3.1 Thermal Concepts

Question Paper

Course	DP IB Physics
Section	3. Thermal Physics
Topic	3.1 Thermal Concepts
Difficulty	Medium

Time allowed: 70

Score: /56

Percentage: /100

Question 1a

This question is about modelling the thermal processes involved when a person is exercising.

When cycling, a person generates thermal energy but maintains an approximately constant temperature.

(a)
Define thermal energy and temperature and distinguish between the two concepts.

[3 marks]

Question 1b

The following model may be used to estimate the rise in temperature of a cyclist assuming no thermal energy is lost.

A closed container holds 65 kg of water, which represents the mass of the cyclist. The water is heated at a rate of 2000 W for 20 minutes. This represents the energy generation in the cyclist.

(b)
Calculate:

(i)
the thermal energy generated by the heater.

[2]

(ii)
the temperature rise of the water, assuming no energy losses. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

[2]

[4 marks]

Question 1c

The temperature rise calculated in (b) would be dangerous to the cyclist.

(c)
Outline one mechanism, other than evaporation, by which the container in the model would transfer energy to its surroundings.

[2 marks]

Question 1d

A further process by which energy is lost from the cyclist is the evaporation of sweat.

The percentage of generated energy lost by sweating is 40%. The specific heat of vaporization of sweat is 2.26×10^6 J kg^{-1}.

(d)
Using the information above, and your answer to part (b) (i), estimate the mass of sweat evaporated from the cyclist.

[3 marks]

Question 2a

This question is about water as it changes state.

Water at constant pressure boils at a constant temperature.

(a)
Outline, in terms of the energy of the molecules, the reason for this.

[2 marks]

Question 2b

In an experiment to measure the specific latent heat of vaporization of water, steam at 100 °C was passed into water in an insulated container.

The following data are available.

- Initial mass of water in container = 0.260 kg
- Final mass of water in container = 0.278 kg
- Initial temperature of water in container = 20.4 °C
- Final temperature of water in container = 53.4 °C
- Specific heat capacity of water = 4.18×10^{3} J kg^{-1} K^{-1}

(b)
Show that the specific latent heat of vaporization of water is about 1.8×10^{6} J kg^{-1}.

[4 marks]

Question 2c

The accepted value of *L* is greater than that given in part (b).

(c)
Explain why, other than through experimental or calculation error, this is the case.

[2 marks]

Question 2d

The insulated container is replaced with one made of iron and the experiment is repeated with the same starting temperature and masses of steam and water.

After a period of time, the container reaches thermal equilibrium with the water at a temperature of 30.7 °C. The specific heat capacity of iron is 447 J kg^{-1} K^{-1}.

(d)
Assuming no energy is lost to the surroundings, calculate the mass of the container.

[3 marks]

Question 3a

This question is about thermal energy transfers involved in sweating.

(a)
Distinguish between the concepts of temperature and internal energy.

[3 marks]

Question 3b

An athlete loses 2.4 kg of water through sweat whilst training for 2 hours.

(b)
Estimate the rate of energy loss by the athlete due to sweating. The specific latent heat of vaporization of water is 2.3×10^6 J kg^{-1}.

[2 marks]

Question 3c

The athlete sits down to rest on an aluminium chair of mass 40 kg following her training session.

(c)
The temperature of the athlete is 37.8 °C and the temperature of the chair is 293 K. The specific heat capacity of aluminium is 900 J kg^{-1} K^{-1}.

(i)
Outline two properties that can be determined by the relative temperatures of the athlete and the chair.

[2]

(ii)
Calculate the amount of energy transferred to the chair in order to change its temperature to be in thermal equilibrium with the athlete.

Assume the athlete maintains a constant temperature.

[2]

[4 marks]

Question 3d

When the sweat evaporates from the athlete it turns from a liquid to a gas.

(d)
State, in terms of molecular structure and motion, two differences between a liquid and a gas.

[2 marks]

Question 4a

This question is about a slowly melting iceberg.

(a)
Distinguish the difference between liquid water and solid ice, with reference to molecular motion and energy.

[2 marks]

Question 4b

The following data is available regarding an iceberg:

- The iceberg has a density of 920 kg m^{-3}
- The temperature of the iceberg is −25 °C
- The volume of the iceberg is 78 000 m^3
- The specific latent heat of fusion of ice is 3.3×10^5 J kg^{-1}
- The specific heat capacity of ice is 2.1×10^3 J kg^{-1} K^{-1}

(b)
Calculate the energy required to melt the iceberg to form water at 0 °C.

[4 marks]

Question 4c

The Sun supplies thermal energy to the iceberg at an average rate of 450 W m^{--2}. Assume that the iceberg has a consistent surface area of 312 m^2.

(c)
Estimate the time taken, in years, to melt the iceberg, assuming the melted water is immediately removed, and no heat is lost to the surroundings.

[3 marks]

Question 4d

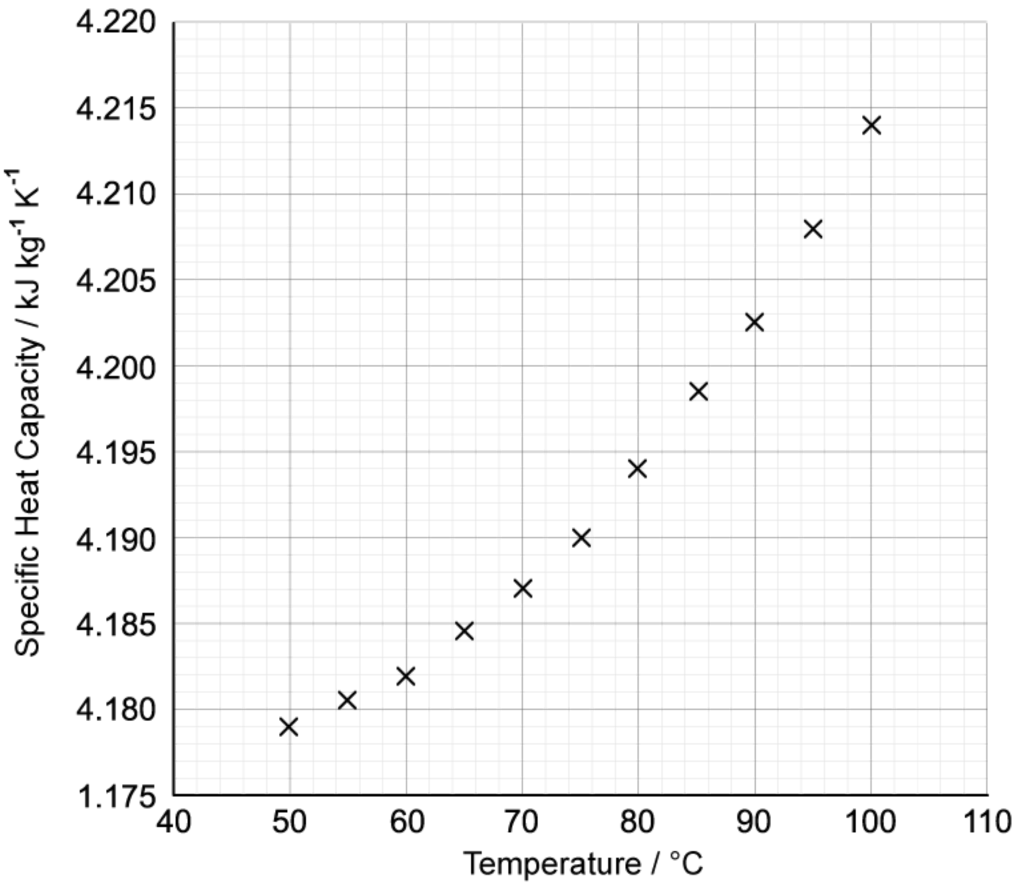
In reality, there is heat transferred between the sea, which is at a temperature greater than 0°C, and the iceberg.

(d)
Outline what effect this will have on the rate of melting of the iceberg.

[2 marks]

Question 5a

This question is about an experiment to examine how the specific heat capacity of water varies with temperature.



(a)
Draw the line of best fit for the data.

[2 marks]

Question 5b

(b)

(i)
Determine the gradient of the line at a temperature of 70 °C.

[2]

(ii)
State the unit for the quantity represented by the gradient.

[1]

[3 marks]

Question 5c

(c)

(i)
Estimate the area under the curve and give the unit.

[2]

(ii)
State what the area represents.

[1]

[3 marks]

Question 5d

(d)

The experiment used water that reached a height of 40 cm in a cylindrical can of diameter 50 cm. The average density of water between 70 °C and 90 °C is 970 kg m^{-3}.

(i)

Estimate the mass of water used in this experiment.

[2]

(ii)

Hence, estimate the amount of energy transferred heating the water from 70 °C to 90 °C.

[1]

[3 marks]