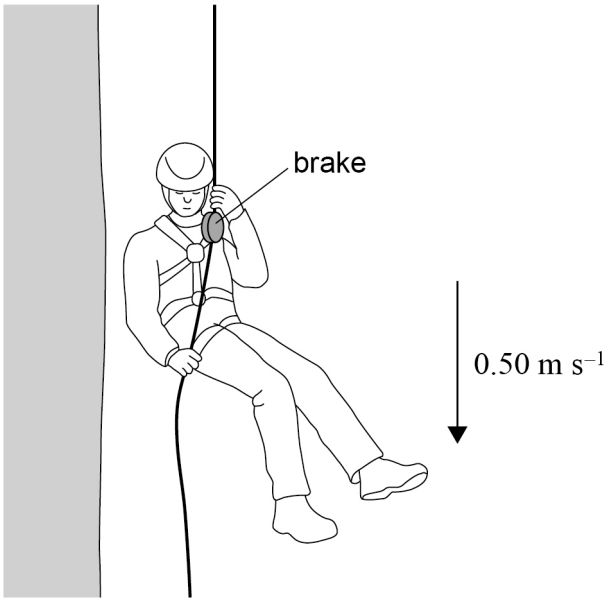
Do not write outside the box

2 7 A climber wears a harness attached to a rope. The rope passes through a brake. There is friction between the rope and the brake.



The climber uses the brake to descend at a steady speed of $0.50\ \text{m s}^{-1}$.
The combined mass of the climber, the harness and the brake is $60\ \text{kg}$.

What is the rate of energy transfer to the brake and rope?

[1 mark]

A 15 W ⬭

B 29 W ⬭

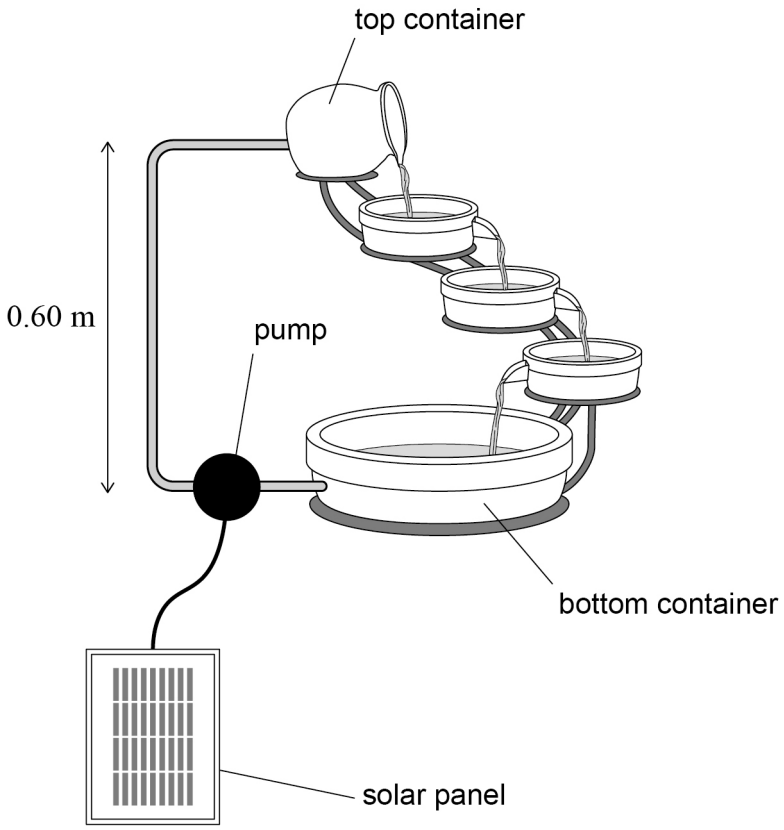
C 150 W ⬭

D 290 W ⬭

Turn over for the next question

Do not write outside the box

2 8 A solar panel powers a pump for a water feature.



Solar energy is incident on the solar panel at a rate of $1.5\ \text{W}$.
Water from the bottom container is continually pumped through a vertical height of $0.60\ \text{m}$ to the top container.

The overall efficiency of the solar panel and the pump is 20%.

What mass of water can be pumped into the top container each second?

[1 mark]

A $5\ \text{g}$ ⬭

B $50\ \text{g}$ ⬭

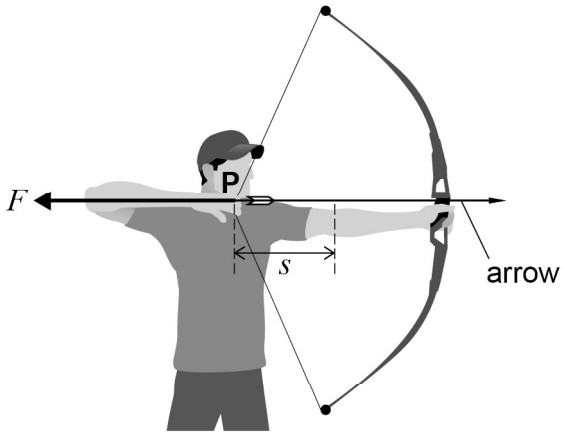
C $100\ \text{g}$ ⬭

D $250\ \text{g}$ ⬭

Do not write outside the box

0 4 **Figure 4** shows an archer using a bow in a competition.

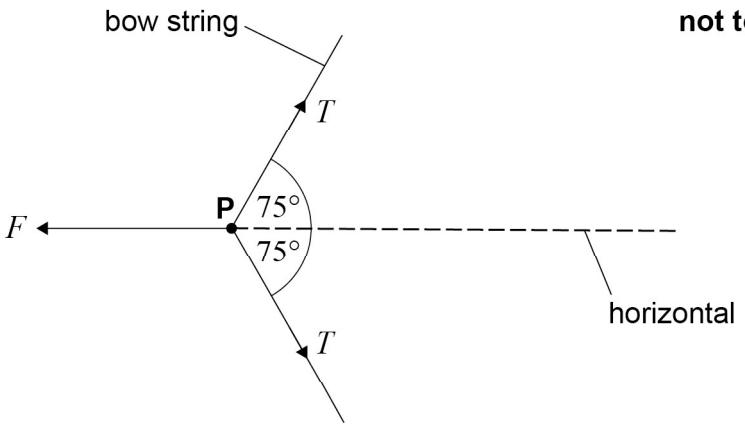
Figure 4



The archer exerts a force F to pull point **P** on the string back through a distance s.

0 4 . 1 **Figure 5** is a simplified diagram of the bow string showing the forces acting on **P**. The tension in the string is T and the string makes an angle of $75°$ to the horizontal.

Figure 5



In **Figure 5**, F is 160 N and **P** is in equilibrium.

Calculate T.

[2 marks]

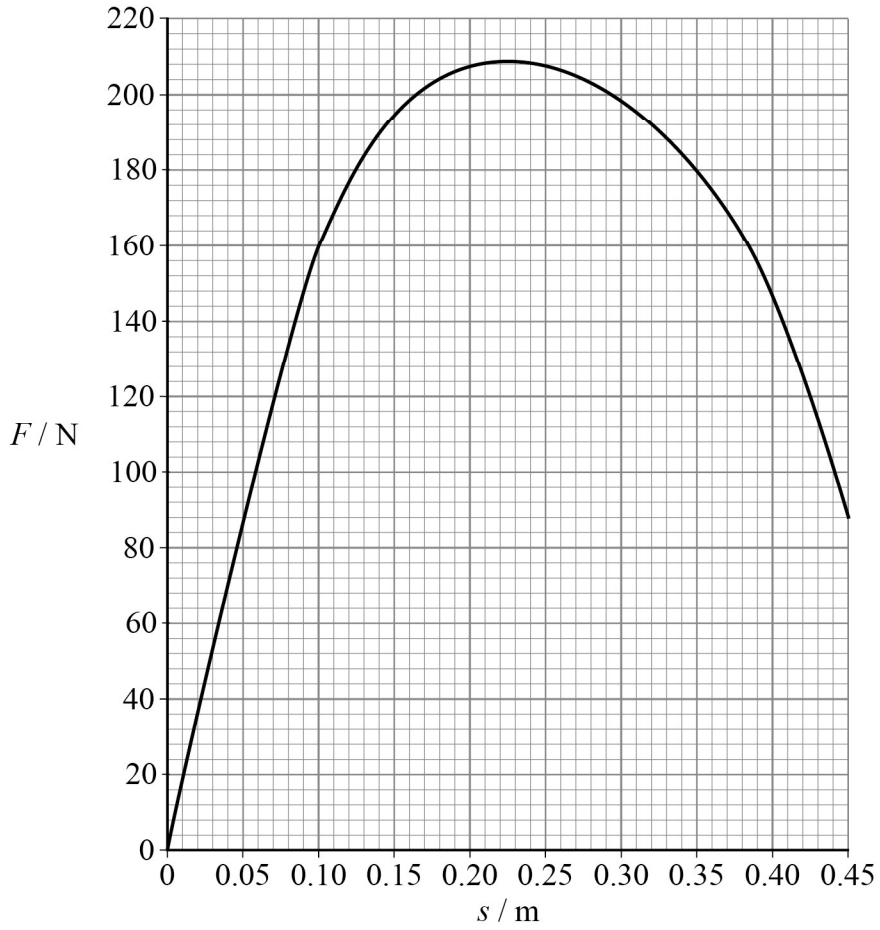
$T =$ _____ N

Question 4 continues on the next page

Do not write outside the box

The bow is designed so that F varies with s as shown in **Figure 6**.

Figure 6



0 4 . 2 An arrow of mass $21\ \text{g}$ is placed in the bow.

The archer pulls **P** back by a distance s of $0.22\ \text{m}$ and then releases the arrow in a horizontal direction.

Assume that there are no resistive forces acting on the arrow as it is released.

Determine the initial horizontal acceleration of the arrow.

[2 marks]

initial horizontal acceleration = _____ m s^{-2}

Do not write outside the box

The arrow is replaced with a different arrow of mass m.
The archer pulls **P** back by a distance s_r so that the energy stored in the bow is 64 J and F is 160 N.

0 4 . 3 Deduce s_r.

[2 marks]

$s_r =$ _____ m

0 4 . 4 The bow has an efficiency of 0.82

The arrow leaves the bow in a horizontal direction with a velocity of 190 km h^{-1}.

Calculate m.

[3 marks]

$m =$ _____ kg

9

Turn over ►

Do not write outside the box

0 5 **Figure 7** shows a robotic helicopter that is used on Mars. The helicopter is powered by a battery. Before each flight, the battery is charged by a solar panel.

Figure 7

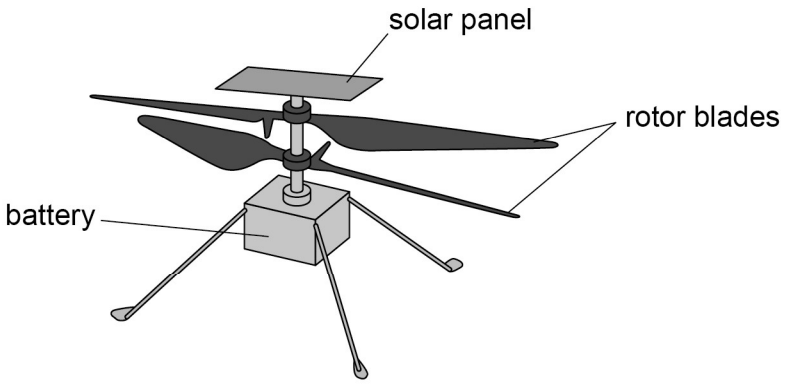
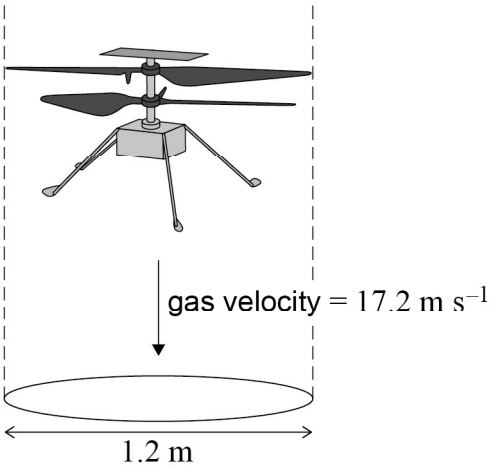


Figure 8 shows the helicopter hovering at a constant height above the surface of Mars. The rotor blades move a column of atmospheric gas vertically downwards at a velocity of $17.2\ \text{m s}^{-1}$. The diameter of this column is $1.2\ \text{m}$.

Figure 8



Do not write outside the box

0 5 . 1 The gas moved by the rotor blades has a density of $0.020\ \text{kg m}^{-3}$.

Show that the helicopter moves approximately $0.4\ \text{kg}$ of gas every second.

[3 marks]

The movement of the gas creates an upward force on the helicopter. This upward force enables the helicopter to hover at a constant height.

The gravitational field strength on Mars is $3.72\ \text{N kg}^{-1}$.

0 5 . 2 Calculate the mass of the helicopter.

[3 marks]

mass = _____ kg

Question 5 continues on the next page

Do not write outside the box

0 5 . 3 The battery stores $0.035\ \text{kW h}$ of energy before a flight.
The flight lasts for $39\ \text{s}$.
The battery has a power output of $340\ \text{W}$ during the flight.

Determine the percentage of the initial energy stored in the battery that is transferred during the flight.

[2 marks]

percentage = _____ %

0 5 . 4 The helicopter has a maximum flight time of a few minutes due to the limited amount of energy stored in the battery. The battery accounts for about 15% of the helicopter's mass.

A student suggests that adding another identical battery that doubles the energy available to the helicopter would double its flight time.

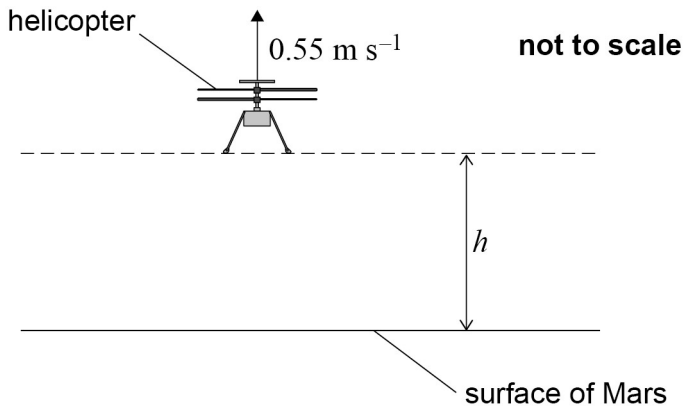
Deduce without calculation whether the student's suggestion is correct.

[3 marks]

Do not write outside the box

Figure 9 shows a simplified side view of the helicopter moving vertically upwards with a speed of $0.55\ \text{m s}^{-1}$.
At the instant shown, the helicopter is at a height h and the blades stop rotating.

Figure 9



The gravitational field strength on Mars is $3.72\ \text{N kg}^{-1}$.

The weight of the helicopter is the only force acting on it when the blades stop rotating. Drag forces on the helicopter are negligible as it rises to a maximum height and then falls back to the surface.

0 5 . 5 Calculate the time taken for the helicopter to reach its maximum height from the instant the blades stop rotating.

[2 marks]

time = _____ s

0 5 . 6 When the helicopter makes contact with the surface it has a velocity of $2.2\ \text{m s}^{-1}$.

Calculate h.

[2 marks]

h = _____ m

Question 5 continues on the next page

Turn over ►

Do not write outside the box

0 5 . 7 A student suggests that the acceleration of the helicopter is constant from the instant the blades stop rotating until the helicopter makes contact with the surface.

Discuss this suggestion with reference to an appropriate Newton's law of motion.

[2 marks]

17