lower efficiency? Explain briefly. (4 marks)

9. 1994/I/2

A bob $P$ of mass 0.4 kg moves on a smooth horizontal ground with speed $3 \text{ m s}^{-1}$. A bob $Q$ of mass 0.6 kg is suspended by a light inextensible string as shown in Figure 3 and is initially at rest. After colliding with $Q$, $P$ comes to a rest.

(a) Find

(i) The momentum of $P$ before the collision,
(ii) The speed of $Q$ immediately after the collision,
(iii) The average force acting on $P$ during the collision, assuming that the time of contact is 0.05 s. (5 marks)

(b) Is the collision elastic? Show your calculation. (3 marks)
(c) After the collision, bob $Q$ swings upwards.
   (i) Find the maximum height reached by $Q$.
   (ii) The string exerts a tension on $Q$. Is there any work done by the tension when $Q$ swings upwards? Explain briefly. (5 marks)

(d)

In another experiment, bob $P$ moves towards and sticks to a lump of plasticine, which is fixed to the ground. In this collision, the total momentum of $P$ and the plasticine is not conserved. Explain briefly. (2 marks)

10. 1995/I/1

Figure 1 shows a rough track. The highest point $C$ of the circular loop is 0.5 m above its lowest point $D$ and $DE$ is horizontal. A small object of mass 0.1 kg slides down from rest at $A$, completes the circular loop and finally stops at $E$. The speed of the object at $C$ is $3 \text{ m s}^{-1}$. When it comes down to $D$ after completing the loop, its speed becomes $4 \text{ m s}^{-1}$.

*(a) Describe the energy changes when the object travels from $A$ to $C$. (4 marks)

(b) Find
   (i) The kinetic energy of the object at $C$, (1 mark)
   (ii) The potential energy of the object at $C$ (taking the potential energy at $D$ as zero), (1 mark)
   (iii) The work done against friction as the object travels from $C$ to $D$. (3 marks)

(c) The object travels with uniform deceleration along $DE$.
   (i) Sketch the displacement-time graph of the object as it travels from $D$ to $E$, starting from the moment it passes through $D$. (2 marks)
   (ii)
Figure 2 shows a strobe photograph of the object as it travels along DE. The stroboscopic lamp is flashing at a frequency of 5 Hz. Find the deceleration of the object. (4 marks)

11. 1995/I/2

(a)

A metal ball P of mass 0.5 kg moves with speed 10 m s\(^{-1}\) on smooth horizontal ground. It collides with a heavier metal ball Q, which is initially at rest. After collision, P moves backwards in the opposite direction. Figure 4 shows the variation of the velocity of P with time.

(i) Find

1. The momentum of P before the collision.
2. The change in momentum of P in the collision.
3. The time of contact of P and Q.
4. The average force acting on P during the collision. (6 marks)

(ii) Is the average force acting on Q during the collision equal to that acting on P? Explain briefly. (2 marks)

* (iii) Comment on the following statement:

Momentum and kinetic energy must be conserved in this collision. (5 marks)

(b) For safety reasons, the front and rear parts of cars should not be made of very strong material. Explain briefly. (2 marks)
12. 1996/I/2
Susan takes part in a 100 m race at an athletic meet. She starts at time $t = 0$ and accelerates at a uniform rate of $1.6 \text{ m s}^{-2}$ for 5 s. She then maintains a uniform speed afterwards and reaches the finishing line at $t = 1.5$ s.

(a) Find
   (i) The speed of Susan at $t = 5$ s,
   (ii) Susan’s average speed for the whole journey. (3 marks)

(b) On graph paper, draw the graph of Susan’s speed against time from $t = 0$ to 15 s. State the physical meaning of the area under the graph. (5 marks)

(c) Susan’s mass is 45 kg. Find the resultant force acting on Susan in the race
   (i) During the first 5 s;
   (ii) After $t = 5$ s. (3 marks)

(d) Mary also takes part in the same race. She first accelerates at a uniform rate of $1.5 \text{ m s}^{-2}$ for 6 s and then maintains a uniform speed afterward. Explain whether Susan or Mary will reach the finishing line first. (4 marks)

13. 1996/I/3
Two metal balls $P$ and $Q$ are suspended by light inextensible strings. Ball $P$ is pulled to a point $A$ which is at a height $h$ above its initial position $B$ and is then released. (See Figure 4.) After colliding at $B$, the two balls move away in opposite directions. (See Figure 5)

(a) Draw a diagram to show all the forces acting on $P$ when it swings from $A$ to $B$. Label the forces. (2 marks)

*(b) Describe the energy changes in the balls, from the moment $P$ is released until the balls swing up to their maximum heights after the collision. (4 marks)

(c) The mass of $P$ is 0.3 kg and its speeds immediately before and after the collision is found to be 1.0 m s$^{-1}$ and 0.5 m s$^{-1}$ respectively.
   (i) Find $h$.
   (ii) Find the average force acting on $P$ during the collision, assuming that the time of contact is 0.02 s. (2 marks)
   (iii) Consider the following set of data:
<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass / kg</td>
<td>0.3</td>
<td>0.75</td>
</tr>
<tr>
<td>Velocity before collision / m s(^{-1})</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>(towards the right)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity after collision / m s(^{-1})</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>(towards the left)</td>
<td>(towards the right)</td>
<td></td>
</tr>
</tbody>
</table>

(1) Show that the above set of data obeys the law of conservation of momentum.

(2) Explain why the above set of data is impossible. (5 marks)

14. 1997/I/1

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 traveled 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)
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)

16. 1998/I/1

Figure 1 shows the layout of a runway $ABC$ in an amusement park. $AB$ is an icy smooth inclined plane and $BC$ is a rough horizontal surface. At time $t = 0$, a boy sitting on a sledge slides down from rest at $A$ along the runway. At $t = 5$ s, the sledge reaches $B$ with a speed of $8$ m$^{-1}$. The sledge then decelerates uniformly along $BC$ and finally stops at point $D$ at $t = 15$ s.

(a) Sketch the graph of the speed of the sledge against time from $t = 0$ to 15 s. (3 marks)

(b) Consider the sledge and the boy as one body. Draw a labeled diagram to show all the forces acting on the body as it slides along $AB$. (2 marks)

(c) Find
(i) the acceleration of the sledge as it slides along $AB$;
(ii) The stopping distance $BD$;
(iii) The frictional force acting on the sledge as the sledge travels along $BC$. (Given: Total mass of the sledge and the boy = 60 kg.) (6 marks)

*d* Suppose the angle of inclination of the smooth plane is increased. (See Figure 2.) Then the boy sitting on the sledge slides down from rest at a point $P$ on this runway, where $P$ is at the same height as point $A$ in the original runway. Would there be any change in the stopping distance along $BC$ when compared with (c) (ii)? Explain your answer. (4 marks)
17. 1998/I/2

Figure 3 shows a cannon of mass 1000 kg. It fires a metal ball of mass 10 kg in order to destroy a fixed target. Assume the ball travels with a constant horizontal speed of 100 m s\(^{-1}\) towards the target.

(a) Suppose that the minimum energy required to destroy the target is 60 000 J. Explain whether the ball will destroy the target. (2 marks)

(b) The cannon recoils as the ball is fired.
   (i) Find the recoil speed of the cannon. (2 marks)
   (ii)

To stop the cannon, a smooth plane inclined at 15° to the horizontal is placed behind the cannon. (See Figure 4.) How far will the cannon move up along the inclined plane? (3 marks)

(c) Suppose that in firing the ball, 80 000 J of energy is lost as heat, light and sound. Find the efficiency of the cannon in firing the ball. (3 marks)

(d) The ball hits the target and becomes embedded in it.
   (i) If the ball takes 0.05 s to come to a rest inside the target, find the average force exerted by the target on the ball. (2 marks)
   (ii) A student thinks that as the ball and the target are both at rest after impact, momentum has been lost. He asks why the law of conservation of momentum does not apply in this process. If you were a teacher, how could you answer this question? (3 marks)

18. 1999/I/3

A toy car of mass 0.2 kg is moving at a speed 3 m s\(^{-1}\) on a smooth horizontal runway. When the car passes through a point A on the runway, a lump of plasticine of mass 0.1 kg is dropped from a height slightly above it and sticks to it.

(a) Find the speed of the car after the plasticine sticks to it. (2 marks)

(b) The runway is curved upwards to a height 0.25 m at point P as shown in Figure 3. Can the car pass point P? Show your calculations. (3 marks)
A lorry, with a heavy metal framework placed on top, is traveling at a uniform speed of 16 m s\(^{-1}\) along a straight road. (See Figure 6.) At time \(t = 0\), the driver observes that a traffic light, which is at a distance of 42 m from the lorry, is turning red. The driver applies the brake at \(t = 0.5\) s. The lorry then decelerates uniformly and comes to a rest at \(t = 4.5\) s.

(a) Sketch the speed-time graph of the lorry from \(t = 0\) to \(t = 4.5\) s.       (3 marks)
(b) Find the deceleration of the lorry form \(t = 0.5\) to \(t = 4.5\) s.        (1 mark)
(c) Explain whether the lorry will stop in front of the traffic light.       (3 marks)
(d) The driver is charged by a policeman for not fastening the framework on the lorry. State two daily situations in which the framework will slip from the moving lorry.    (2 marks)

Figure 7 shows the forces acting on the metal framework when the lorry is decelerating. The mass of the framework is 1000 kg.

(i) Name the forces \(F_1\) and \(F_2\).             (2 marks)
(ii) Explain whether \(F_1\) and \(F_2\) are pair of action and reaction according to Newton’s third law motion.                 (2 marks)
(iii) Find the magnitude of the friction if the framework decelerates at the same rate as the lorry. (2 marks)
(iv) The driver is charged by a policeman for not fastening the framework on the lorry. State two daily situations in which the framework will slip from the moving lorry.    (2 marks)
Figure 3 shows a water chute in a swimming pool. A boy of mass 50 kg slides down from rest at point A and reaches point B with speed 12 m s⁻¹, where A is 10 m above B.

(a) Find
   (i) the potential energy of the boy at A (taking the potential energy at B as zero),
   (ii) the kinetic energy of the boy at B. (2 marks)
(b) Describe the energy change as the boy slides from A to B. (2 marks)

21. 2000/I/4

A car of mass 1000 kg moves along a straight road with a speed 10 m s⁻¹. It collides with a lorry of mass 3000 kg, which is initially at rest. Immediately after the collision, the lorry moves forward with a speed 4.5 m s⁻¹. The time of contact of the car and the lorry is 0.5 s. Find
(a) the speed of the car immediately after the collision,
(b) the average force acting on the lorry during the collision,
(c) the average force acting on the car during the collision. (5 marks)

22. 2000/I/7

(a) Susan uses the following method to examine John’s reaction time:

She holds a graduated ruler upright with the zero mark starting at the bottom. John lines up his fingers near the bottom of the ruler. (See Figure 6.) Without any warning, Susan releases the ruler and John grips the ruler with his finger as fast as possible. It is found that John grips at the 20 cm mark of the ruler. (See Figure 7.)

(i) Show that John's reaction time is 0.2 s. (2 marks)
(ii) If a heavier ruler is used, how would the result of the above test be affected? Explain your answer. (2 marks)
(iii) Susan marks the other side of the ruler as shown in Figure 8 so that the reaction time can be read directly.
Explain whether Susan’s scale for the reaction time is correct or not. (3 marks)

(b) John is riding a bicycle along a straight road with uniform speed 10 m s\(^{-1}\). At time \(t = 0\), he sees a warning signal. John applies the brake for 2 s to bring the bicycle to rest with uniform deceleration. Assume John’s reaction time (i.e. the time lapse between seeing the signal and starting to apply the brake) is 0.2 s.

(i) Find the distance travelled by the bicycle from \(t = 0\) to \(t = 0.2\) s. (2 marks)

(ii) Find the distance travelled by the bicycle when it is decelerating. (2 marks)

*(iii) Using Newton’s laws of motion, explain why it is dangerous for John to carry an excessive amount of goods on the bicycle when he is riding in the street. (4 marks)

23. 2001/I/1

A lump of plasticine of mass 0.2 kg is hanging freely in air from a string (see Figure 1). A bullet of mass 0.01 kg is fired from an air gun. It hits the plasticine and becomes embedded in it. The plasticine then swings to a maximum height of 0.06 m above its initial position.

(a) Find the speed of the plasticine immediately after the bullet is embedded in it. (2 marks)

(b) Hong Kong Ordinance states that the kinetic energy of bullets fired from air guns should not exceed 2 J. By considering the speed of the bullet before it hits the plasticine, explain why the above gun violates the Ordinance. (3 marks)
Figure 7 shows a horizontal straight highway with a speed limit of 100 km h\(^{-1}\) (i.e. 27.8 m s\(^{-1}\)). For safety reasons, drivers are advised to maintain a safety distance of 80 m from the cars ahead. Large arrows (chevrons) are painted on the highway (each at 80 m apart) and road signs are set up to remind drivers of this safety distance (see Figures 7 and 8).

(a) Find the time taken by a car to drive from one arrow to another when it is travelling at 100 km h\(^{-1}\). 

(b) A car is travelling at 100 km h\(^{-1}\) on the highway. At time \(t = 0\), the driver observes that an accident has happened and a lorry stops 80 m ahead. He applies the brakes to stop the car with uniform deceleration. The reaction time of the driver is 0.8 s and the decelerating time of the car is 4 s.

(i) Sketch the speed-time graph of the car. 
(ii) Explain whether the car will hit the lorry. 
(iii) The total mass of the car and the driver is 1200 kg. Find the average braking force on the car. 

*(c) Suppose the highway in Figure 7 is on a slope with traffic running downhill. Do you think the distance between two arrows should be greater than, equal to or less than 80 m? By considering the forces acting on a car, or otherwise, explain your answer. Assume that the speed limit of the highway and the braking force acting on the car remain unchanged.

25. 2002/I/8

A car is travelling with a speed \(u\) on a road. The stopping distance of the car includes two parts:

1. the thinking distance \(l\) (i.e. the distance travelled after the driver has seen a danger and before the brakes are on).
2. the braking distance \(s\) (i.e. the distance travelled after the brakes have been put on).

Figure 12 shows the variations between \(l\) and \(s\) with \(u\).
(a) Find the slope of the straight line in Figure 12 and state its physical meaning. (3 marks)

(b) Assume that the deceleration $a$ of the car remains unchanged at different speeds. Write down an equation relating $u$, $s$ and $a$. Using Figure 12, find the value of $a$. (3 marks)

(c) A boy was hit by the car when he was crossing a zebra-crossing. Figure 13 shows a sketch of the accident drawn by the police. Let $d$ be the distance between the car and the boy at the moment the driver first observed the boy. The driver applied the brakes and a skid mark 36.0 m long was left on the road. After hitting the boy, the car travelled a distance of 19.7 m before coming to rest. You may neglect the change in speed of the car during the impact.

(i) Write down the braking distance of the car. (1 mark)

(ii) Using Figure 12, estimate the value of $u$. (1 mark)

(iii) Estimate the thinking distance and the value of $d$. (3 marks)

*(iv) The speed limit of the road is 50 km h$^{-1}$ (i.e. 13.9 m s$^{-1}$). If the car is travelling at this speed, explain whether it would hit the boy. (4 marks)
26. 2003/I/3
A squash ball of mass 0.024 kg travelling with a horizontal speed of 16 m s\(^{-1}\) is hit by a racket. After the impact, the ball travels with a speed of 20 m s\(^{-1}\) in opposite direction. Assume the time of contact between the ball and the racket is 0.15 s.

(a) Find the increase in kinetic energy of the ball. (2 marks)
(b) Find the average force acting on the ball by the racket during the impact. (3 marks)

27. 2003/I/11
In 4 July, 1997, the lander ‘Mars Pathfinder’ landed on the surface of Mars. A teacher presents the following simplified information about the last two stages of the landing process (see Figure 12).

Stage 1: When the spacecraft (including the lander embedded in some airbags, a parachute and decelerating rockets) was at a height of 80 m above Mars’ surface, it was falling with a speed 75 m s\(^{-1}\). At this instant, the rockets were fired. The parachute and rockets exerted a total upward force of 16900 N on the lander and brought it to instantaneous rest at a height of 15 m above the surface.

Stage 2: At the instant when the lander was 15 m above the surface, the parachute and rockets were separated from it. The lander then fell from rest to the surface under the action of the gravity of Mars.

You may assume that the lander descended vertically and the resistance exerted by the atmosphere on the lander was negligible.

(a) Consider Stage 1 and answer the following:
   (i) By using formula \(v^2 = u^2 + 2as\), find deceleration of the lander (2 marks)
   (ii) Draw a labeled diagram to show all the forces acting on lander. (2 marks)
   (iii) The Mass of the lander was 360 kg. Estimate the acceleration due to gravity on Mars’ surface. (3 marks)
(b) Consider Stage 2 and answer the following:

(i) Find the time required for the lander to reach the surface. 
    (2 marks)

(ii) Explain how the airbags helped the lander to land on the surface safely.  
    (2 marks)

(iii) The lander bounced a few times on the surface before coming to rest. A student draws a sketch of the velocity-time graph of the lander, with t=0 denoting the instant when the lander was 15 m above the surface (see Figure 13). Assume that the motion took place in a vertical direction.

![Figure 13](image)

Explain whether the sketch is correct or not. If it is incorrect, draw a correct sketch for the graph.  
(4 marks)

28. 2004/I/2

Figure 3 shows a water rocket. The rocket is filled with water and compressed air. Explain why the rocket rises when the trigger is pulled and name the law or principle involved.  
(4 marks)

29. 2004/I/7

In a road test, John drives his car along a straight horizontal road (see Figure 9). The car takes 9.3 s to accelerate from rest to 100 km h\(^{-1}\). The total mass of John and his car is 1400 kg.

(a) Show that a speed of 100 km h\(^{-1}\) is approximately equal to 27.8 m s\(^{-1}\).  
   (1 mark)

(b) Find the total kinetic energy of John and his car when traveling at 100 km h\(^{-1}\).  
    Hence estimate the average output power of the car when it is accelerating to 100 km h\(^{-1}\).  
    (3 marks)
A similar road test is conducted on an inclined road. The car now takes 16.2 s to accelerate from rest to 100 km h\(^{-1}\) along the road (see Figure 10). Assume the output power of the car remains unchanged.

(i) Explain why it takes a longer time for the car to accelerate up an inclined road than along a horizontal road. 

(ii) Find the increase in height of the car after accelerating for 16.2 s along the inclined road.

On a certain day, the car was involved in a traffic accident. John braked hand to stop the car and skid marks were left on a horizontal road (see Figure 11). Investigation by the police revealed the following information:

length of the skid marks = 30.5 m

average frictional force between the tyres of the car and the road surface = 11 200 N.

(i) Describe energy change involved when the car was braking.

(ii) John claimed that he was driving at a speed below 70 km h\(^{-1}\) before the accident. Explain whether John was telling the truth or not.
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)
Ejection seats (see Figure 21) are important safety devices in military planes. The pilot, together with the seat, is 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 parachute on the dummy increases with its speed.

33. 2006/I/3

A student releases a book of mass 0.154 kg from rest under a motion sensor as shown in Figure 5. The velocity-time graph is recorded in Figure 6.

(a) From the graph, estimate the distance traveled by the block.
(b) Find the loss in potential energy of the book during the journey in (a). (1 mark)

(c) From the graph, find the maximum kinetic energy of the book. (2 marks)

(d) Account for the difference in the values obtained in (b) and (c). (1 mark)

34. 2006/I/4

Figure 7 shows a conveyor belt in a factory. A parcel of mass 10 kg is placed at position P when the belt remains at rest. The workman controls the belt such that the parcel undergoes a motion described in Table 1. The parcel and the conveyor belt move together without slipping during the entire motion.

<table>
<thead>
<tr>
<th>Position of the parcel</th>
<th>Motion</th>
<th>Data given</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P \rightarrow Q$</td>
<td>Uniform acceleration</td>
<td>$PQ = 5$ m and time required = 2 s</td>
</tr>
<tr>
<td>$R \rightarrow S$</td>
<td>Uniform deceleration to rest</td>
<td>------</td>
</tr>
<tr>
<td>$Q \rightarrow R$</td>
<td>Uniform velocity</td>
<td>------</td>
</tr>
</tbody>
</table>

Table 1

(a) Consider the motion when the parcel travels from $P$ to $Q$.

(i) Draw a free-body diagram to show all forces acting on the parcel in the space provided below. Name the forces. (2 marks)

(ii) Find the net force acting on the parcel. (3 marks)

(b) In Figure 8, sketch a graph to show the variation of the frictional force exerted by the conveyor belt on the parcel. (3 marks)
35. 2006/I/9

Read the following descriptions about a ‘crash cushion system’ and answer the questions that follow.

Figure 16 and Figure 17 show a crash cushion system installed at some junctions on highways. The system consists of a number of identical cushion boxes, containing sand or water, lined up and fixed on the road surface. During a crash, the boxes will burst one after another when the car runs through them. The boxes will act as a series of cushions and offer protection to the passengers.

In a pilot test on the cushion boxes, a car of mass 1600 kg traveling at a speed of 27 m s⁻¹ run through the boxes on a road (see Figure 18). The speed $v$ of the car after running through all the boxes is recorded. The test is repeated by varying the number of boxes $N$ installed in the system. Table 4 shows the results obtained.

<table>
<thead>
<tr>
<th>$N$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v$ m s⁻¹</td>
<td>25.2</td>
<td>22.8</td>
<td>21.1</td>
<td>18.2</td>
</tr>
</tbody>
</table>

Table 4

(a) Assume that the deceleration of the car remains unchanged in the test.

(i) Using the data in Table 4, plot a graph of $v^2$ against $N$ in Figure 19, with $v^2$ ranging from 0 to 100 m² s⁻² and $N$ from 0 to 10.

Hence or otherwise, estimate
(1) The average resistive force exerted by the cushion boxes on the car during the collision (given that the thickness of each cushion box is 1 m),

(2) The minimum number of cushion boxes required in order to stop the car in the test.  

(ii) If the test is repeated with a heavier car traveling at an initial speed lower than 27 m s\(^{-1}\), sketch a graph of \(v^2\) against \(N\) in Figure 19 that you would expect to obtain. Use a dotted line to sketch the graph. Assume that the average resistive force acting on the car remains unchanged throughout all the tests.

(b) Explain why it is undesirable to replace the cushion boxes with concrete blocks.

36. 2007/I/1

A balloon is filled with air and is attached to a puck. It released air through a hole at the bottom of the puck. The balloon puck then moves on a horizontal straight track (see Figure 1) and its velocity-time graph is shown in Figure 2.

(a) (i) Describe the motion of the balloon puck from \(t = 0\) to 1.4 s.

(ii) Explain why the motion of the balloon puck changes at \(t = 1.0\) s.
(b) If the balloon is filled with less air and its initial velocity is still 0.5 m s\(^{-1}\), sketch the corresponding velocity-time graph of the balloon puck in Figure 2. (2 marks)

37. 2007/I/2

Figure 3 shows Player X trying to block the ball from Player Y in a volleyball game. Standing on the ground with his arms fully stretched upwards, Player X’s hands are 2.25 m above ground. In order to block the ball, Player X has to jump up such that his hands reach a height of 3 m.

![Figure 3](image)

* (a) Using Newton’s laws of motion, explain why Player X in Figure 3 can gain an initial speed to leave the ground vertically. (4 marks)
(b) Player X jumps up vertically and his hands can just reach at 3 m. Estimate the initial speed of Player X at the instant he leaves the ground. Assume that air resistance is negligible. (2 marks)
(c) Player Z is a teammate of Player X. His hands can also reach a height of 2.25 m when his arms are fully stretched upwards, but he is heavier than Player X. If he jumps up such that his hands just reach a height of 3 m, explain whether the initial vertical speed of Player Z will be the same as Player X. (2 marks)

38. 2007/I/9

A golf ball, of mass 40 g and initially at rest, is struck with a club in teeing off (see Figure 14). The ball leaves the club with a speed 44 m s\(^{-1}\). Assume that air resistance is negligible.

![Figure 14](image)
(a) (i) Calculate the change in momentum of the golf ball before and after teeing off. (2 marks)
(ii) The time of impact between the club and the ball during teeing off is 1 ms. Determine average force acting on the ball during the impact. (2 marks)

(b) Robert finds that the club is harder than the golf ball. He claims that the force exerted on the club is smaller than that exerted on the golf ball during teeing off. Explain whether his claim is correct or not. (2 marks)

(c) When the golf ball is 2.5 m away from the hole, it is given a sharp horizontal push from rest and just reaches the hole (see Figure 15). Estimate the initial speed of the golf ball if the average resistive force exerted on the ball is 0.03 N. (3 marks)

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39. 2008/I/1

Figure 1 shows an athlete lifting a barbell of mass 115 kg by a vertical distance of 1.8 m from the ground.

(a) Find the potential energy gained by the barbell after it is lifted up. (2 marks)
(b) The mass of the athlete is 70 kg. Find the normal reaction acting by the ground on the athlete when she is lifted the barbell and stands still. (2 marks)
(c) After finishing the lifting, the athlete releases the barbell. It falls from rest to the ground freely. Find the time required for the barbell to reach the ground. (2 marks)
40. 2008/I/2
An electric toy boat (see Figure 2) of mass 1.2 kg is moving horizontally in still water with a constant velocity of 1.5 m s\(^{-1}\). The water resistance on the boat is 0.45 N.

(a)  (i)  Find the magnitude of the propelling force acting on the boat.  
(ii)  Find the power developed by this force.  

(b)  (i)  Find the kinetic energy of the boat.  
(ii)  Using the result in (b) (i), find the distance travelled by the boat before it comes to rest after the propeller is turned off. Assume the water resistance on the boat remains constant throughout the motion.

41. 2008/I/3
Read the following passage about Mega Drop and answer the questions that follow.

Figure 3 shows a “Mega Drop” in an amusement park. The vehicle carrying the passengers is lifted by an electric motor-winch and steel ropes. Once it reaches the top of the tower, the vehicle remains at rest for a while. It is then released and falls under gravity. When the vehicle gets very close to the ground, it decelerates and finally stops.

Let’s consider why the passengers experience weights when the vehicle is at the top of the tower (Figure 4). The earth attracts our bodies while the rest also gives a supporting force on us. These two forces are equal in magnitude but opposite in direction. Our bodies experience the supporting force and thus we can experience our weight.

When we are falling in a “Mage Drop”, we are nearly free falling and experience weightlessness. This feeling gives an excitement to the passengers.
(a) Consider when the passenger is at rest at the top of the tower.

(i) Explain in terms of force acting on the passenger why the passenger is at rest. (2 marks)

(ii) Explain whether the force acting on the passenger mentioned in the passage is action-reaction pair. (2 marks)

(b) Consider when the “Mage Drop” falls with acceleration:

(i) Compare the magnitude of the vertical forces acting on the passenger with those mentioned in (a) (ii). (2 marks)

(ii) Hence, explain why the passenger experiences “weightlessness”. (1 mark)

42. 2008/I/9

Figure 14 shows a cable car system for transporting passengers from station A to station B on the top of a hill.

(a) The mass of the cable car C is 600 kg. State the magnitude and the direction of its weight. (2 marks)

(b) Figure 15 shows cable car C which is suspended by the cable with tension $T_1$ and $T_2$ on two sides. The cable car is moving at a constant velocity towards the top of the hill. Assume air resistance is negligible. Complete the vector diagram in Figure 16 to show $T_1$, $T_2$ and their resultant $T$. $T_1$ is already drawn in the figure. (2 marks)
(c) The cable car \( C \) enters terminal \( B \) with a constant velocity \( 4.5 \text{ m s}^{-1} \) in a horizontal direction. In order to allow the passengers to leave the cabin, the cable car \( C \) begins to slow down with a constant deceleration after it passes \( X \). The velocity is reduced to \( 0.5 \text{ m s}^{-1} \) at \( Y \) (see Figure 17). Then it moves with a constant velocity again. It takes 8 s for the cable car \( C \) to travel from \( X \) to \( Y \).

(i) Sketch the velocity-time graph of the cable car for the journey between \( X \) and \( Q \) in Figure 18.

(ii) Hence or otherwise, find the distance between \( X \) and \( Y \).

Take the direction of the motion of the cable car as the positive direction.

(iii) A 60 kg person sits in the cable car. Find the change of momentum of the person during the journey between \( X \) and \( Y \).

(iv) Hence or otherwise, find the net force acting on the person during the deceleration period.
1. 1990/I/5a,b
A vertical vibrator generates waves on a string. It takes 0.25 s to produce a complete wave of wavelength 0.8 m on the string.

(a) Find the frequency and speed of the waves on the string. (3 marks)

(b) Figure 6 shows the shape of the string at the instant when the vibrator has made one complete vibration.

(i) At the instant shown, which of the particles A, B, C, D is/are

1) moving downwards,

2) at rest?

(ii) Sketch the shape of the string after 0.125 s, showing the position of the particles A, B, C and D. (6 marks)

2. 1990/I/6a,b

Figure 8 shows an experiment set-up to study image formation by a convex lens A of focal length 40 cm. The object is an illuminated letter 'J' placed a few metres away. The tracing paper is moved to catch a sharp image.

(a) (i) What is the approximate distance between lens A and the image? Explain briefly.

(ii) Sketch the shape of the image seen by the observer. (4 marks)

(b) If the experiment is repeated with a convex lens of longer focal length, what will be the change in the size of the image? Illustrate your answer with a ray diagram. (4 marks)

3. 1991/I/3

Figure 4 shows a ray of red light entering a semi-circular glass block in the direction AC. The angle of
incidence at $C$ is $30^\circ$. The critical angle of red light for the glass block is $39^\circ$.

(a) How would the frequency, wavelength and speed of the ray be affected when it enters the glass block?

(b) When the ray reaches $C$, it splits into two. Copy Figure 4 into your answer book and sketch the two rays.

(c) Calculate
   (i) the refractive index of the glass block,
   (ii) the angle of refraction of the ray on leaving the glass block.

(d) What happens if the ray reaches $C$ with an angle of incidence greater than $39^\circ$?

(e) A periscope consists of two right-angled prisms.
   (i) Draw a ray diagram to show how the periscope works.
   (ii) State one advantage of using right-angled prisms over plane mirrors.

4. 1991/I/4

Figure 5 shows the experimental set-up to study the interference of sound. $P$, $Q$ are two identical loudspeakers. $PC = 2.05$ m and $QC = 2.31$ m.

(a) Initially only $P$ is connected to the signal generator and sound is emitted. A microphone connected to an oscilloscope is placed at point $C$. Figure 6 shows the trace on the oscilloscope. The speed of sound in air is $325$ ms$^{-1}$. Find the frequency and wavelength of the sound.

(b) Now both $P$ and $Q$ are connected to the signal generator and they emit sound of the same frequency and intensity as in (a). Interference is observed when the microphone is moved along $AB$.
   (i) Is the interference of sound at $C$ constructive or destructive? Explain your answer.
   (ii) Compared with (a), how do the pitch and loudness of the sound at $C$ change?
(iii) The amplitude of the trace on the oscilloscope is not zero at the positions of destructive interference. Suggest two possible reasons.

(iv) A student says that alternate constructive and destructive interference will also be observed along XY. (X is the mid-point of PQ.) State whether his statement is true or false. Explain briefly.

5. 1992/I/3

A student holds a magnifying glass close to his eye to look at some small print on a paper. The image of the letters "EX" is shown in Figure 4. The magnification is 3.

(a) What kind of lens is used as a magnifying glass? (1 mark)

(b) State the nature (real or virtual, erect or inverted) of the image. (2 marks)

(c) The paper is placed at a distance of 8 cm from the lens. In Figure 5, AB represents the object, and p, q are incident rays. A scale of 1 cm representing 4 cm for the object distance is used.

(i) Draw the refracted rays of p and q and the image of AB in Figure 5.

(ii) From the ray diagram, measure

(1) the image distance, (2) the focal length of the lens. (6 marks)

(d) If the paper is placed closer to the lens, how would the size of the image and the image distance be affected? Illustrate your answer with a ray diagram. (4 marks)

(e) If the paper is moved away from the lens to a position beyond the focus, the student finds that a clear
image cannot be observed. Explain briefly. (2 marks)

6. 1993/I/3
(a)

A ray of light travelling in the direction $AO$ in air enters a semi-circular glass block as shown in Figure 4. The ray is refracted along $OB$ in the glass block. Different values of the angle of incidence $\theta$ are used and the corresponding values of the angle of refraction $\phi$ are measured. The following result is obtained:

<table>
<thead>
<tr>
<th>$\theta$</th>
<th>15°</th>
<th>20°</th>
<th>25°</th>
<th>30°</th>
<th>35°</th>
<th>40°</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi$</td>
<td>9.0°</td>
<td>12.9°</td>
<td>16.3°</td>
<td>19.0°</td>
<td>22.3°</td>
<td>25.1°</td>
</tr>
</tbody>
</table>

(i) Using a scale of 1 cm to 0.05, plot the graph of $\sin \theta$ (vertical axis) against $\sin \phi$ (horizontal axis) on graph paper.

(ii) Find the slope of the graph and state its physical meaning.

(iii) A student predicts that the total internal reflection will occur when $\theta = 45^\circ$. Is he right or wrong? Explain briefly. (11 marks)

(b) Thin glass fibres can be used as a light guide.

(i) Explain, with the aid of a diagram, how a light ray is transmitted along a curved glass fibre.

(ii) State one application of light guides. (4 marks)

7. 1994/I/3
(a) A student uses the set-up shown in Figure 5 to study the image information of a lens. An illuminated object is placed at a distance of 20 cm from the lens. A screen is placed on the other side of the lens. When the screen is moved to a point 60 cm from the lens, a sharp image is formed on the screen.

(b) What kind of lens is used in the experiment? (1 mark)

(c) Is the image real or virtual? (1 mark)

(c) In Figure 6, $AB$ represents the illuminated object and $p, q$ and $r$ represent the incident rays.
(i) Draw the refracted rays of \( p \), \( q \) and \( r \) and the image of \( AB \) in Figure 6.

(ii) Find the magnification of the image.

(iii) Find the focal length of the lens.

(d) How would the image formed on the screen be affected when the upper half of the lens is covered by opaque paper?

(e) Describe briefly a simple laboratory method to measure directly the focal length of the lens. Illustrate your answer with a ray diagram.

8. 1994/I/5

A train of straight waves is generated in a ripple tank. Figure 9 shows the displacement-time graph of a cork placed in the water. The waves take 0.5 s to travel a distance of 12 cm.

(a) Find the amplitude, frequency, speed and wavelength of the waves.

(b) Suggest one method to prevent water waves from bouncing back at the edges of the tank.

(c) A barrier with an opening is placed in the ripple tank and the waves travel towards it as shown in Figure 10.
(i) Copy Figure 10 into your answer book and sketch the wave pattern formed on the other side of the barrier.

(ii) Name this wave phenomenon. (3 marks)

(d) The barrier in (c) is replaced by one with two smaller openings.

(i) Figure 11 shows the wave pattern at a certain instant. Of the 4 points A, B, C, D, state a point of constructive interference and a point of destructive interference.

(ii) A student says that at a point of constructive interference, a crest is always formed. Is the student correct? Explain briefly. (5 marks)

9. 1995/I/3a

(a) A boy 1.5 m tall stands a few metres in front of a plane mirror AB which is hung on a vertical wall. The boy's eyes are 1.4 m above the ground. He can see all of himself in the mirror. In Figure 5, PQ represents the boy and E denotes his eyes.

(i) State three properties of the boy's image as formed by the mirror. (2 marks)

(ii) In Figure 5, draw

(1) the image of the boy formed by the mirror,
(2) the paths of two rays, one from P and one from Q, to show how the rays reach his eyes. (4 marks)
(iii) Using (ii), or otherwise, find the minimum length of the mirror $AB$ for the boy to see all of himself in the mirror? In Figure 6, draw a ray diagram to illustrate your answer. (3 marks)

10. 1995/I/4a
(a)

Figure 7 shows a set-up to investigate the interference of microwaves. Microwaves emitted from a transmitter $T$ pass through two narrow slits $A$ and $B$, which are equidistant from $T$. The receiver is connected to a meter, which indicates the intensity of microwaves received.
Figure 8 shows the variation of the meter reading as the receiver is moved from X to Y. X is equidistant from A and B.

(i) Explain briefly why the meter shows maximum and minimum readings. (2 marks)

(ii) What type of interference is observed at P? (1 mark)

(iii) If AP = 36 cm, BP = 33 cm, find the wavelength and frequency of the microwaves.

(Given: Speed of light = $3 \times 10^8$ ms$^{-1}$) (4 marks)

(iv) Sketch a graph to show the variation of the meter reading as the receiver is moved from X to Z (XZ is perpendicular to XY). Explain briefly why the reading varies in this way. (4 marks)

11. 1996/I/1

In Figure 1, the image of an illuminated letter ‘J’ formed by a lens is caught by a translucent screen.

(a) (i) What kind of lens is being used? Explain your answer. (2 marks)

(ii) Sketch the shape of the image seen by the observer. (2 marks)

(b) Figure 2 shows the relation between the image distance $v$ and the object distance $u$.

(i) Find the magnification of the image when $u = 18$ cm. (2 marks)

(ii) Find the value of $u$ when $u = v$. Hence find the focal length of the lens. (3 marks)

(c) The illuminated letter is now placed closer to the lens. In Figure 3, AB represents the letter and the path of a ray from A through the lens is shown.
(i) In Figure 3, draw the path of a ray from A which passes through the optical centre of the lens and construct the image of AB. (3 marks)

(ii) State an application of the lens in which an image like that shown in Figure 3 is formed. (1 mark)

(iii) Comment on the following statement:

After adjusting the position of the screen, the image formed in Figure 3 can still be caught. (2 marks)

12. 1997/I/2

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 ms$^{-1}$.

(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)
(c) 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)

13. 1998/I/7

A longitudinal wave is travelling from left to right in a medium. Figure 8 shows the equilibrium positions of some particles A to K in the medium. Figure 9 shows the positions of the particles at a certain time $t$ when the wave is passing through them.

(a) What is meant by a longitudinal wave? Give an example of a longitudinal wave. (2 marks)

(b) Point out a particle in Figure 9 which is

(i) at the centre of a compression,

(ii) at the centre of a rarefaction. (2 marks)

(c) Table 1 shows the displacement of particles $A$ and $B$ at time $t$. (Note: Displacement to the right is taken to be positive.)

(i) Using Figures 8 and 9, find the displacements of the other particles and complete Table 1. (2 marks)

(ii) In figure 10, draw a graph showing the displacements of the particles along the wave at time $t$. (2 marks)

(iii) Find the amplitude and wavelength of the wave. (2 marks)

(iv) If each particle takes 0.25 s to complete one oscillation, find the speed of the wave. (2 marks)

(d) Suppose the wave travels into another medium where it travels more slowly.

(i) How would the frequency and wavelength of the wave be affected? (2 marks)

(ii) Name this wave phenomenon. (1 mark)

<table>
<thead>
<tr>
<th>Particle</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement/cm</td>
<td>0</td>
<td>−6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1
A diver stays at a depth of 3 m under water in a lake. When the diver looks upwards, the scene above the water surface is compressed into a circular patch of radius $r$ at the water surface. (See Figure 5). The refractive index of water is 1.33.

(a) Calculate
(i) the critical angle of the water,
(ii) the radius $r$.

(b) A fisherman stands beside the lake as shown in Figure 5. Can the diver see the fisherman? Draw a ray diagram to illustrate your answer.
Peter lives in a house A on one side of a hill. A transmitting station \( T_1 \) is located at site \( P \) on the other side of the hill. (See Figure 11.) The station transmits radio waves of frequency 600 kHz and TV waves of frequency 500 MHz. (Note: 1 MHz = \( 10^6 \) Hz.)

(a) Given that the speed of electromagnetic waves is \( 3 \times 10^8 \) m s\(^{-1} \), find the wavelengths of the radio waves and TV waves.  
(b) (i) Name the wave phenomenon which enables the waves transmitted by \( T_1 \) to reach Peter's house.  
(ii) Peter finds that the radio reception is better than the TV reception. Explain this phenomenon.
(c) Peter is watching TV in his house. He finds that the reception is affected when an aeroplane flies overhead. Explain this phenomenon.
(d) Another transmitting station will be built at site \( Q \). (See Figure 11.) Mary lives in a house \( B \) such that \( BP = 3.95 \) km and \( BQ = 3.20 \) km.
   (i) Find the path difference at \( B \) from \( P \) and \( Q \).
   *(ii) Mary listens to the radio in her house. How will the reception be affected if both stations transmit identical radio waves at 600 kHz? Explain your answer. (Neglect the reflection of waves from the hill.)*
(e) Table 3 shows the broadcasting frequencies of RTHK Radio 1 (FM) in different districts:

<table>
<thead>
<tr>
<th>District</th>
<th>Frequency/MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong north</td>
<td>92.6</td>
</tr>
<tr>
<td>Hong Kong south</td>
<td>93.6</td>
</tr>
<tr>
<td>Kowloon east</td>
<td>94.4</td>
</tr>
<tr>
<td>Kowloon west</td>
<td>92.9</td>
</tr>
<tr>
<td>Shatin, Ma On Shan</td>
<td>93.5</td>
</tr>
<tr>
<td>Tai Po, Fanling</td>
<td>93.2</td>
</tr>
<tr>
<td>Tuen Mun, Yuen Long</td>
<td>93.4</td>
</tr>
</tbody>
</table>

Table 3

State one advantage of broadcasting at different frequencies in different districts.

16. 2000/I/1

An illuminated object is placed 30 cm in front of a convex lens and a sharp image is formed on a screen on the other side of the lens. The image is of the same size as the object.

(a) Is the image real or virtual? Explain your answer.
(b) In Figure 1, draw a ray diagram to show how the image of the illuminated object is formed. Hence, or otherwise, determine the focal length of the lens.
Figure 10 shows a vibrator producing straight water waves in a ripple tank. Figure 11 shows a loudspeaker which is emitting low-frequency sounds.

(a) You are given the following equipment:
- a cork, a slinky spring, a candle and matches, a ruler.

Select suitable equipment and describe
(i) a method to demonstrate that the water waves in Figure 10 are transverse, and
(ii) a method to demonstrate that the sound waves in Figure 11 are longitudinal. (4 marks)

(b) A barrier with an opening is placed in the ripple tank as shown in Figure 10.

(i) Copy Figure 10 into your answer book and draw the wave pattern formed on the other side of the barrier.
Name this wave phenomenon. (3 marks)

(ii) The wavelength of the water waves is increased as shown in Figure 12.

(1) Suggest two methods which can be used to increase the wavelength of the water waves. (2 marks)

(2) Copy Figure 12 into your answer book and draw the wave pattern formed on the other side of the barrier. (2 marks)

*(c)*
Figure 13 shows a loudspeaker unit with two speaker cones, a big one and a small one. One speaker cone emits low-frequency sounds and the other emits high-frequency sounds. The sound waves generated by the speaker cones will bend around the rim of the cones in a way similar to water waves bending around corners of obstacles. Which cone is more suitable for emitting high-frequency sounds? Explain your answer.

(4 marks)

18. 2001/I/3

Figure 2

A student holds a lens above a picture and the image observed is shown in Figure 2.

(a) What kind of lens is used by the student? Explain your answer. (2 marks)

(b) Sketch a ray diagram to show how the image in Figure 2 is formed. (3 marks)

19. 2001/I/4

A dipper $S_1$ is connected to a vibrator and produces circular water waves in a ripple tank. A cork is placed at a point $P$ on the water surface as shown in Figure 3.

(a) Describe the motion of the cork as the water waves pass through it. (1 mark)

(b) Suppose another dipper $S_2$ is connected to the same vibrator and produces identical water waves. It is known that $S_1P = 6.0$ cm, $S_2P = 7.8$ cm and the wavelength of the water waves is 1.2 cm.

(i) Name the wave phenomenon that occurs when both dippers vibrate. (1 mark)

(ii) How would the motion of the cork be affected? Explain your answer. (3 marks)

20. 2001/I/6a,b

Explain the following phenomena:

(a) In a thunderstorm, lightning is seen before thunder is heard. (1 mark)
(b) Sound waves can bend around a corner but light cannot. (2 marks)

21. 2001/I/7

(a) A ray of light travelling in air in the direction PO enters a semicircular glass block as shown in Figure 5. The ray travels along the direction OQ inside the block. Different values of the angle of incidence $\theta$ and the corresponding values of $\phi$, the angle between OQ and the normal, are measured. The following results are obtained:

<table>
<thead>
<tr>
<th>$\theta$</th>
<th>0</th>
<th>15°</th>
<th>30°</th>
<th>45°</th>
<th>60°</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi$</td>
<td>0</td>
<td>9.5°</td>
<td>19.0°</td>
<td>27.0°</td>
<td>34.0°</td>
</tr>
</tbody>
</table>

(i) Name the wave phenomenon shown in Figure 5. (1 mark)
(ii) Using a scale of 1 cm to 0.05, plot a graph of $\sin \theta$ against $\sin \phi$ on graph paper. (5 marks)
(iii) Using the graph in (ii), find the critical angle of the glass. (3 marks)
(iv) If the glass block is replaced with a perspex block with a smaller refractive index, on the same graph in (ii), draw the graph of $\sin \theta$ against $\sin \phi$ you expect to obtain. (2 marks)

*(b) Given that the refractive index of diamond is 2.4 and the refractive index of glass is about 1.6, explain why a diamond sparkles more than a piece of glass of similar shape.
[Hint: You may consider the paths of rays entering the diamond and the glass from the top (see Figure 6).] (4 marks)
22. 2002/I/1

(a) Figure 1 shows an ambulance. Explain why the word AMBULANCE is printed in the form as shown in the figure. (2 marks)

(b) Figure 2 shows the structure of part of a pair of binoculars, which consists of two triangular prisms.
   (i) Copy Figure 2 into your answer book and complete the path of the ray. (1 mark)
   (ii) Give one advantage of using triangular prisms over plane mirrors in making binoculars. (1 mark)

23. 2002/I/4

A wave is generated on a string. Figure 6 shows the shape of the string at a certain instant. At this instant, both particles \( P \) and \( Q \) are moving downwards.

(a) State the kind of wave generated on the string (transverse or longitudinal, travelling or stationary). (2 marks)

(b) Find the wavelength of the wave. (1 mark)

(c) Describe the motions of particles \( P \) and \( Q \) at a quarter of a period later. (2 marks)
Two identical loudspeakers $S_1$ and $S_2$ are connected to a computer. The set-up generates a sound of frequency 200 Hz. Mary and Susan stand at positions $P$ and $Q$ respectively in front of the loudspeakers, where $PS_1 = 6.10 \text{ m}$, $PS_2 = 8.65 \text{ m}$ and $QS_1 = QS_2$. The speed of sound in air is $340 \text{ m s}^{-1}$.

(a) Find the wavelength of the sound emitted by the loudspeakers. (2 marks)

(b) (i) Find the path difference at $P$ from $S_1$ and $S_2$. (1 mark)

(ii) Explain whether Mary will hear a loud or a soft sound. (2 marks)

(c) The set-up now generates sound of frequencies 200 Hz and 400 Hz alternately. Susan predicts that constructive and destructive interference will occur alternately at $Q$. Explain whether Susan is correct or not. (2 marks)

25. 2002/I/11

Kitty designs a simple peephole which is installed at an entrance door to identify visitors (see Figure 17). The peephole consists of a metal tube with a concave lens of focal length 10 cm fixed inside.

(a) A visitor stands at a distance 30 cm in front of the peephole (see Figure 18 on next page).

(i) In Figure 18, draw the refracted rays of the three incident rays and the image formed. (4 marks)

(ii) Find the magnification of the image formed. (2 marks)

(b) Suggest one reason to explain why the concave lens inside the peephole cannot be replaced by a convex lens. (2 marks)

(c)
Figure 19 shows the top-view of the peephole. The metal tube will only allow Kitty to see those images formed in the shaded region. Now a visitor stands at a point $P$ and Kitty cannot see him through the peephole.

(i) Explain, by drawing a ray diagram in Figure 20, why Kitty cannot see the visitor. (3 marks)

(ii) The lens is now replaced by another concave lens of a shorter focal length and Kitty can just see the visitor at $P$. In Figure 20, locate the image observed and find the focal length of this lens. (4 marks)
26. 2003/I/2
(a) A ray of light travels from water to air with an angle of incidence 30°. The refractive index of water is 1.33.
   (i) Find the angle of refraction of the ray in air. (2 marks)
   (ii) Find the critical angle of water. (2 marks)

(b) Peter places a coin in an empty cup. As shown in Figure 2, he cannot see the coin. After pouring some water into the cup, he finds that he can see the coin without changing the position of the cup or his eyes. In Figure 2, draw a ray diagram to illustrate how Peter can see the coin. (2 marks)

27. 2003/I/5
(a) Name the wave phenomenon observed. (1 mark)
(b) The amplitude of the trace reaches a maximum when the microphone is at point X, where PX = 1.74 m and QX = 1.96 m. A student says that one possible wavelength of the sound waves is 0.44 m. Explain whether the student is correct or not. (3 marks)
In a factory, an engineer uses a device to monitor the thickness of the wall of a metal pipe for conveying chemical solutions. The device consists of a transmitter and a receiver. During the test, the device is placed on the surface of the pipe. The transmitter emits an ultrasonic pulse of frequency \( 2 \times 10^6 \text{ Hz} \). The pulse travels with a speed of \( 6 \times 10^3 \text{ m s}^{-1} \) inside the wall. The pulse is reflected from the other surface of the wall and is recorded by the receiver (see Figure 7). The device is connected to a CRO, which displays the transmitted and reflected pulses (see Figure 8).

(a) Find the wavelength of the pulse inside the wall.

(b) Which of the two pulses in Figure 8 is reflected pulse? Explain your answer.

(c) The engineer conducts the test every five weeks and measures the total time of travel of the pulse inside the wall. The results are shown in Table 1.

<table>
<thead>
<tr>
<th>Time ( t )/weeks</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time of travel / ( 10^{-6} ) s</td>
<td>14.5</td>
<td>14.0</td>
<td>13.3</td>
<td>12.8</td>
<td>12.2</td>
<td>11.5</td>
</tr>
<tr>
<td>Thickness of the wall ( d )/mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1

(i) Show that the thickness of the wall at time \( t = 0 \) is 43.5 mm.

(ii) Plot a graph of the thickness of the wall \( d \) against time \( t \) on graph paper, with \( d \) ranging from 0 to 50 mm and \( t \) ranging from 0 to 40 weeks.

(iii) The pipe has to be replaced when the thickness of the wall drops to 30 mm. Using the graph in (c)(ii), estimate the time at which the pipe has to be replaced.
Figure 9 shows the CRO display of the test result on a certain day. The engineer points out that there may be a small crack in the wall of the pipe. Explain how the engineer arrives at such a conclusion. (2 marks)

29. 2004/I/1

Figure 1 shows a set-up used to study the relationship between the angle of incidence $\alpha$ and the angle of refraction $\beta$ of a ray of light travelling from air into a semi-circular glass block. Figure 2 shows a graph of $\sin \alpha$ against $\sin \beta$.

(a) Find the slope of the graph in Figure 2 and state its physical meaning. (3 marks)

(b) Philip predicts that if $\alpha$ is increased to 50°, total internal reflection will occur. Explain whether he is correct or not. (2 marks)
Figure 5 shows the display panel of a radio and the broadcasting frequencies of two radio channels $R_1$ and $R_2$. Given: speed of electromagnetic waves $= 3 \times 10^8 \text{ m s}^{-1}$.

(a) Find the wavelength of the radio waves used by channel $R_1$. (2 marks)

(b) Anita's house is surrounded by hills and at her house, the reception of one of the two radio channels is better. For which radio channel is the reception better? Explain your answer. (3 marks)

Figure 6 shows a sectional view of a beach. Two boats are located at positions $P$ and $Q$ as shown, where $PQ = 20 \text{ m}$. Straight water waves travel towards the beach. The waves take 4 s to travel from $P$ to $Q$.

(a) Find the average speed of the waves between $P$ and $Q$. (2 marks)

(b) Figure 7 shows the view of the beach from above. Copy Figure 7 into your answer book and draw the wave pattern observed when the waves travel towards the beach. (2 marks)

(c) Name the wave phenomenon that occurs as the waves travel towards the beach. (1 mark)
Peter designs a simple slide projector (see Figure 17). A slide is placed in front of a bright light source. A sharp image of the slide formed by a lens is projected onto a screen. The focal length of the lens is 40 mm and the distance between the slide and the lens can be adjusted within the range of 41 to 55 mm.

(a) What kind of lens is used in the projector? Explain your answer. (2 marks)

(b) The projector is placed on a trolley in front of a screen (see Figure 17). The lens is placed at 50 mm from the slide.

(i) In Figure 18, draw a ray diagram to show how the image of the slide is formed by the lens. (4 marks)
(ii) Find the magnification of the image formed.  
(2 marks)

(iii) Peter finds that the size of the image formed on the screen is too small.

1) Without replacing the lens, describe a method to increase the size of the image formed on the screen.  
(2 marks)

2) Karen suggests that the size of the image can also be increased by replacing the lens with one that has a focal length of 60 mm. Explain whether Karen's suggestion will work or not.  
(2 marks)

(c)

The projector is designed so that the lens can be moved up and down by adjusting the rollers. The screen is now hung at a higher position. In order to project the image onto the screen again, Karen suggests that the lens should be moved up (see Figure 19). Is Karen correct? Sketch a ray diagram to illustrate your answer.  
(3 marks)

33. 2005/I/4

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)

34. 2005/I/5

Figure 7 shows a ripple tank with 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)

Suggest one method of obtaining the wave pattern in \( Q \) as shown in Figure 9. Illustrate your answer by completing Figure 9. (2 marks)

35. 2005/I/6

You are provided with the apparatus shown in 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)
36. 2005/10a,c
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]

   (2 marks)

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

   (1 mark)

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

   (2 marks)

37. 2006/I/1
RADAR (RAdio Detecting And Ranging) is a useful device in air traffic control. In Figure 1, an aircraft is flying near a radar station. A pulse of electromagnetic wave with a speed of $3 \times 10^8$ m s$^{-1}$ and a frequency of $1.2 \times 10^9$ Hz is emitted from the radar station towards the aircraft.
(a) Find the wavelength of the electromagnetic wave.

   (2 marks)

(b) The electromagnetic wave pulse is emitted is reflected by the aircraft back to the radar station. The emitted and reflected pulses are displayed on the screen of a CRO as shown in Figure 2. The time-base setting of the CRO is 5 µs per division ($1 \mu s = 10^{-6}$ s). Estimate the distance between the radar station and the aircraft.

   (3 marks)
38. 2006/I/2

RADAR, as mentioned in Question 1, is a useful device to detect aircraft. However, the airforces of many countries try to build aircraft that can hide away from their enemies. Read the following passage about a stealth bomber (see Figure 3).

(a) (i) In Figure 4, draw a ray to show how a wave from the radar is reflected at the bottom of the stealth bomber. (1 mark)

(ii) If the stealth bomber flies horizontally to a particular position around the radar, it can be detected by the radar. Mark this position with a symbol X in Figure 4. (1 mark)

(b) All of the exhausts in a stealth bomber pass through cooling vents before flowing out of the plane. Explain how this can help the stealth bomber to hide away from enemy detection. (2 marks)

(c) Apart from the designs which help prevent the stealth bomber being detected by radar and infrared sensors, state two other essential features which are important in building the stealth bomber so that it can hide away from enemy detection. (2 marks)
Figure 9 shows a plastic lens $L$ mounted on the rear window of a car. The driver can view his friend David, and the surroundings at the back of the car through either the rear window or lens $L$ as shown in Figure 10.

(a) What kind of lens is $L$? Explain your answer. (2 marks)

(b) Suppose that David in Figure 10 stands at 60 cm from lens $L$ of focal length 30 cm. In Figure 11, David is plotted as $AB$. Draw a ray diagram to show how the image of David is formed by lens $L$. Use a horizontal scale of 1 cm to 10 cm.
(c) State one advantage of using lens $L$. 

(1 mark)

40. 2007/I/5

Figure 8 shows a playground after raining. Images can be seen on the calm water surface of the wet ground.

(a) Explain why images can be seen on the calm water surface. 

(2 marks)

(b) Figure 9 shows an object $AB$ above the water surface $PQ$. 


In Figure 9,
(i) draw the reflected rays of the incident rays $x$ and $y$;
(ii) hence, draw the image of $AB$.  

41. 2007/I/6

John wants to find out the time he takes to run 100 metre. A starter at the starting point uses a horn to emit a sound signal of frequency 425 Hz to notify John to start running. A time keeper presses a stop watch to record the time when he hears the sound signal (see Figure 10). Given that the speed of sound in air is 340 ms$^{-1}$.

(a) Find the wavelength of the sound signal emitted by the horn. 

(b) (i) Find the time $t$ taken by the sound signal to travel 100 metres.

(ii) As it takes time $t$ for the sound signal to travel from the starter to the time keeper, David suggests the following ways to reduce the time delay $t$:
1. using a horn emitting sound of higher frequency;
2. lowering a flag instead of using a horn to notify time keeper.

Explain whether each of the above suggestions will work.
In Figure 16, two identical loudspeakers $P$ and $Q$ are connected to a signal generator. Position $A$ is the mid-point of $PQ$. A microphone connected to a CRO is moved along $BC$ to measure the loudness of the sound. The amplitude of the CRO trace increases as the loudness of the sound detected increases. Figure 17 shows the result.

![Diagram](image)

(a) (i) Explain why the loudness of the sound varies at different positions along $BC$. (2 marks)
(ii) State ONE reason why the amplitude of the CRO trace is **NOT** zero at position $X$. (1 mark)

(b) If $PY = 5.10 \text{ m}$ and $QY = 5.78 \text{ m}$, find
(i) the path difference at position $Y$ from $P$ and $Q$; (1 mark)
(ii) the wavelength of the sound. (2 marks)
43. 2008/I/5

Figure 7 shows a plastic box floating on the water surface of a pool which has a deep region and a shallow region. A boy tries to get the box back. He throws a stone into the water to produce waves and he expects that the water waves will "push" the box towards the poolside.

(a) According to the direction of motion of the water molecules, state the kind of wave produced on the water surface.

(b) Explain whether the water waves can "push" the box to the poolside.

(c) Figure 8 shows a continuous water wave travelling towards the poolside. Deduce the relationship between the velocity of the water wave and the depth of water in the pool. Show your reasoning.
44. 2008/I/6
Using the apparatus in Figure 9, describe the procedures of an experiment to find the focal length of a cylindrical convex lens.

![ray box with a single slit connected to a 12V power supply](image1)
![cylindrical convex lens on a paper with its optical centre at the intersection O of two perpendicular lines AB and XY, the line XT is the principal axis of the lens](image2)
![ruler](image3)

Figure 9

45. 2008/I/10
A teacher performs an experiment by directing a red light beam from air normally to the straight edge of a semi-circular glass block with centre O (see Figure 19). The refractive index of glass is 1.48.

![semi-circular glass block](image4)

Figure 19

(a) Find the critical angle of the glass block. (2 marks)

(b) If $\theta = 45^\circ$,
   (i) describe and explain what happens when the light beam hits point X. (2 marks)
   (ii) complete the path of the light beam in Figure 19 until it finally emerges from the glass block to the air. (2 marks)

(c) If the light beam travels in the same direction but with a shorter distance from O, with $\theta < 40^\circ$, sketch the path of the refracted beam at Y and mark the angle of refraction as $r$ in Figure 20. (2 marks)
Figure 20
1. 1990/I/7

Figure 9 shows a 3-pin electrical plug and a transformer. The three wires $X$, $Y$ and $Z$ of the transformer are to be connected to the plug. The plug will be connected to a 200 V a.c. supply. The output voltage of the transformer will be 110 V. Assume the transformer is 100% efficient.

(a) (i) To which of the terminals $A$, $B$ and $C$ of the plug should each of the wires $X$, $Y$ and $Z$ be connected?
(ii) Explain briefly why the fuse should be connected to the terminal $B$.
(iii) Suggest one reason why it is necessary to have the $X$-wire connection.
(iv) Find the turns ratio (primary coil to secondary coil) of the transformer. (8 marks)

(b) An iron of rated values '110 V, 1100 W' is connected to the output of the transformer and switched on for four half an hour.
(i) Calculate the current drawn from the transformer by the iron.
(ii) Calculate the cost of electricity if one kilowatt-hour of electrical energy costs 80￠.
(iii) If fuses marked 1A, 3A and 7A are available, which one is most appropriate to be used in the plug in Figure 9? Explain your choice. (7 marks)

2. 1991/I/6a

A thermistor is connected to a resistor $R$ and a 6 V power supply as shown in Figure 8. The resistance of $R$ is 470Ω. A voltmeter of high resistance is connected across $R$. Figure 9 shows the variation of resistance of the thermistor with temperature.
(i) The reading of the voltmeter is 4.7 V. At this instant, find
   (1) the current flowing through $R$,
   (2) the resistance of the thermistor,
   (3) the temperature of the thermistor.

(ii) How would the voltmeter reading change if the temperature of the thermistor increases? Explain briefly. (8 marks)

3. 1992/I/5

A student uses the following components to measure the resistance of a light bulb:
   A battery, an ammeter, a voltmeter, a switch, a variable resistor and the light bulb.

Figure 7 shows an incomplete circuit for the experiment.

(a) Copy Figure 7 into your answer book and use suitable circuit symbols to complete the circuit. Indicate on your diagram the positive terminals of the ammeter and voltmeter with "+" signs. (5 marks)

(b) What is the function of the variable resistor in the circuit? (2 marks)

(c) Figure 8 shows the result obtained in the experiment.

(i) What is
   (1) the voltmeter reading,
   (2) the ammeter reading?

(ii) Calculate the resistance of the light bulb. (4 marks)

(d) The rating of the light bulb is 200 V, 100 W.

(i) Calculate the resistance of the light bulb when it is working at its rated value.

(ii) Explain why the resistance found in (d)(i) is much greater than that found in (c)(ii). (4 marks)
4. 1993/I/5

(a) Figure 6 shows a solenoid passing through a piece of horizontal cardboard. A direct current passes through the solenoid from A to B to produce a magnetic field.

(i) Describe a method to find the magnetic field pattern on the cardboard using iron fillings.

(ii) Draw a diagram to show the pattern and direction of the magnetic field on the cardboard.

(5 marks)

(b) A student designs a simple door bell as shown in Figure 7. When switch (S) is pressed and then released, two notes 'ding-ding' are heard.

(i) Explain how the two notes are produced.

(ii) Suggest one way to modify the bell so that two notes of different frequencies 'ding-dong' are produced.

(iii) Comment on the following two statements:

Statement 1: The bell does not work if the spring is made of copper.

Statement 2: The bell does not work if the polarities of the battery are reversed.

(10 marks)

5. 1995/I/5
Two long wires $AB$ and $CD$ of total resistance $4 \Omega$ are used to connect a d.c. power supply to a lamp. The lamp is working at its rated value '12 V, 24 W'.

(a) Find

(i) the resistance of the lamp,

(ii) the current flowing through the lamp,

(iii) the power loss in the wires,

(iv) the efficiency of the circuit supplying power to the lamp.

(b) To reduce the power loss in the wires, an a.c. power supply and two transformers are used as shown in Figure 11.

(i) In Figure 12, draw wires to connect the terminals of the components according to Figure 11.

* (ii) Explain how the arrangement can reduce the power loss in the wires.

6. 1996/I/7

*(a)
A bar magnet is pushed with constant speed from left to right through a solenoid as shown in Figure 12. Describe the change in the direction of the current passing through the galvanometer during the motion of the magnet. (4 marks)

(b)

Figure 13 shows the structure of a simple a.c. generator. An e.m.f. is induced when the coil is set into rotation. The output of the generator is displayed on a CRO as shown in Figure 14. The time base of the CRO is set at 20 ms cm$^{-1}$ and Y-gain at 50 mV cm$^{-1}$.

(i) Which points (P, Q, R and S) in Figure 14 correspond to instants at which the plane of the coil is parallel to the magnetic field? (2 marks)

(ii) Find the peak voltage and frequency of the output of the generator. (3 marks)

(iii) Describe what happens to the peak voltage and frequency of the output of the generator in each of the following cases:

1. Increasing the speed of rotation of the coil.
2. Winding the coil on a soft-iron core. (4 marks)

(iv) Steam is commonly used to drive generators in power stations. Suggest two other practical means of driving generators. (2 marks)

7. 1997/I/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)

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)

8. 1998/I/4

Figure 5 shows a 3-pin plug and a kettle.

(a) To which of the pins $A$, $B$ and $C$ of the plug should each of the wires $X$, $Y$ and $Z$ of the kettle be connected? (2 marks)

(b) (i) Explain why it is safer to have pin $A$ of the plug longer than the other two pins. (2 marks)
(ii) Explain why switch $S$ of the kettle is connected in wire $X$ instead of wire $Y$. (2 marks)

(c) The rating of the kettle is '220 V, 2000 W'.

(i) If the kettle is switched on for half an hour, calculate the cost of electricity. (Given: One kilowatt-hour of electricity costs $0.9.) (2 marks)

(ii)

A housewife plugs the kettle and an oven of rating '220 V, 2500 W' into a 15 A socket. (See Figure 6.) Explain why this connection is dangerous. Show your calculations. (3 marks)
*(d) A student makes the following note in his book:

In case either wire $X$ or $Y$ touches the metal case of the kettle accidentally, the kettle will stop working.

Explain whether the student's note is correct. (4 marks)

9. 1998/I/5

Figure 7 shows a type of motor. $PQ$ and $RS$ are solenoids. The solenoids and the coil $ABCD$ are connected in parallel to a battery.

(a) State

(i) the polarity at end $Q$ of the solenoid $PQ$,

(ii) the direction of rotation of the coil as seen by the observer. (2 marks)

(b) Name the component $E$ and explain its function. (3 marks)

(c) Suggest two ways of increasing the rotating speed of the coil. (2 marks)

*(d) A student says "If the battery in Figure 7 is replaced by a 50 Hz a.c. supply, the coil will only oscillate to and fro. Hence the motor will not function properly."

Explain why the student is incorrect. (5 marks)

(e) Describe, with the help of a diagram, how the motor in Figure 7 can be converted to a direct current generator. (3 marks)

10. 1999/I/1
Figure 1 shows the front view of a socket and the earth (E), live (L) and neutral (N) wires of the 220 V mains supply.

(a) Copy Figure 1 into your answer book and show how the socket is connected to the mains supply. (2 marks)

(b) Copy Figure 2 into your answer book and show how the electrical appliance is connected to the mains supply. (2 marks)

Figure 2 shows the label attached to an electrical appliance. If the appliance is switched on for 150 hours in a month, calculate the cost of electricity. (Given: 1 kWh of electricity costs $0.87.) (2 marks)

11. 1999/I/4

Figure 4 shows the structure of a moving-coil microphone. Describe the working principle of the microphone (i.e. how the microphone works when someone speaks in front of it). (5 marks)

12. 2000/I/6
A rectangular coil is free to rotate in a magnetic field as shown in Figure 5. Initially the coil lies horizontally. The switch is now closed.

(a) State the initial direction of rotation of the coil as seen by the observer. (1 mark)

*b(b) The coil turns, oscillates a few times about the vertical position and then comes to a rest. Explain the motion of the coil. (5 marks)

13. 2000/I/10

(a) A transformer is used to operate a ‘110 V, 1000 W’ electric cooker at its rated value from the 220 V a.c. mains supply in Hong Kong. The primary coil of the transformer has 5000 turns and the efficiency of the transformer is 80%. Find

(i) the number of turns in the secondary coil of the transformer,
(ii) the operating resistance of the cooker,
(iii) the power input of the transformer,
(iv) the current flowing in the primary coil of the transformer. (8 marks)

(b) Figure 14 shows a travel cooker and the label attached on it. The cooker has a voltage selector switch as shown in Figure 15.

Model No : EA 2000
a.c. 120 V/240 V
360 W
~50-60 Hz

Figure 14

Voltage

120 V
240 V

Figure 15

(b) (i) A fuse is installed in the cooker. Explain the function of the fuse. (2 marks)

*(ii) Two students make the following remarks about using the cooker in Hong Kong:
John: The voltage selector switch should be set to 120 V and the output of the cooker would be 360 W.
Peter: The voltage selector switch should be set to 240 V and the output of the cooker would be less than 360 W.

Explain whether each of the above remarks is correct. (5 marks)
Figure 4 shows how electrical power generated in a power station is transmitted over long distances to consumers.

(a) State the function of the transformer $T_1$.  

(b) Explain why a.c. and high voltages are used for long distance power transmission.

Mary wants to estimate the efficiency of an electric water heater in her kitchen. She uses a container to collect the water and a thermometer to measure the temperature (see Figure 9). She finds that when the heater is switched on, 1.6 kg of water at 23°C is heated to 67°C in one minute. The rating of the heater is ‘220 V, 6000 W’ and the specific heat capacity of water is 4200 J kg$^{-1}$ K$^{-1}$.

(i) Find the energy absorbed by the 1.6 kg of water in one minute.  
(ii) Estimate the efficiency of the heater.  
(iii) State one reason to explain why the efficiency found in (ii) is less than 100%.

(b) Figure 10 shows a household electrical wiring circuit. The mains cable (containing live and neutral wires) is connected to a consumer unit via a meter M. At the consumer unit, the wires branch out into a number of parallel circuits. Figure 10 also shows the power circuit in the kitchen. It is in the form of a ring circuit with three sockets tapped off from the ring.

(i) Name the meter M. What physical quantity does the meter record?
The following appliances are connected to the ring circuit in the kitchen:

**Rating**
- a refrigerator: 220 V, 600 W
- an electric kettle: 220 V, 2000 W
- an oven: 220 V, 1500 W

If the appliances are all switched on, find the total current drawn from the mains supply. (3 marks)

(iii) Explain why the water heater mentioned in (a) is not connected to the sockets in the ring circuit but directly connected to the mains via a separate circuit. (2 marks)

(iv) State one advantage of the ring circuit arrangement. (2 marks)

16. 2001/I/10

A spring is hanging freely from the ceiling and John stretches the spring with his hand as shown in Figure 11. It is known that the extension of the spring is directly proportional to the stretching force (see Figure 12).

(a) Using Figure 12, find the stretching force if the extension of the spring is 5 cm. (1 mark)
(b) John wants to use a voltmeter to measure the force he applies to stretch the spring. He sets up a device as shown in Figure 13. \( XY \) is a uniform resistance wire of length 20 cm and \( P \) is a metallic sliding contact. \( XY \) is fixed vertically and \( P \) can slide smoothly along \( XY \) as the spring is stretched. The voltage of the battery is 4.5 V and the resistance of \( XY \) is 20 W. The resistance of the variable resistor is set to 40 W. \( P \) touches end \( X \) of the wire when the stretching force is zero.

(i) Draw a circuit diagram for the circuit in Figure 13. (4 marks)

(ii) Show that the voltmeter reads 1.5 V when \( P \) touches end \( Y \) of the wire. (2 marks)

(iii) If the voltmeter reading is 1.2 V, find

1. the distance of \( P \) from end \( X \),
2. the stretching force. (4 marks)

*(iv) John finds that the device is not sensitive enough (i.e. the voltmeter reading shows no observable change when he slightly alters his stretching force). In order to increase the sensitivity, he suggests reducing the resistance of the variable resistor. Explain whether John’s suggestion is appropriate. (4 marks)

17. 2002/I/6

A soft-iron rod is inserted into a solenoid \( AB \), which is connected to a battery and a switch \( S \). Initially \( S \) is open. An aluminium ring is also inserted into the rod and placed beside the solenoid as shown in Figure 8. \( S \) is now closed.

(a) State the polarity at end \( B \) of the solenoid. (1 mark)
*(b) Explain why the aluminium ring will move away from the solenoid.  

18. 2002/I/7a,b

In a science project competition, a student constructs a hand-dryer. He connects an electric fan of rating ‘20 W, 24 V’ and a heating coil to a 24 V power supply (see Figure 9). When switch S is closed, the fan will operate at its rated value.

(a) Are the fan and the heating coil connected in series or in parallel? Explain your answer.  
(b) If the output power of the heating coil is 200 W, find
   (i) the operating resistance of the heating coil,
   (ii) the total current drawn from the power supply when S is closed.

19. 2003/I/6

Figure 5 shows a battery-powered electric fan. Mary wants to construct a simple generator from the fan. She removes the motor of the fan and connects it to a light bulb (see Figure 6). When the blades of the fan are turned rapidly, the bulb lights up.

(a) Name two essential components of a motor.  
*(b) Explain why the bulb lights up when the blades are turning.
Figure 10 shows a travel steam iron with a rated power output of 1100 W. The water tank in the iron is filled with water. When the iron is turned on, water drips continuously from the tank to a hot plate inside the iron, generating steam for ironing clothes. Assume the initial temperature of the water drops is 20°C.

Given: specific heat capacity of water = 4200 J kg\(^{-1}\) \(^\circ\text{C}^{-1}\),

specific latent heat of vaporization of water = 2.26 \(\times\) \(10^6\) J kg\(^{-1}\).

(a) Calculate the energy required to vaporize 1 kg of water at 20°C into steam. (2 marks)

(b) Assume that 80% of the power output of the iron is used to generate steam. Estimate the maximum mass of steam that can be generated by the iron in 1 s. (2 marks)

(c) The iron is designed to operate at 220 V or 110 V with the same power output of 1100 W.

(i) In each of the following cases, find the resistance of the heating element of the iron:

1. when operating at 220 V,
2. when operating at 110 V. (3 marks)

(ii) The heating element of the iron consists of two identical resistance wires as shown in Figure 11.

1. Draw two diagrams to show how the resistance wires are connected when the iron is operating at 220 V and at 110 V respectively. (3 marks)
2. What is the resistance of each resistance wire? (1 mark)

*(iii) A tourist switches the iron to the 220 V mode but connects it to a 110 V supply. Explain whether the iron can function normally. (4 marks)
An engineer designs an electric vehicle. The vehicle is driven by a power pack which consists of six identical 12 V batteries. The power pack provides an operating voltage of 72 V and can supply a total energy of $8 \times 10^7$ J to drive the car. Test results indicate that when the vehicle is travelling at a uniform speed of 45 km h$^{-1}$ along a straight horizontal road, the total energy required to overcome the air resistance and friction in travelling a distance of 1 km is 225 kJ.

(a) Should the six batteries be connected in series or in parallel? (1 mark)

(b) Assume that 60% of the energy supplied by the power pack is used to overcome air resistance and friction.

(i) Based on the test results, estimate the farthest distance travelled by the vehicle when travelling at a uniform speed of 45 km h$^{-1}$. (2 marks)

(ii) State one reason why the actual distance travelled is smaller than that found in (b)(i) when the vehicle is put to use in practical situations. (1 mark)

(c) When the energy stored is used up, the power pack is connected to a charger operating at 220 V and an average current of 13 A. Assume there is no energy lost in the charging process.

(i) Estimate the time required to recharge the power pack fully. (3 marks)

(ii) If one kWh of electrical energy costs $0.92, calculate the cost of recharging the power pack fully. (2 marks)

*(d) Describe the energy changes involved when the vehicle is accelerating along a straight horizontal road. (5 marks)

(e) State one advantage of electric vehicles over petrol-driven vehicles. (1 mark)

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22. 2004/I/10

![Diagram](image_url)

**Figure 16**
Figure 16 shows an electric toothbrush. It consists of a brush unit and a charging unit.

(a) Inside the brush unit, there is a 1.2 V rechargeable cell for driving a motor. When the toothbrush is in operation, the current flowing through the motor is 1.8 A. Calculate
   (i) the power consumed by the motor, and
   (ii) the energy consumed by the motor in 3 minutes. (4 marks)

(b) When the energy stored in the cell is used up, the brush unit is placed on the charging unit to recharge the cell. The charging unit is connected to the mains supply and its label is also known in Figure 16. It takes 16 hours to recharge the cell fully. Calculate the energy drawn by the charging unit from the mains supply in 16 hours. (2 marks)

(c) The cell inside the brush unit is connected to coil X located at the bottom of the unit. Another coil Y is located inside the charging unit with a soft-iron bar fixed inside it (see Figure 16). When the brush unit is placed on the charging unit, the soft-iron bar lies inside coil X.

*(i) The brush unit and the charging unit are completely covered by plastic cases and there is no metal contact between them. Explain how a current is produced in the brush unit to recharge the cell. (4 marks)

(ii) If coil Y has 11 000 turns, estimate the number of turns of coil X. Assume the output voltage of coil X is 3 V a.c. (2 marks)

(iii) State the function of the soft-iron bar. (1 mark)

(d) The charging unit is fitted with a two-pin plug (see Figure 16).
   (i) To which two wires of the mains supply should the pins of the plug be connected? (1 mark)
   (ii) Suggest one reason why it is safe for the charging unit to be fitted with a two-pin plug. (1 mark)

23. 2005/I/9

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 \( \sqrt{\text{V}} \) 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.

(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. (2 marks)

(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. (3 marks)
24. 2005/I/10b

*(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.

![Diagram of earpiece]

(4 marks)

25. 2005/I/11

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 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 $\Omega$
- Rate of air flowing through the dryer = 0.05 kg $s^{-1}$
- Temperature of air flowing into the dryer = 20$^o$C
- Specific heat capacity of air = 1000 J kg$^{-1}$C$^{-1}$

![Diagram of hairdryer and circuit diagram]
Estimate the temperature of the air flowing out of the dryer, and 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)

26. 2005/I/12

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>$V_1$ / V</th>
<th>$V_2$ / 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>

(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. (3 marks)

27. 2006/I/6b,c

(b) Using the information in Table 2,
   (i) estimate the energy required to heat a full tank of water from 15°C to 65°C, (2 marks)
   (ii) hence estimate the current drawn by the water heater when it is operating at 220 V. (3 marks)

(c) Explain why thick wires are used to connect the water heater to the mains supply. (2 marks)

28. 2006/I/7

In a physics lesson, you are asked by the teacher to investigate the relationship between the strength of an electromagnet and the number of turns of its coil by using the apparatus shown in Figure 13. Describe the procedure for the experiment you should conduct. State clearly how you can measure the strength of the electromagnet. (6 marks)
A teacher gives Jane a sealed box in which a light bulb is connected to a variable resistor. The teacher asks Jane to find out how the bulb and the variable resistor are connected together inside the sealed box. Jane then sets up a circuit as shown in Figure 22. She reduces the resistance $R$ of the variable resistor and records the changes as shown in Table 6.

<table>
<thead>
<tr>
<th>Data:</th>
<th>Voltage of the power supply = 3 V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial value of $R = 15 \Omega$</td>
</tr>
<tr>
<td></td>
<td>Final value of $R = 5 \Omega$</td>
</tr>
<tr>
<td></td>
<td>Initial ammeter reading = 2.6 A</td>
</tr>
<tr>
<td></td>
<td>Final ammeter reading = 3.0 A</td>
</tr>
</tbody>
</table>

Observation: Brightness of the bulb remains unchanged

Table 6

(a) (i) Jane correctly concludes that the variable resistor and the bulb are connected in parallel inside the box. Give a reason to support Jane's conclusion. (1 mark)

(ii) In the space provided below, draw a circuit diagram to illustrate how the apparatus in Figure 22 are connected, including the components inside the box. Use the symbol $\text{--}\text{-}\text{--}$ to denote the low voltage power supply. (2 marks)

(iii) Using the data in Table 6, find the resistance of the bulb.

*(b)* Jane's classmate Mary conducts the same experiment by replacing the low voltage power supply with two 1.5 V dry cells which are connected in series. If the internal resistance of the dry cells is not negligible, explain why the brightness of the bulb decreases when $R$ is reduced. (4 marks)

(c) The teacher asks Mary, "What happens if the variable resistor is set to zero?"

"The light bulb will burn out," Mary answered. Explain whether Mary's answer is correct. (2 marks)
30. 2007/I/7

A teacher conducts an experiment to study the energy conversion of a filament light bulb. A simple circuit is connected (see Figure 11) and the bulb is immersed into 0.09 kg of oil inside a foam cup (see Figure 12). The bulb is lighted up for 300 s, and the temperature of the oil is increased from 20°C to 42°C.

In the experiment, the ammeter and voltmeter readings are 1.4 A and 12 V respectively. The specific heat capacity of the oil is 2100 J kg\(^{-1}\) °C\(^{-1}\).

(a) Calculate the energy absorbed by the oil. 

(b) Describe the energy conversion when a current passes through the filament light bulb.

(c) (i) Estimate the amount of energy that is converted into light energy in the experiment, and state ONE assumption made in your calculation.

(ii) Hence, determine the percentage of electrical energy consumed by the filament light bulb that is converted into light energy.

31. 2007/I/11

A copper rod PQ is hung at rest by insulating threads in a uniform magnetic field pointing into the paper (see Figure 18). The other ends of the threads are connected to a spring balance fixed on the ceiling. The two contacts P and Q at the ends of the copper rod can slide smoothly along two fixed vertical conducting rails AB and CD. The rails AB and CD are connected to the positive and the negative terminals of a d.c. power supply respectively. As a result, a current I passes through the copper rod.

Assume that the copper rod always remains horizontal and does not leave the magnetic field throughout the experiment.
(a) (i) In Figure 18, indicate the direction of the Force $F$ acting on the copper rod due to the current passing from $P$ to $Q$. 
(1 mark)
(ii) Suggest THREE methods to increase the force $F$. 
(3 marks)
(iii) Express the magnitude of force $F$ in terms of the reading $R$ of the spring balance and the weight $W$ of the copper rod. 
(1 mark)

(b) A teacher conducts an experiment with the setup in Figure 18 to find out how the reading $R$ of the spring balance changes with the current $I$. Table 2 shows the data collected.

<table>
<thead>
<tr>
<th>$R$ / N</th>
<th>1.4</th>
<th>1.1</th>
<th>0.8</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I$ / A</td>
<td>0.0</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

(i) Plot a graph of $R$ against $I$ in Figure 19. A scale of 1 cm representing 0.25 N and 0.25 A is used. 
(4 marks)

(ii) Find the weight of the copper rod. 
(1 mark)
(iii) Find the maximum value of $I$ such that the insulating threads remain taut. 
(1 mark)
(iv) If the experiment is replaced is repeated with a heavier copper rod, sketch a graph of $R$ against $I$ you would expect to obtain in Figure 19, and label it as $L$. 
(2 marks)
32. 2007/I/12

Figure 20 shows a setup to generate electricity. A magnet is set into rotation between two fixed solenoids. The output terminals \( X \) and \( Y \) are connected to a light bulb.

\( \begin{align*}
\text{axis of rotation} \\
\text{fixed solenoid} \\
\text{magnet} \\
\text{fixed solenoid} \\
\end{align*} \)

*Figure 20*

*(a) Explain how alternating current is generated in the above setup. (4 marks)*

(b) The bulb is now removed from the setup. \( X \) and \( Y \) are then connected to the primary coil of a transformer. The secondary voltage output of the transformer is found to be 12 V. If the turns ratio of the primary coil to the secondary coil is 1 : 8, find the primary voltage. (2 marks)

(c) State the advantages of using
   (i) a.c., and
   (ii) high voltages
   for long distance power transmission. (2 marks)

33. 2008/I/7

Figure 10 shows a ceiling lamp in Jack’s home. The lamp has two filament light bulbs, each rated "220 V 40 W". The lamp is turned on or off by a switch (see Figure 11) on the wall.

\( \begin{align*}
\text{filament light bulbs} \\
\text{Figure 10} \\
\text{Figure 11} \\
\end{align*} \)

(a) Give two advantages of connecting the two light bulbs to the 220 V mains supply in parallel. (2 marks)

(b) Explain why the switch should be connected to the live wire of the main supply. (2 marks)

(c) Jack decides to replace each filament light bulb with an energy saving bulb of the same brightness. Table 2 shows the details of the two kinds of bulbs. Considering the price of the bulbs and the electricity fee, find the total money saved per energy saving bulb after operating for 4000 hours.
Figure 12 shows the simplified structure of a motor with the plane of the coil at horizontal position. At this moment, it carries a current in the direction indicated by the arrow.

(a) Mark the direction of the magnetic force acting on the side $AB$ in Figure 12. (1 mark)

(b) Explain how the commutator helps to keep the coil rotating in one direction. (2 marks)

(c) When the coil reaches the vertical position, the current is zero. Explain why the coil keeps on turning even no magnetic force is acting on it. (1 mark)
(d) If the coil is not fully inserted between the magnets as shown in Figure 13, describe and explain how this would affect the motion of the coil. Assume the current is the same as before. (1 mark)

35. 2008/I/11
A student uses the setup in Figure 21 to study the current induced in a solenoid when a magnet is falling through it. When a current is passing through the current sensor from A to B, a positive reading is obtained. Figure 22 shows the result after the magnet is released at a certain height.

Figure 21

Figure 22

(a) State the polarity of end Y of the magnet. (1 mark)

(b) Explain why the reading of the induced current is negative when the magnet leaves the solenoid. (4 marks)

(c) Explain why the magnitude of "negative peak" is greater than that of "positive peak". (2 marks)