3.1 Thermal Concepts

Question Paper

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

Time allowed: 60

Score: /45

Percentage: /100

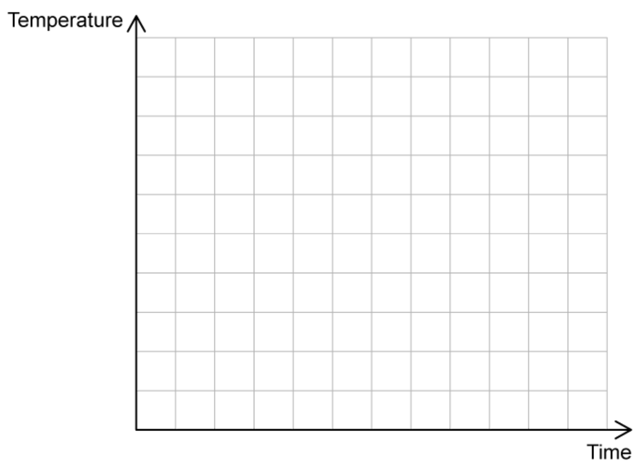
Question 1a

Four identical ice cubes are dropped into a thermally isolated cylinder containing water.

Side length of each ice cube	1.9 cm
Density of ice	920 kg m^{-3}
Initial temperature of ice cubes	-5.6°C
Mass of water in the container	825 g
Initial temperature of water	19.75 °C
Specific heat capacity of ice	2.1 kJ kg^{-1} K^{-1}
Specific latent heat of fusion of ice	0.336 MJ kg^{-1}
Specific heat capacity of water	4.2 kJ kg^{-1} K^{-1}

(a)

Sketch a graph to show how the temperature of the ice varies with time; from the point they are added to the water until they are in thermal equilibrium.



[4]

[4 marks]

Question 1b

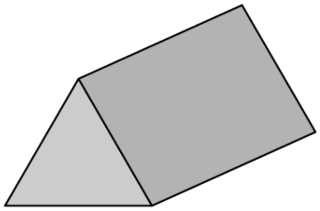
(b)
Calculate the final temperature of the water.

[4]

[4 marks]

Question 1c

The experiment is repeated with the same mass of ice but formed into triangular prisms instead of cubes.



(c)
State and explain the similarities and differences that be would be observed when repeating this experiment.

[3]

[3 marks]

Question 1d

The process is now carried out using a container that is not thermally isolated from its surroundings. The air temperature in the room where the process is repeated is 25 °C.

(d)
Describe and explain how the final temperature of the water will be different from your answer to part (b)).

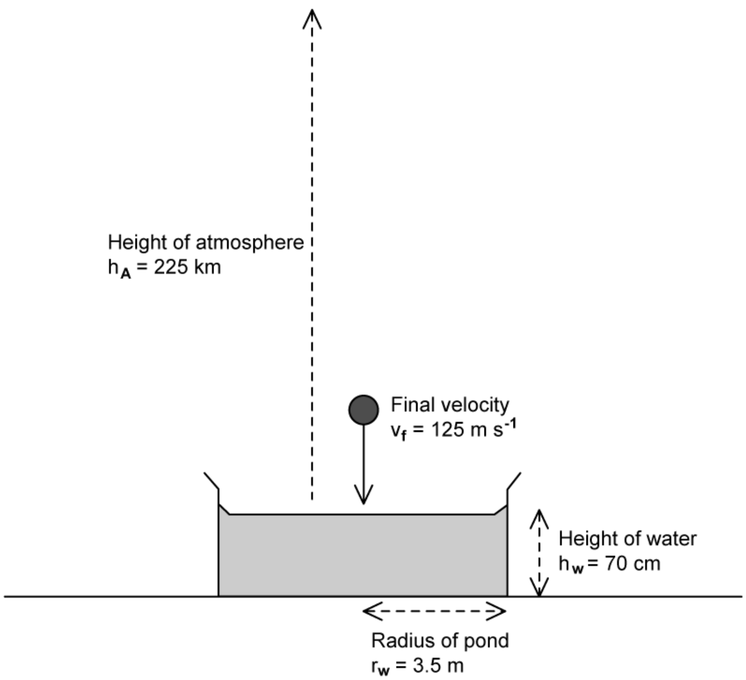
[2]

[2 marks]

Question 2a

A meteorite of pure nickel with a constant mass of 3.9 kg falls to Earth and begins to accelerate uniformly from the atmosphere's edge at a height h_A = 225 km and velocity 95 m s^{-1}. Initially in the atmosphere, it accelerates, reaches a constant velocity and continues to fall. It falls into a circular pond of water at a temperature of 18 °C with a velocity of 125 m s^{-1}.

The pond has a radius of 3.5 m and a depth of 70 cm. The nickel has a specific heat capacity of 0.44 J g^{-1} K^{-1} and had a temperature of –270 °C before it started to fall.



(a)

(i)

Calculate the temperature of the meteorite immediately before it hits the ground.

[2]

(ii)

Explain whether this figure is likely to be similar to the real value of the temperature of the meteorite upon hitting the ground.

[2]

[4 marks]

Question 2b

The specific heat capacity of the water is 4200 J $kg^{-1}K^{-1}$ and the density of the water is 1000 kg m^{-3}.

(b)
Determine the increase in the temperature of the water, assuming that the meteorite and the water reach thermal equilibrium and no thermal energy is lost to the surroundings.

[2]

[2 marks]

Question 3a

A car of mass 875 kg is travelling on a flat road at a constant speed of 35 m s^{-1}. An obstacle appears in the road, the brakes are applied and the car comes to a stop.

The car has four brake disks and each has a mass of 1.3 kg. The specific heat capacity of the brake disk material is 460 J $kg^{-1}K^{-1}$.

(a)
Calculate the overall increase in the temperature of the disks.

[2]

[2 marks]

Question 3b

When brakes are applied in a car, incompressible brake fluid forces the brake pads into place. The brake fluid heats up because it is in contact with the brake pads. It must not boil, or it will compress and the brakes will not work.

A certain brand of brake fluid uses a material called glycol. Engineers with the brand are investigating mixing some water with glycol to make the brake fluid less likely to overheat.

Specific heat capacity of glycol	2.4 kJ kg^{-1} K^{-1}
Boiling temperature of glycol	195 °C
Specific heat capacity of water	4.2 kJ kg^{-1} K^{-1}
Boiling temperature of water	100°C

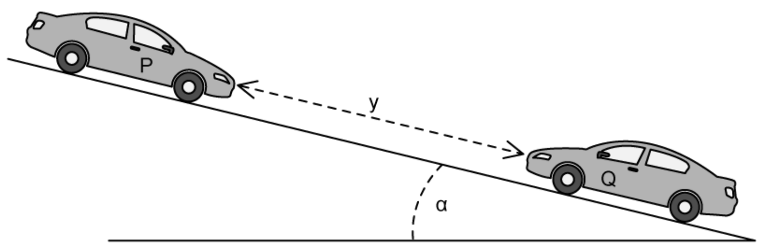
(b)
Evaluate whether adding water to glycol will make the brake fluid safer from overheating.

[3]

[3 marks]

Question 3c

A car manufacturer is developing brakes that bring the car to a stop over the same distance whether the car is going up or downhill.



Cars P and Q are on a slope at an angle α to the horizontal and at a distance of *y* m apart. The cars have an identical mass, *m*, velocity, *v* and four identical brake pads of mass m_D.

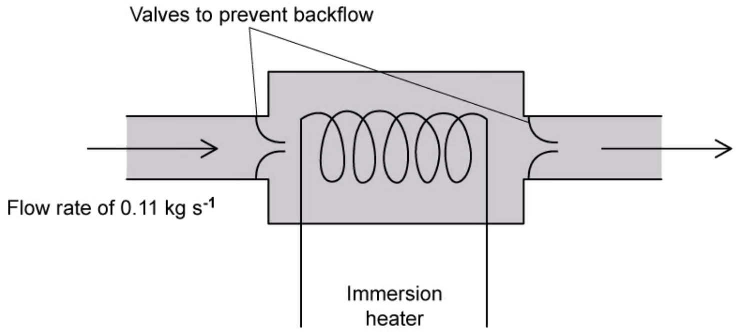
(c)
Determine an expression for the difference in temperature increase of the brake pads of each car when they both come to a stop after braking over a distance of $\frac{y}{2}$.

[4]

[4 marks]

Question 4a

An electrical immersion heater with a power of 5 kW is used to heat water flowing past it in a cylinder. The water flows through the heating cylinder at a rate of 0.11 kg s^{-1}. Valves at the beginning and end of the cylinder prevent the water from flowing backwards.



The specific heat capacity of water is 4200 J $kg^{-1}K^{-1}$.

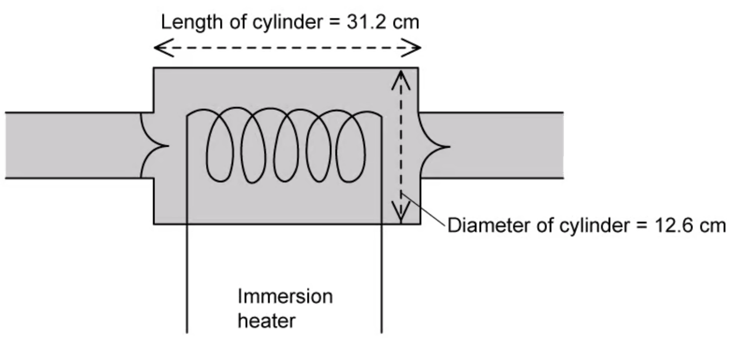
(a)
Calculate the rise in temperature of the water as it flows through the heater.
Assume all the energy is transferred to the water.

[2]

[2 marks]

Question 4b

A fault in the pump that pushes water through the heater causes the water to stop flowing. The valves at each end of the heating cylinder close and the water inside continues to heat. The closed cylinder has a length of 31.2 cm and a diameter of 12.6 cm.



The water temperature is 21.5 °C when the valves are shut. Water has a density of 1000 kg m^{-3}.

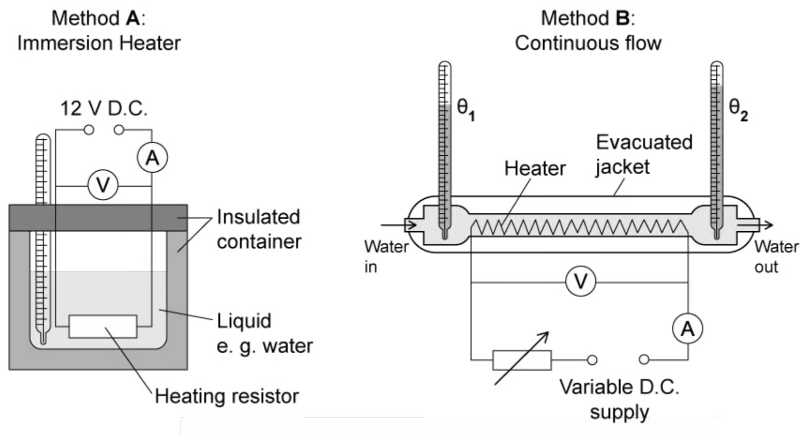
(b)
Calculate the time taken for the water to boil at 100 °C if the immersion heater continues supplying energy at the same rate.

[2]

[2 marks]

Question 4c

There are two main methods that are used to measure the specific heat capacity of liquids.



Method A, Immersion Heater: involves submerging an immersion heater in the liquid to be tested.

Method B, Continuous Flow: involves flowing the liquid to be tested past a heater.

(c)
Discuss the two different methods for measuring the specific heat capacity of a liquid.

In your answer:

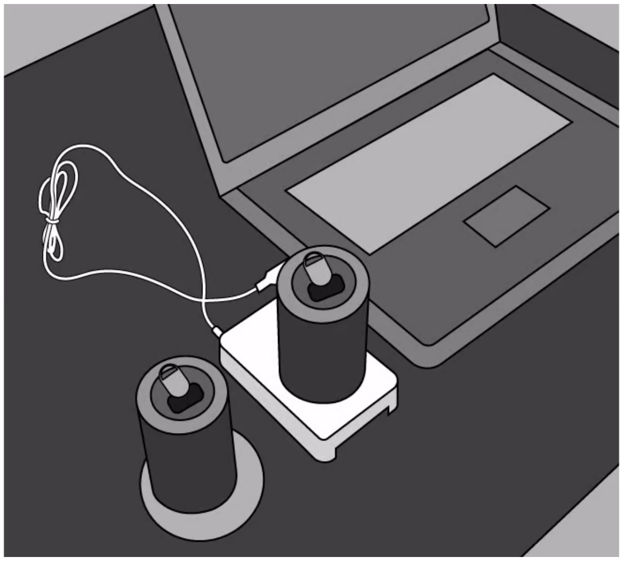
- Explain how a value for the specific heat capacity is obtained
- Explain any systematic problems with the methods, and how they will affect the final result
- Explain how a continuous flow method can compensate for energy lost as thermal radiation during the experiment

[6]

[6 marks]

Question 5a

An unopened soda drinks can is cooled using an electric chiller that is powered using a USB connection with a laptop computer. The chiller is advertised as using 37 W of power and cools drinks to 12 °C from any room temperature and then maintains the drink at that temperature.



A can of soda has a mass of 16 g when empty, and contains 324 g of soda. The can is a metal alloy that has a specific heat capacity of 800 J kg^{-1} K^{-1} and the soda has a specific heat capacity of 3700 J kg^{-1} K^{-1}.

(a)
Calculate the time it takes to cool the can from a room temperature of 23 °C to 12 °C.

[2]

[2 marks]

Question 5b

An alternative way to cool drinks is to add ice to them. Ice can be made in an ice maker. A particular model advertises that it can produce 15 kg of ice in 24 hours and requires 230 W when working. It produces ice cubes at a temperature of –5 °C.

The specific latent heat of fusion of ice is 0.336 MJ kg^{-1}.

The specific heat capacity of ice is 2100 J $kg^{-1}K^{-1}$.

The specific heat capacity of water is 4100 J $kg^{-1}K^{-1}$.

(b)
Determine whether the ice cube maker or the electric chiller from part (a) is a more energy efficient method for cooling drinks from 23 °C to 12 °C.

[5]

[5 marks]