2 **(a)** State what is meant by two objects being in thermal equilibrium.

....

....

.... [2]

(b) A mass X of ice at 0 °C is placed in a beaker containing a mass M of water at Celsius temperature t. The beaker is perfectly insulated and has negligible heat capacity. After some time, the ice that was added reaches thermal equilibrium with the original water in the beaker.

The specific latent heat of fusion of water is L. The specific heat capacity of water is c. The final Celsius temperature of the system is θ.

Give expressions, in terms of some or all of X, M, t, θ, L and c, for the thermal energy:

(i) E_1, gained by the ice as it melts to become water at 0 °C

E_1 = ... [1]

(ii) E_2, lost by the water as its Celsius temperature decreases from t to θ

E_2 = ... [1]

(iii) E_3, gained by the melted ice as its Celsius temperature increases from 0 °C to θ.

E_3 = ... [1]

(c) Use your answers in **(b)** to show that the final Celsius temperature θ of the system is given by

$$\theta = \frac{Mct - XL}{c(M + X)}.$$

[2]

[Total: 7]

3 **(a)** Two metal cuboids P and Q are in thermal contact with each other.

(i) P and Q are in thermal equilibrium.

State what is meant by the term thermal equilibrium.

....

....

.... [2]

(ii) Data for P and Q are given in Table 3.1.

Table 3.1

	P	Q
specific heat capacity / $J\,kg^{-1}\,K^{-1}$	390	910
mass / kg	0.54	0.37

P and Q are initially both at the same temperature.

P is supplied with 24 kJ of thermal energy. After some time, P and Q are once again both at the same temperature as each other.

P and Q are perfectly insulated from the surroundings.

Determine the change in temperature ΔT of Q.

ΔT = ... K [3]

(b) Nitrogen may be assumed to be an ideal gas. A fixed amount of nitrogen gas is contained at a constant pressure of 1.6×10^5 Pa.

The variation of the volume V of the gas with the temperature θ of the gas is shown in Fig. 3.1.

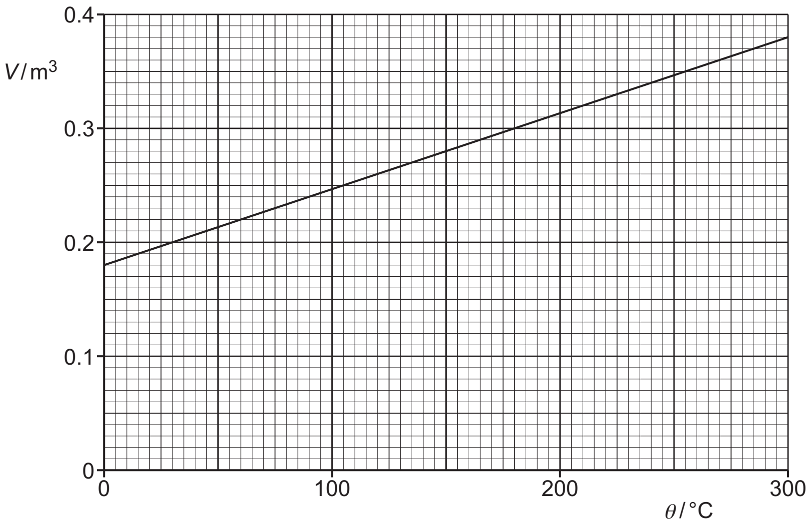

Fig. 3.1

(i) The temperature of the nitrogen gas is increased from 0 °C to 210 °C.
Determine the work done on the gas.

work done = ... J [3]

(ii) Determine the number N of molecules of nitrogen gas.

N = ... [2]

(iii) The mass of a nitrogen molecule is 4.7×10^{-26} kg.

Calculate the root-mean-square (r.m.s.) speed of a nitrogen molecule at 210 °C.

r.m.s. speed = ... m s^{-1} [2]

[Total: 12]