2 A spherical balloon is filled with a fixed mass of gas. A small block is connected by a string to the balloon, as shown in Fig. 2.1.

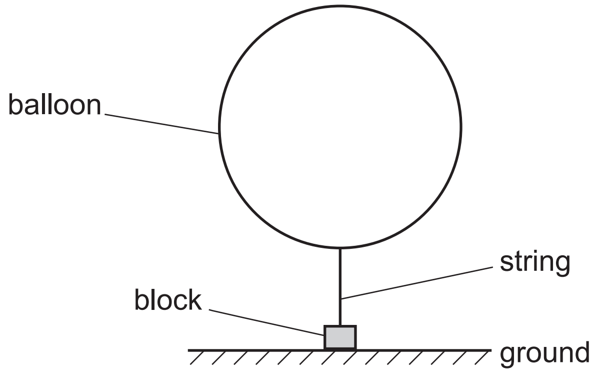

Fig. 2.1 (not to scale)

The block is held on the ground by an external force so that the string is vertical. The density of the air surrounding the balloon is $1.2\,\mathrm{kg\,m^{-3}}$. The upthrust acting on the balloon is 0.071 N. The upthrust acting on the string and block is negligible.

(a) By using Archimedes' principle, calculate the radius r of the balloon.

r = ... m [2]

(b) The total weight of the balloon, string and block is 0.053 N.

The external force holding the block on the ground is removed so that the released block is lifted vertically upwards by the balloon.

Calculate the acceleration of the block immediately after it is released.

acceleration = ... $\mathrm{m\,s^{-2}}$ [3]

(c) The balloon continues to lift the block. The string breaks as the block is moving vertically upwards with a speed of $1.4\,\text{m}\,\text{s}^{-1}$. After the string breaks, the detached block briefly continues moving upwards before falling vertically downwards to the ground. The block hits the ground with a speed of $3.6\,\text{m}\,\text{s}^{-1}$.

Assume that the air resistance on the block is negligible.

(i) By considering the motion of the block after the string breaks, calculate the height of the block above the ground when the string breaks.

height = ... m [2]

(ii) The string breaks at time $t = 0$ and the block hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the velocity v of the block with time t from $t = 0$ to $t = T$.

Numerical values of t are not required. Assume that v is positive in the upward direction.

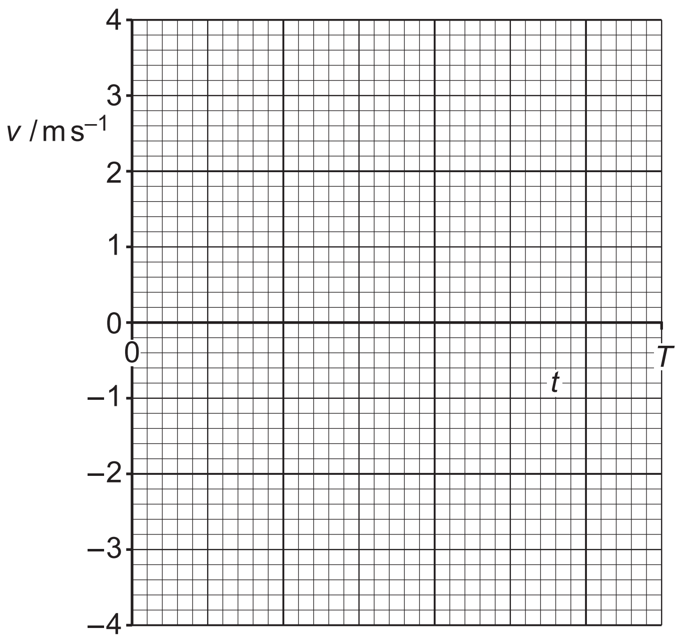

Fig. 2.2

[2]

[Total: 9]