O Level Pure Physics Structured

Thermal Properties of Matter Test 1.0

Q1

The boiling point of nitrogen is –196 °C.

(a) State what is meant by *boiling point* of nitrogen is –196 °C.

....

.... [1]

(b) The energy of liquid nitrogen changes as it turns into a solid at the melting point. State and explain how the energy changes, using ideas about molecules.

....

....

.... [2]

(c) The liquid nitrogen reaches –196 °C, its boiling point. A small piece of metal at 20 °C is lowered slowly into the liquid nitrogen. The small piece of metal has a mass of 50 g. When it is lowered into the liquid nitrogen, the metal cools to –196°C.
The specific heat capacity of the metal is 390 J/(kg°C).
The specific latent heat of vaporisation of nitrogen is 200 J/g.
Calculate the mass of nitrogen that boils away when the metal is placed in it.

mass = ... [3]

Q2

Fig. 11.1 shows the circuit diagram of a hairdryer. A motor-driven fan and a heating element are used to generate warm air. The hairdryer is connected to a 240 V a.c. supply.
Switch S can be connected to either contact X or Y.

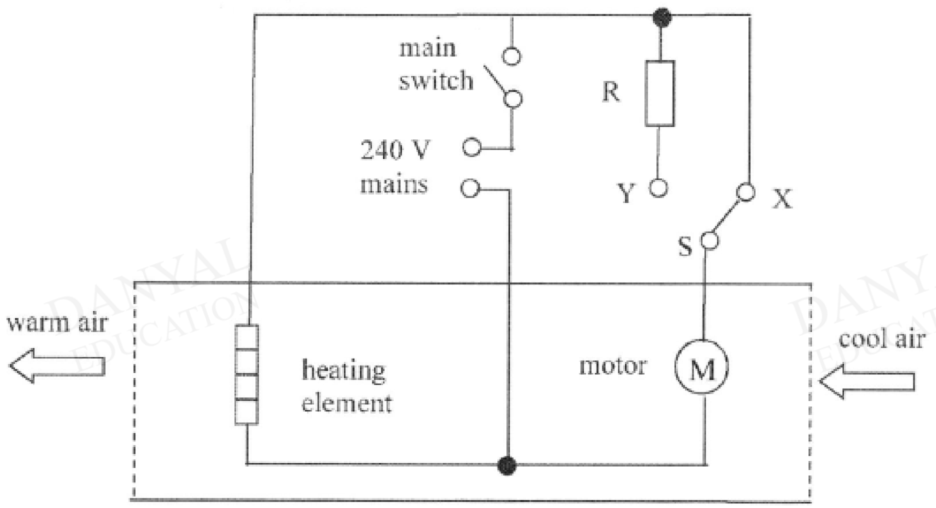

Fig. 11.1

(a) The hairdryer is used to dry wet hair. Explain, using kinetic model of particles, how the hairdryer can increase the rate of evaporation of water from the wet hair.

....

....

....

.... [3]

(b) During quality control tests of the hairdryer in the factory, switch S is first connected to contact X. Some measurements are made to obtain the data shown in **Fig. 11.2**.

resistance of the heating element	30 Ω
resistance of resistor R	20 Ω
temperature of air entering the hairdryer	25 °C
rate of air flow through the hairdryer	0.055 kg/s
specific heat capacity of air	1 000 J/kg°C

Fig. 11.2

(i) Estimate the temperature of the air flowing out of the hairdryer.

temperature = ... [2]

(ii) State one assumption in your calculation.

....

.... [1]

(c) Switch S is then connected to contact Y. State and explain how this change will affect the speed of the motor-driven fan.

....

....

.... [2]

(d) Calculate the cost of using the hair dryer for 10 minutes if the hair dryer is set to the lower heating setting and the cost of electricity is 20 cents per kWh.

cost = ... [2]

Q3

Fig. 5.1 shows the heating curve of a substance X. The mass of X is 200 g and the heater used is rated at 100 W.

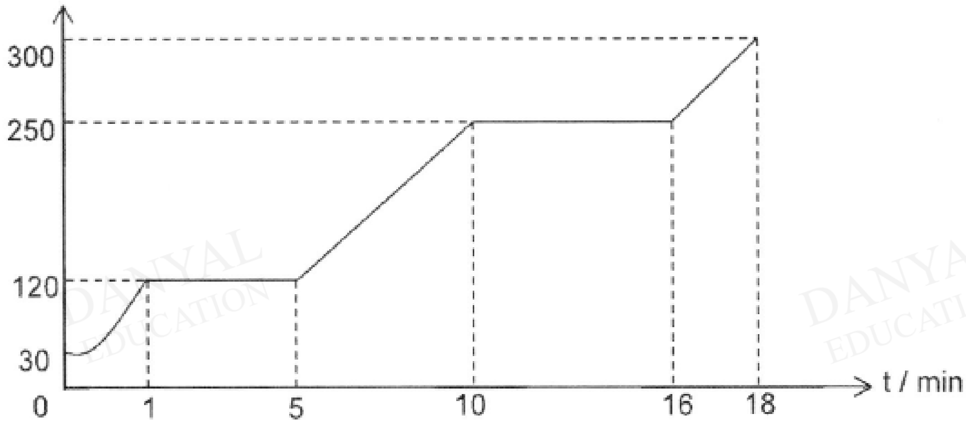

Fig. 5.1

(a) Define *specific heat capacity.*

____

____ [1]

(b) Calculate the specific heat capacity of liquid X.

specific heat capacity of liquid X = _______________ [2]

(c) Using the kinetic theory of matter, explain why the temperature remains constant from t = 10 min to t = 16 min.

____

____

____

____ [2]

(d) Calculate the specific latent heat of vaporisation.

specific latent heat of vaporisation = _______________ [2]

Q4

Cappuchino is an Italian, coffee-based drink prepared with espresso (a type of coffee), steam milk and milk foam. To make steamed milk, hot steam is passed into the cold milk to heat up the milk. Fig. 11.1 shows a machine where hot steam is passed into the milk.

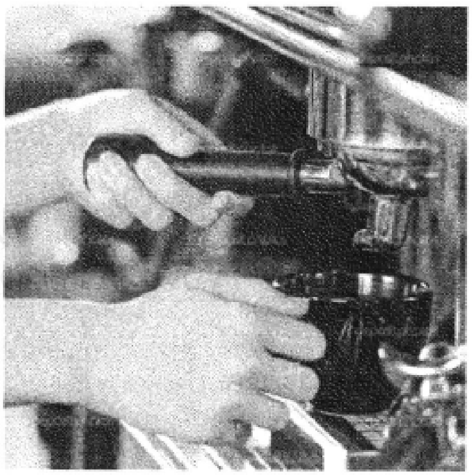

Fig. 11.1

Table 11.1 and 11.2 shows some of the specific heat capacities for different substances. You may assume that milk and water have the same specific heat capacity.

Substances	Specific heat capacity / J kg $^{-1}$ °C $^{-1}$
Glass	837
Ice	2090
Water	4200
Steam	2010

Table 11.1

Substance	Melting point / °C	Specific latent heat of fusion / J kg $^{-1}$	Boiling point / °C	Specific latent heat of vaporization /J kg $^{-1}$
Water	0.0	3.3×10^5	100	2.26×10^6

Table 11.2

(a) Define the term specific heat capacity of a substance. **[1]**

____

____

____

(b) Suggest why the value of the specific latent heat of vaporisation is higher than the specific latent heat of fusion of water. **[1]**

____

____

____

(c) 300 g of milk is poured into a 100 g of glass container. With the aid of the information from Table 11.1 and 11.2,

(i) calculate the thermal energy required to warm the 300 g of milk in a 100 g of glass container from 20 °C to 55 °C. **[2]**

(ii) if hot steam of initial temperature 120 °C is used to warm the 300 g of milk in a 100 g of glass container instead, calculate the minimum mass of steam required to heat the milk and the container from 20 °C to 55 °C. **[2]**

(d) A person suggested to use a 10.0 kW heating lamp to heat up a cup of milk as shown in Fig. 11.2. However, he found that this process of heating up 250 g of milk in the 150 g of glass container from 20 °C to 40 °C is only 5.0 % efficient.

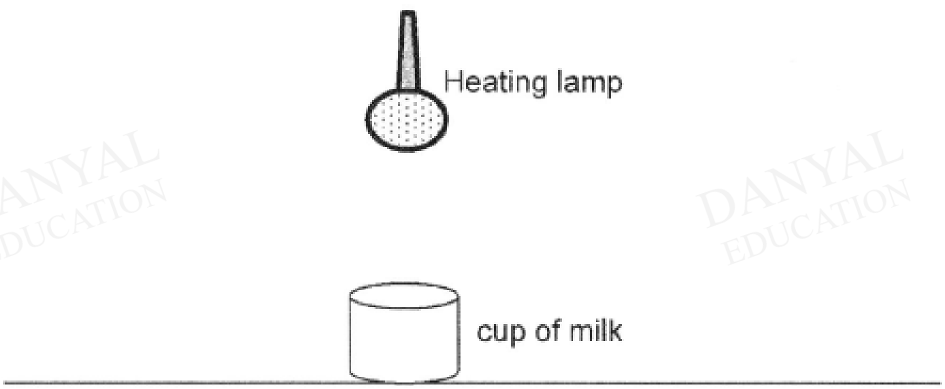

Fig. 11.2

(i) State the main mode of thermal transfer from the heating lamp to the cup of milk. **[1]**

____

(ii) Suggest a reason for the low efficiency. **[1]**

____

____

____

(iii) Calculate the time required to warm the milk in (d) using the heating lamp. **[2]**

Q5

The label on an electric kettle is marked 220 V, 4.8 kW. One such kettle contains 1.2 kg of water at 20°C. It takes 4 minutes to raise the temperature of the water to 100°C. It takes a further 3.5 minutes to boil away 0.17 kg of the water.

The specific heat capacity of water is 4200 J/kgK.

The specific latent heat of vaporization of water at 100°C is 2300 kJ/kg.

(a) State the meaning of 220 V, 4.8 kW.

....

....[2]

(b) Calculate:

(i) the energy output of the electric element in the kettle in 4 minutes.

energy output = ... [2]

(ii) the energy required to raise the temperature of the 1.2 kg of water from 20°C to 100°C.

energy required = ... [2]

(iii) the energy required to boil away 0.17 kg of water at 100°C.

energy required = ... [1]

(c) Estimate the energy supplied by the electric element

(i) during the first 4 minutes which was not used to increase the temperature of 1.2 kg of water from 20°C to 100°C,

energy = ... [1]

(ii) during the last 3.5 minutes which was not used to boil away the 0.17 kg of water.

energy = ... [1]

(d) Suggest why the energy loss in **(c)(i)** and **(c)(ii)** are different. You may describe the possible energy changes in the body of the kettle.

....

....

....[1]

Answers

Thermal Properties of Matter Test 1.0

Q1

a	Nitrogen hanges from liquid to vapour/ gaseous state at a **constant** temperature of –196 °C [B1]
b	Energy of nitrogen decreases. [B1] Energy is released as intermolecular bonds are formed (or to strengthen forces of attraction between molecules) when liquid solidifies to form a solid. [B1]
c	Energy given out by the metal = $mc\Delta\theta$ Energy given out by the metal = (50/1000)(390)(20 – (-196)) [M1] Energy given out by the metal = 4212 J [M1] Mass of nitrogen = 4212/200 = 21.06 = 21 g [A1]

Q2

a	Hair dryer causes fast moving air molecules to collide with the water molecules on the hair and transfer energy to them. [B1] **More** water molecules increase in KE and they move more vigorously. [B1] Overcome forces of attraction between the remaining molecules and doing work to overcome atmospheric pressure. [B1] OR The water molecules once evaporated from the hair are removed away by the movement of the air molecules from the motor [B1] thus freeing up the space for the remaining water molecules to escape [B1]. OR The water molecules can evaporate at a greater rate at a lower humidity level [B1] as the hot air from the motor reduces the moisture level in the air [B1].
bi	Heat lost by heater in 1 s = heat gained by air in 1 s $V^2/R=mc(\Delta\theta)$ or 2402/30 = 0.055 x 1000 x $\Delta\theta$ [B1] $\Delta\theta$ = 34.9 [B1] Temperature of air flowing out = 34.9 + 25 = 59.9 °C or 60 °C [A1]

bii	Assume room temperature is constant or Assume no heat is lost by the heating circuit to other parts of the circuit or All the heat energy is transferred to the cold air and not lost to the surrounding eg by radiation Or Assume resistance of motor is zero ohm. Any one – [B1]
c	Speed of rotation of the motor decreases and produces moving cool air at a slower rate. [A1] When switch is connected to Y, the addition of resistor R only reduces current flow to the motor. [A1]
d	Total Power of heating element and motor = $240^2/30 + 240^2/20$ = 1920 + 2880 = 4,800 W [B1] Cost = (4,800/1000) x (10/60) x 20 = 16.6 cents [A1]

Q3

5(a)	Specific heat capacity is the amount of thermal energy needed by a unit mass to raise its temperature by 1K or 1°C.	[1]
(b)	$Q = mc\Delta\Theta$ 100 x (5.0 x 60) = 0.20 x c x (250 – 120) c = 1150 $Jkg^{-1}{}^{o}C^{-1}$ (to 3 sig. fig)	 [1] [1]
(c)	During boiling, **energy is absorbed to overcome the forces of attraction between the molecules**, thus **internal potential energy increases and kinetic energy remains constant**. Since K.E. is constant, temperature is also constant.	[1] [1]
(d)	100 x (6 x 60) = 0.20 x l_f l_f = 180 000 J/kg	[1] [1]

Q4

(a)	Specific heat capacity is the amount of thermal energy required to raise the temperature of 1K per unit mass of an object.	B1
(b)	Specific latent heat of vaporisation is higher than the specific latent heat of fusion of water because for water to change state to gas, it requires more energy per unit mass **as the distance between each molecule is much further from water to gas than from solid to water.**	B1
(i)	Thermal energy gained = mc $\Delta\theta$ (milk) + mc $\Delta\theta$ (glass) = $\Delta\theta$ [mc (milk) + mc (glass)] = 35 [(0.3)(4200) + 0.1 x837] = 47029.5 J = 47.0 kJ	M1 A1
(ii)	mc $\Delta\theta$ (Steam 120 °C to 100 °C)+ m lv + mc $\Delta\theta$ (water 100 °C to 55 °C) = T.E gained by the milk and glass m (2010 x 20 + 2.26 x 10^6 + 4200 x 45) = 47029.5 J mass of steam = 0.0189 kg	M1 A1
	= 18.9 g	
(d) (i)	Thermal radiation.	B1
(ii)	Thermal energy from the heating lamp will be transferred to the surrounding air as well hence it explains the low efficiency of this method.	B1
(iii)	E = P x t 5% efficiency 0.05 x(P x t)= mc $\Delta\theta$ (milk) + mc $\Delta\theta$ (glass) 0.05 x 10 000 x t = 0.25 x 4200 x 20 + 0.15 x 837 x 20 t = 47 s	M1 A1

Q5

1(a)	When supplied with a voltage of 220 V, the power output is 4.8 kW	[1] [1]
MC	This question was poorly answered by most students	
(b)(i)	Energy = power x time = 4.8 x 1000 x 4 x60 =1152 kJ	[1] [1]
b)(ii)	Energy = 1.2 x 4200 x 80 =403.2 kJ	[1] [1]
b)(iii)	Energy = 0.17 x 230 000 = 391 kJ	[1]
c)(i)	1152 - 403.2 = 749 kJ(3sf)	[1]
c)(ii)	1152 - 391 = 761 kJ	[1]
MC	Most students were able to answer 11(b) & (c) fairly well.	
(d)	As the kettle gets hotter, there will be increasing heat loss through conduction and convection. These make heating less effective, thus accounting for the increase in unused power in (c)(ii).	[1]