**4** A pinball machine uses a spring to launch a small metal ball of mass $4.5 \times 10^{-2}$ kg up a ramp. The spring is compressed by $8.0 \times 10^{-2}$ m and held in equilibrium, as shown in Fig. 4.1.

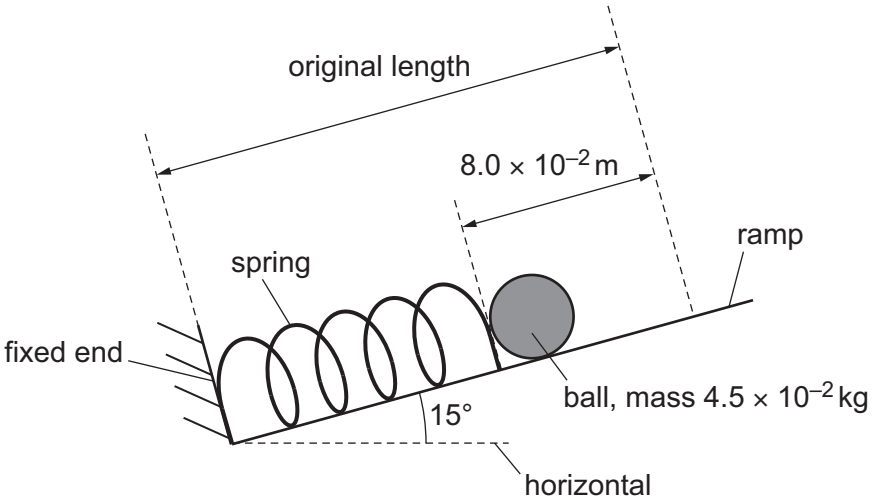


**Fig. 4.1** (not to scale)

The ramp is at an angle of 15° to the horizontal.

**(a)** The spring obeys Hooke's law and has a spring constant of $29\,\text{N}\,\text{m}^{-1}$.

Calculate the elastic potential energy in the compressed spring.

elastic potential energy = ..... J [2]

**(b)** The spring is released and expands quickly back to its original length.

**(i)** Calculate the increase in gravitational potential energy of the ball when the spring returns to its original length.

increase in gravitational potential energy = ..... J [3]

**(ii)** The ball leaves the spring when the spring reaches its original length. Assume that all the elastic potential energy of the spring is transferred to the ball.

Calculate the speed of the ball as it leaves the spring.

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

**(c)** The ball comes to rest on a horizontal trapdoor of negligible mass at a distance *d* from its pivot.
A force *F* acts vertically downwards at a distance of 2.0 cm from the pivot, as shown in Fig. 4.2.

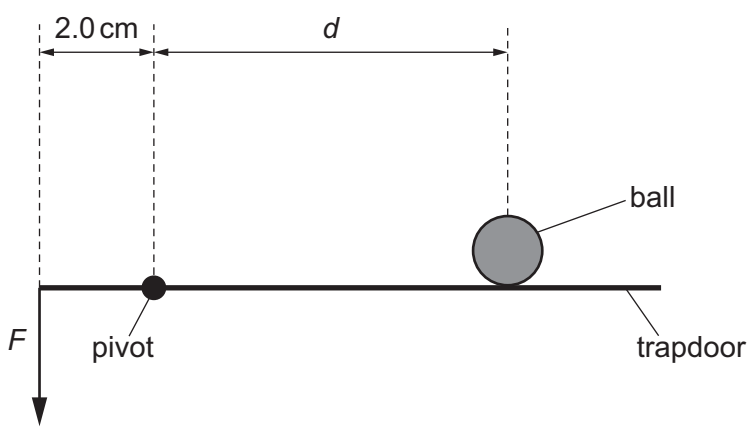


**Fig. 4.2** (not to scale)

**(i)** The trapdoor is in equilibrium when *F* is 1.7 N.

Calculate *d*.

*d* = ..... m [2]

**(ii)** Force *F* is decreased from 1.7 N.

State the direction of the resultant moment about the pivot on the trapdoor.

..... [1]

[Total: 11]