10 In an X-ray tube, electrons are accelerated through a potential difference of 75 kV. The electrons then strike a tungsten target of effective mass 15 g.

The electron energy is converted into the energy of X-ray photons with an efficiency of 5.0%. The rest of the energy is converted into thermal energy.

(a) The X-ray tube produces an image using a current of 0.40 A for a time of 20 ms.

The specific heat capacity of tungsten is 130 $J\,kg^{-1}\,K^{-1}$.

Determine the temperature rise ΔT of the tungsten target.

ΔT = ... K [3]

(b) The linear attenuation coefficient of the X-ray photons in muscle is 0.22 cm^{-1}.

Calculate the thickness t of muscle that will absorb 80% of the incident X-ray intensity.

t = ... cm [2]

(c) Table 10.1 shows the linear attenuation coefficient μ for the X-ray photons in different tissues.

3 **(a)** The equation of state for an ideal gas can be written as

$$pV = NkT.$$

State the meaning of each of the symbols in this equation.

p: .....

V: .....

N: .....

k: .....

T: .....

[3]

(b) Use the equation in **(a)** to show that the average translational kinetic energy E_K of a molecule of an ideal gas is given by

$$E_K = \frac{3}{2}kT.$$

[2]

(c) The mass of an oxygen molecule is 5.31×10^{-26} kg. Assume that oxygen behaves as an ideal gas.

(i) Use the equation in **(b)** to determine the root-mean-square (r.m.s.) speed u of an oxygen molecule at 23 °C.

u = ... $m\,s^{-1}$ [3]

(ii) A fixed mass of oxygen gas at initial pressure P is sealed in a cylindrical container by a movable piston at one end, as shown in Fig. 3.1.

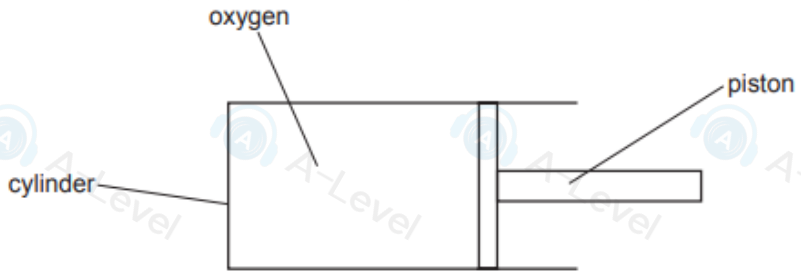

Fig. 3.1

The temperature of the gas is 23 °C.

The piston is slowly moved into the cylinder so that the oxygen gas is compressed. At all times, the gas and the container remain in thermal equilibrium with the surroundings.

On Fig. 3.2, sketch the variation with pressure of the r.m.s. speed of the oxygen molecules as the pressure increases.



Fig. 3.2

[2]

[Total: 10]