3.2 Modelling a Gas

Question Paper

Course	DP IB Physics
Section	3. Thermal Physics
Topic	3.2 Modelling a Gas
Difficulty	Hard

Time allowed: 50

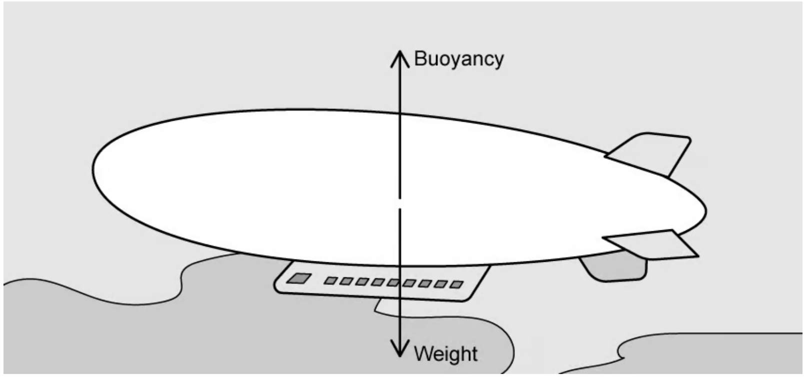
Score: /38

Percentage: /100

Question 1a

An airship floats in air due to a balance of weight and buoyancy forces. The buoyancy force is equal to the weight of the air that would have taken up the space that the airship occupies.

At one point in the flight, the helium gas has a temperature of 12 °C and a mass of 1350 kg. The mass of the airship materials is 6970 kg.



Air has a density of 1.225 kg m^{-3} and the atomic mass of helium is 4 g mol^{-1}.

(a)
Calculate the pressure in the airship at this point in the flight.

[3]

[3 marks]

Question 1b

(b)
Calculate the surface area of the inside surface of the airship at this same point in the flight.

[2]

[2 marks]

Question 1c

The pressure within the airship remains constant as the material surrounding the airship is able to expand and contract when the gas inside changes temperature.

(c)
Determine the temperature, in °C, at which the airship could maintain a constant height.

[2]

[2 marks]

Question 2a

A cylinder is fixed with an airtight piston containing an ideal gas of temperature 20 °C.

When the pressure, *P* in the cylinder is 3×10^4 Pa the volume, *V* is 2.0×10^{-3} m^3.

(a)
Calculate the number of gas molecules present in the cylinder.

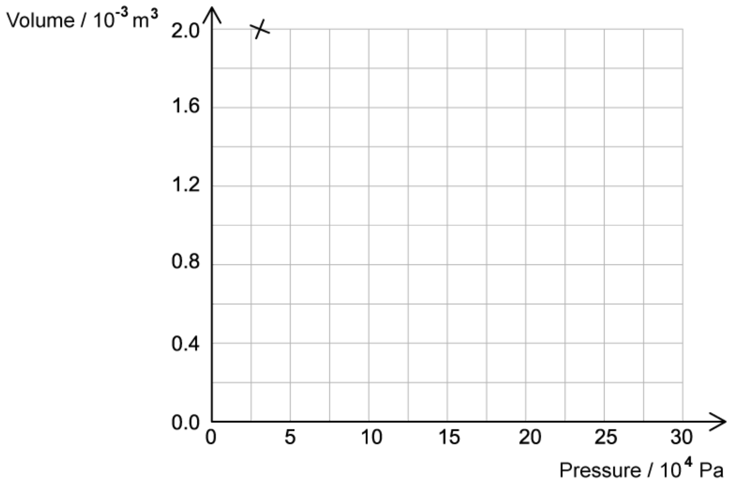
[2]

[2 marks]

Question 2b

The piston is slowly pushed in and the temperature of the gas remains constant.

(b)
Draw a graph by plotting three additional points on the axis to show the relationship between pressure and volume as the piston is slowly pushed in.

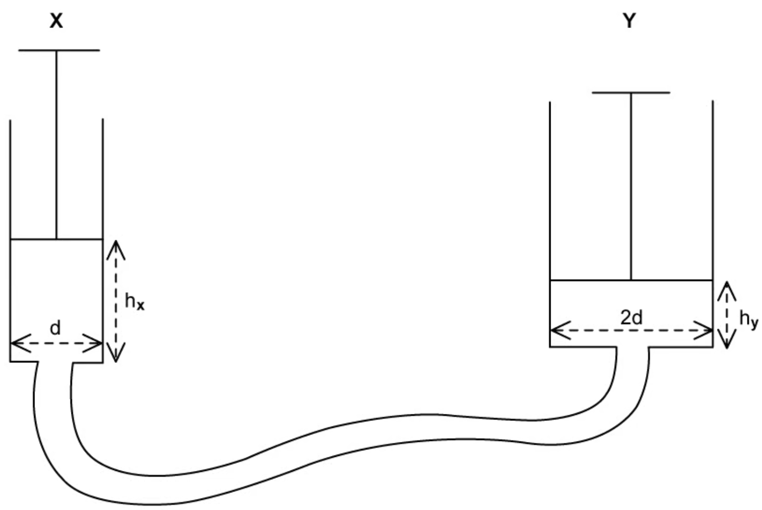


[2]

[2 marks]

Question 2c

The cylinder, cylinder X is connected now to a second cylinder, cylinder Y which is initially fully compressed. Cylinder Y has a diameter two times that of the diameter of cylinder X. The total number of molecules in the system remains the same.



Cylinder X is pushed down by a distance Δh_x causing Y to move up a distance Δh_y. The pressure and temperature within the system both remain constant.

(c)
Determine the ratio $\Delta h_x : \Delta h_y$.

[2]

[2 marks]

Question 2d

Initially, the gas molecules are divided between both cylinders. The diameter, *d*, of cylinder X, is 16 cm. The piston in cylinder X is compressed at a constant rate until all of the gas is moved into cylinder Y over a period of 5 seconds.

Assume that the volume of the connecting tube is negligible.

(d)
(i)
Sketch and label a graph to show how the length of the cylinder Y, h_y changes with time.

[3]

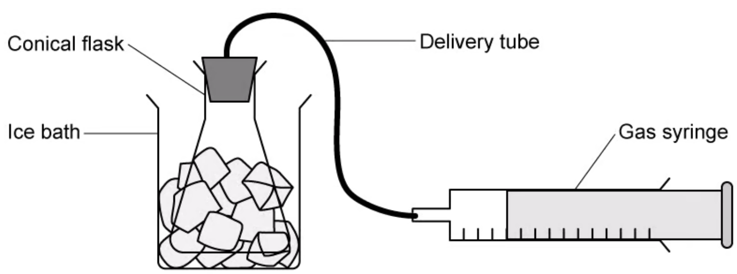
(ii)
Calculate the power exerted during the compression.

[2]

[5 marks]

Question 3a

A gas syringe is connected through a delivery tube to a conical flask, which is immersed in an ice bath. The syringe is frictionless so the gas pressure within the system remains equal to the atmospheric pressure 101 kPa.



The total volume of the conical flask and delivery tube is 275 cm^3, and after settling in the ice bath whilst the ice is melting the gas syringe has a volume of 15 cm^3.

(a)
Calculate the total number of moles contained within the system.

[2]

[2 marks]

Question 3b

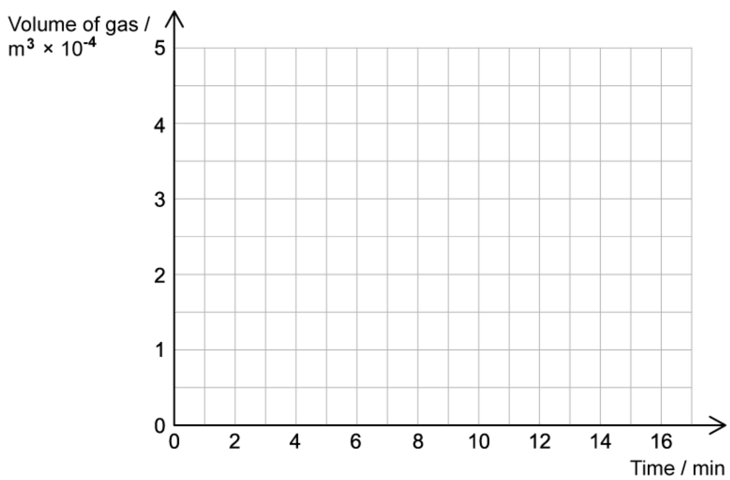
When the ice bath is heated at a constant rate it takes the following time to melt the ice and heat the water:

- Time for ice to melt is 3 minutes
- Time from ice melting to water boiling is 10 minutes
- Time for water to boil is 3 minutes

(b)
(i)
Calculate the volume of the gas at its boiling point.

[1]

(ii)
Sketch a graph to show this process.

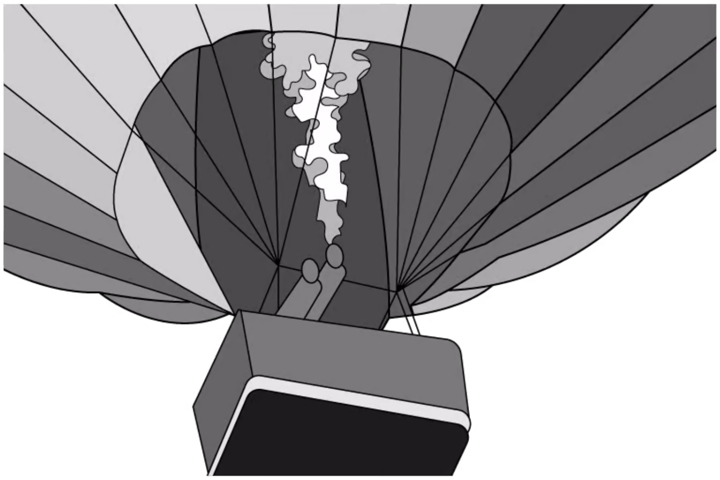


[2]

[3 marks]

Question 3c

A burner in the base of a hot air balloon is used to heat the air inside the balloon.



The mass of the balloon can be reduced by releasing sand from the basket of the balloon.

(c)

(i)

Explain how the burner is used so the balloon can rise.

[3]

(ii)

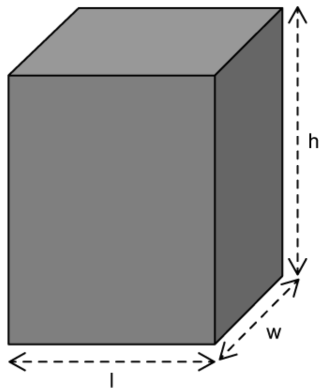
Explain how the forces on the balloon change with altitude and as the mass of the balloon decreases.

[3]

[6 marks]

Question 4a

A sealed container C has the shape of a rectangular prism and contains an ideal gas. The dimensions of the container are *l*, *w* and *h*.



- The average force exerted by the gas on the bottom wall of the container is *F*
- There are *n* moles of gas in the container
- The temperature of the gas is *T*

(a)
Obtain an expression in terms of F, *n* and *T* for the height of the container.

[2]

[2 marks]

Question 4b

A second container D contains the same ideal gas. The pressure in D is a fifth of the pressure in C and the volume of D is four times the volume of C. In D there are three times fewer molecules than in C.

The temperature of cylinder D is 600 K.

(b)
Calculate the temperature of cylinder D in °C.

[2]

[2 marks]

Question 4c

The temperature of a different container *E* is 60 °C. At this temperature, the pressure exerted by the ideal gas is 1.75×10^5 Pa. The container is a cube and has a height of 4 cm.

(c)
Calculate the number of molecules of gas in this container.

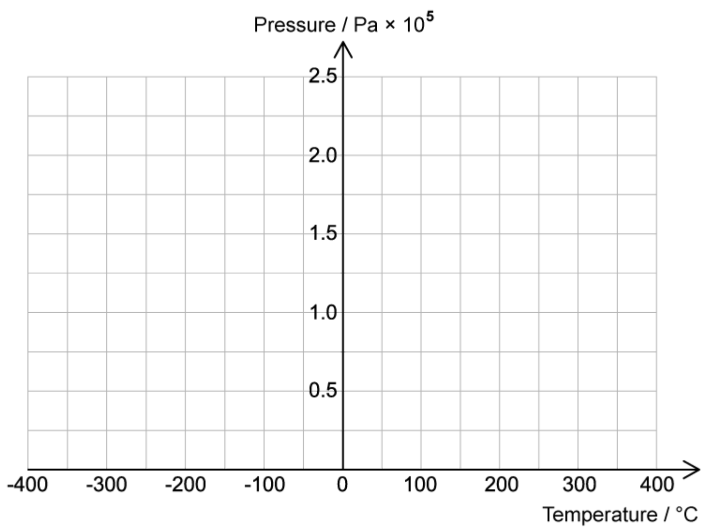
[3]

[3 marks]

Question 4d

In a different container F the pressure of the gas is measured at different temperatures whilst the volume and number of moles are kept the same.

(d)
Plot a graph to show how the pressure varies with temperature for this gas.



[2]

[2 marks]