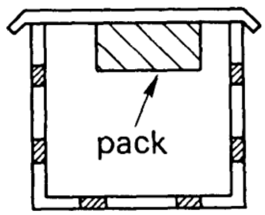
**Name:** **Index No:**

**Date:** **Class:**

## Assignment 09: Thermal processes

1. A pack, which contains a frozen liquid, is placed in a holder under the lid of a box as shown in the diagram. The box is then used to keep the food cold.




(a) Suggest why the frozen pack is placed at the top of the box rather than at the bottom. [3]

When air at the top of the box is cooled, it contracts, becomes denser than surrounding air and sinks. [1]

The warmer and less dense part of air at the bottom of the box rises to replace it and is in turn cooled. [1]

Convection currents are set up due to density difference to keep the food cool. [1]

(b) Why does the food keep cold longer if the walls of the box are made

(i) of rigid plastic rather than of metal, [2]

Plastic is a good thermal insulator/poor thermal conductor/has low thermal conductivity. [1]

Rate of energy conducted from outside environment to food inside the box is decreased, thus the food keeps cold longer. [1]

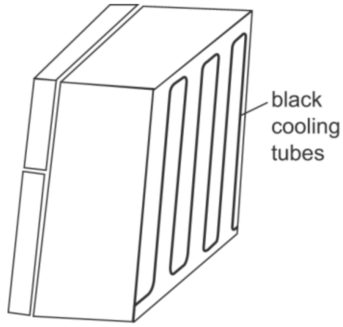
(ii) double-layered? [2]

The double-layered walls trap a layer of air within. Since air is a good thermal insulator/poor thermal conductor/has low thermal conductivity [1],

Rate of energy conducted from outside environment to food inside the box is decreased, thus the food keeps cold longer. [1]

[Note: Must state direction of energy transfer!]

2. The diagram shows the back of a refrigerator. There are some cooling tubes painted black.




(a) Explain why the cooling tubes are painted black. [1]

Black **surfaces** are good **emitters** of thermal radiation / to increase the rate of emission of thermal radiation. [1]

[Reject: Black surfaces are good absorbers of thermal radiation. / Black surfaces are good emitters and good absorbers of thermal radiation. / Black is a good emitter of thermal radiation.]

(b) Explain why the cooling tubes are coiled. [1]

Coiling the cooling tubes increases the total surface area in which thermal radiation is emitted.

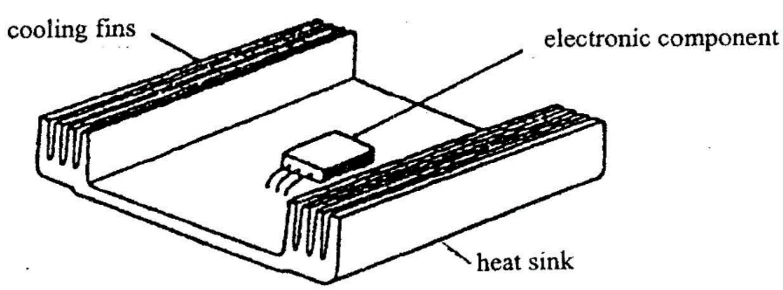
(c) Why is there a need to keep some space between the back of the refrigerator and the wall? [2]

Walls are poor thermal conductors. / Thermal radiation cannot be conducted away quickly by the walls. [1]

The space enables thermal radiation from the tubes to be transferred away more effectively by convection. [1]

Comparison of data:
Thermal conductivity of air: 0.024 W $m^{-1}$ $K^{-1}$
Thermal conductivity of brick for building: 0.6 to 1.0 W $m^{-1}$ $K^{-1}$

3. Electronic components can be damaged by overheating. To overcome this problem, the component is mounted on a 'heat sink' as shown in the diagram below. This is often in the form of a piece of aluminium of mass greater than that of the component.




The purpose of the 'heat sink' is to absorb surplus heat produced by the electric current in the component and transfer this heat to the surroundings.

(a) Suggest reasons for

(i) making the 'heat sink' from aluminium, [1]

Aluminium is a <u>good thermal conductor/has high thermal conductivity.</u> [1]

(ii) having cooling fins on the 'heat sink'. [1]

The cooling fins <u>increase surface area</u> of 'heat sink' so that <u>rate of emission of thermal radiation</u> to the surrounding is <u>increased</u>. [1]

(b) What colour should the 'heat sink' be painted? Explain your answer clearly. [2]

It should be <u>painted black</u> [1]. <u>Black surfaces are good emitters of thermal radiation</u> [1].

(c) The contact between the heat sink and the electronic component may not be optimal due to an air gap. As such, some thermal paste is usually applied between the heat sink and the electronic component. It is found that the electronic component did not overheat when the thermal paste is applied whereas the electronic component overheated when the thermal paste is not applied. The thermal paste is not electrically conducting.

Explain how the application of the thermal paste prevents overheating. [2]

Air has a <u>lower thermal conductivity</u> than thermal paste. [1]

The thermal paste <u>increases rate of energy conducted from component to surroundings</u> and prevents overheating. [1]

<u>Comparison of data:</u>
Thermal conductivity of a high-grade thermal paste: 8.5 W $m^{-1}$ $K^{-1}$
Thermal conductivity of aluminum: 205 W $m^{-1}$ $K^{-1}$

4. Fig. 4.1 shows a kind of cloth lantern in China. It consists of two parts, the outer part and the inner part. A candle is placed at the centre of the lantern and pictures are painted on the inner part and outer part of the lantern. Above the candle, some blades are connected to the inner part of the lantern (See Fig 4.2.) and the inner part rotates continuously when the candle is lit.

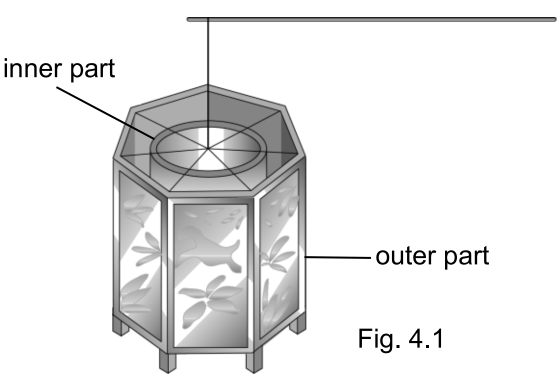



Fig. 4.1

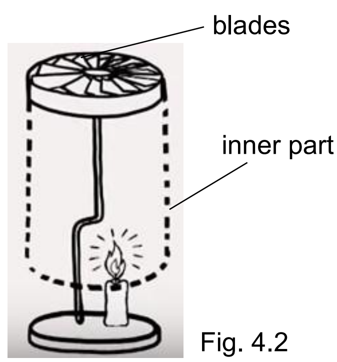



Fig. 4.2

Watch to help you visualize how it works:

Source: https://www.youtube.com/watch?v=3RpevU9FzVM

(a) When the candle is lit, why is the inner part able to rotate? [2]

When the candle is lit, the <u>air above it heats up and rises</u> and <u>cooler surrounding air sinks</u> and replaces it. [1]

This <u>pushes/spins/exerts a force on the blades</u> and rotates the inner part. [1]

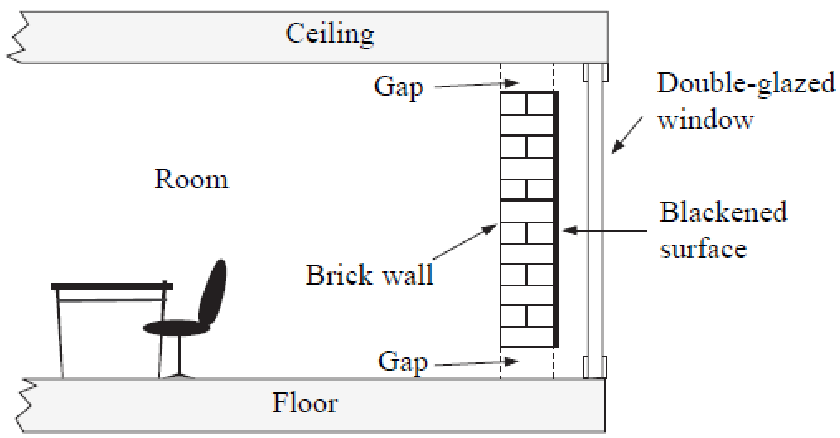
(b) Name the two main thermal processes of energy transfer in the lantern. [2]

Convection (of air around the lantern) [1]
Thermal Radiation (from emission of thermal radiation from candle) [1]

(c) If the candle is replaced with an LED bulb which produces much less heat than a candle, explain whether there will be any change in the motion of the rotating inner part of the lantern. [2]

Speed of rotation of inner part of lantern decreases / there is little or no rotation. [1]
Minimal convection current produced in the lantern. [1]

5. The diagram shows a method of heating a room using solar energy instead of using a heater. A brick wall with a blackened surface is placed behind a double-glazed window facing the sun. During a sunny day, the wall absorbs energy from the sun and its temperature rises.




(a) Why is the surface of the wall blackened? [1]

A black surface is a good absorber of thermal radiation [1]. (Reject: Good emitter of thermal radiation)

(b) Name one method by which energy from the blackened surface is transferred to the air next to it. [1]

conduction or radiation [1]

(c) The double-glazed window consists of two sheets of glass which trap a layer of air between them. Explain how using a double-glazed window increases the rate at which the temperature of the room rises. [2]

Layer of air is a good thermal insulator. [1]
Rate of energy transferred from room to outside environment is decreased, thus increasing the rate of temperature rise in the room. [1]

(d) Give one advantage and one disadvantage of using this method to heat the room instead of using a heater. [2]

Advantage: ..........................................................................................................
No pollution/does not use fossil or non-renewable fuels/renewable energy/does not use electricity [1]

Disadvantage: ......................................................................................................
(more) expensive to build/ no heat at night / too much heat in summer/ rooms overheated on hot days/ less heat in winter/less heat if cloudy/temperature can't be controlled [1]

6. A student investigated the properties of three types of insulation. Fig. 6.1 shows the apparatus the student used. In the investigation, different insulating materials were placed in contact with the hot metal plate. Temperature probes measured the temperature on each side of the material. The temperature probes were connected to a data logger.

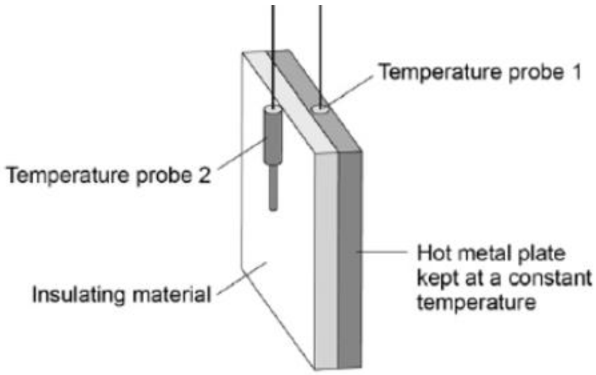



Fig. 6.1

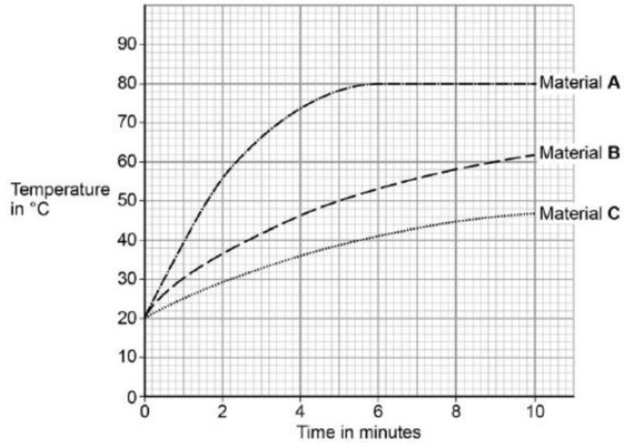



Fig. 6.2

Fig. 6.2 shows the graph of how the temperature measured by temperature probe 2 changes over 20 minutes for each of the materials.

(a) What was the temperature of the hot metal plate? [1]

80°C

……………………………………………………………………………………………………………

(b) Which material (A, B or C) is the best insulator? Explain why. [2]

C is the best insulator. [1]

Rate of increase in temperature is lowest / Temperature increases at slowest rate [1] as rate of energy conducted from hot metal plate to probe 2 is lowest.

(c) Another student repeated the investigation but doubled the thickness for all three insulating materials. Suggest how using thicker insulation would affect the results of the second student's investigation compared with the first student's results. [1]

As thickness increases, rate of conduction (or energy transfer) decreases.

The materials will take a longer time, as compared to the first experiment, to reach 80 °C. / Temperature increases as a slower rate for all three materials. [1]

(d) Using the table, explain which material would be the best to use in cavity wall insulation. [2]

| Type of insulation | Thermal conductivity in W/m °C |
|---|---|
| Felt wool | 0.070 |
| Mineral wool | 0.040 |
| Polyurethane foam | 0.030 |
| Rock wool | 0.045 |

Polyurethane foam [1]

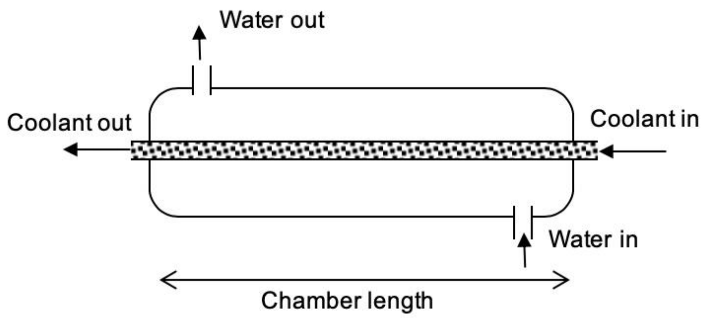
It has the lowest thermal conductivity, thus rate of energy transferred through it is lowest. [1]

7. Energy is transferred from more energetic to less energetic molecules when neighbouring molecules collide. Conductive heat flow occurs in direction of the decreasing temperature since higher temperature is associated with higher average kinetic energy.

The rate of conductive heat flow, Q/t, is given as follows:

$$\frac{Q}{t} = \frac{kA(T_2 - T_1)}{d}$$

where
$k$: thermal conductivity of material, W $m^{-1}$ $K^{-1}$,
$A$: area, in $m^2$,
$d$: material thickness, m
$T_2$ - $T_1$: temperature difference across the material, in K or °C




Tubes in a heat exchanger

The thermal conductivity of copper is 401 $Wm^{-1}K^{-1}$.
In a heat exchanger, copper tubes that have a thickness of 0.003 m and diameter of 0.025 m are used. Every second, 126 kJ of energy is to be conducted from the water in a chamber to the coolant in the copper tubes.

(a) Determine the rate of conductive heat flow, in Watts, between the water and the coolant. [2]

Rate of conductive heat flow = 126 000 J / 1 s [1]
= 126 000 W [1]

(b) If the average temperature of the coolant is 8.0°C and that of the water is 10.0 °C. Calculate the required length of copper tube. [2]

$$\frac{Q}{t} = \frac{kA(T_2 - T_1)}{d}$$

$$126\ 000 = \frac{(401)(L)(0.025)\pi(10.0 - 8.0)}{0.003} \quad [1]$$

$L$ = 6.0 m [1] [Accept: 6 m]