**2** A hot-air balloon floats just above the ground. The balloon is stationary and is held in place by a vertical rope, as shown in Fig. 2.1.

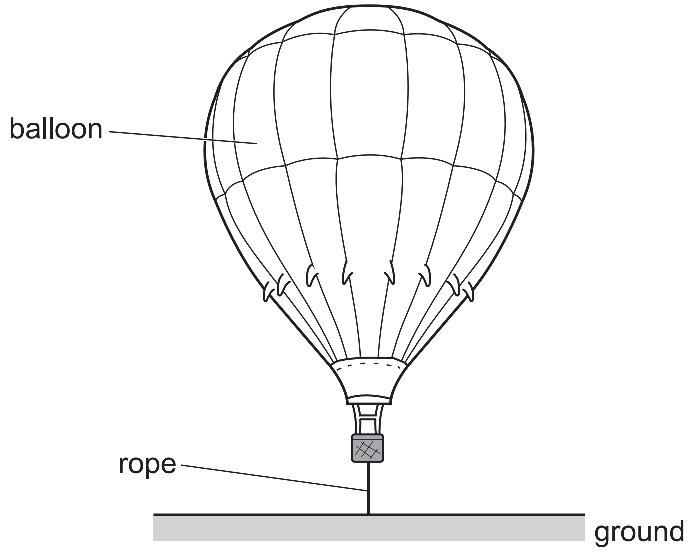


**Fig. 2.1**

The balloon has a weight $W$ of $3.39 \times 10^4$ N. The tension $T$ in the rope is $4.00 \times 10^2$ N.
Upthrust $U$ acts on the balloon.
The density of the surrounding air is $1.23\,\text{kg}\,\text{m}^{-3}$.

**(a)** **(i)** On Fig. 2.1, draw labelled arrows to show the directions of the three forces acting on the balloon. [2]

**(ii)** Calculate the volume, to three significant figures, of the balloon.

volume = .................................................... $\text{m}^3$ [3]

**(iii)** The balloon is released from the rope.

Calculate the initial acceleration of the balloon.

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

**(b)** The balloon is stationary at a height of 500 m above the ground. A tennis ball is released from rest and falls vertically from the balloon.

A passenger in the balloon uses the equation $v^2 = u^2 + 2as$ to calculate that the ball will be travelling at a speed of approximately $100\,\mathrm{m\,s^{-1}}$ when it hits the ground.

Explain why the actual speed of the ball will be much lower than $100\,\mathrm{m\,s^{-1}}$ when it hits the ground.

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**(c)** Before the balloon is released, the rope holding the balloon has a strain of $2.4 \times 10^{-5}$. The rope has an unstretched length of 2.5 m. The rope obeys Hooke's law.

**(i)** Show that the extension of the rope is $6.0 \times 10^{-5}$ m.

[1]

**(ii)** Calculate the elastic potential energy $E_P$ of the rope.

$E_P$ = ..................................................... J [2]

**(iii)** The rope holding the balloon is replaced with a new one of the same original length and cross-sectional area. The tension is unchanged and the new rope also obeys Hooke's law.

The new rope is made from a material of a lower Young modulus.

State and explain the effect of the lower Young modulus on the elastic potential energy of the rope.

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[Total: 16]