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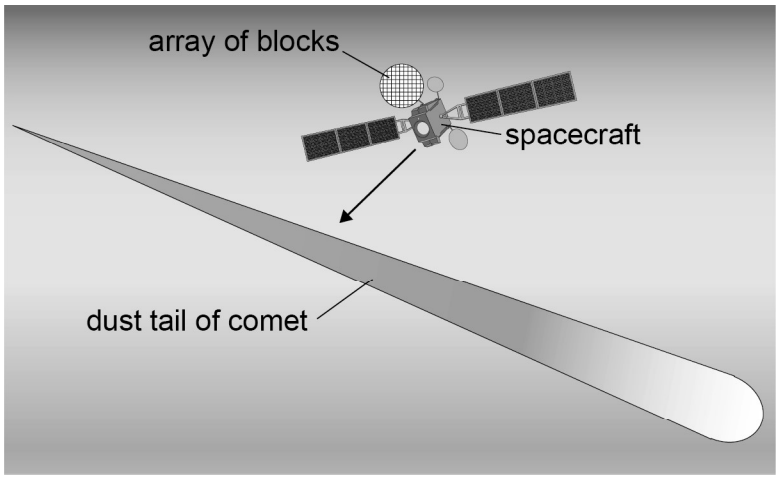
0 3 **Figure 5** shows a spacecraft travelling towards a comet.
The spacecraft has an array of blocks designed to capture small dust particles from the comet's tail.

Figure 5



To test the blocks before launch, a spherical dust particle **P** is fired at a right angle to the surface of a fixed, stationary block.
P has a mass of 1.1×10^{-9} kg. It has a speed of 5.9×10^{3} m s^{-1} when it hits the surface of the block.
P comes to rest inside the block.

0 3 . 1 Calculate the work done in bringing **P** to rest.

[1 mark]

work done = _____ J

0 3 . 2 **P** travels a distance of 2.9 cm in a straight line inside the block before coming to rest.
The resultant force on **P** varies as it penetrates the block.

Calculate the average force acting on **P** as it is brought to rest.

[2 marks]

average force = _____ N

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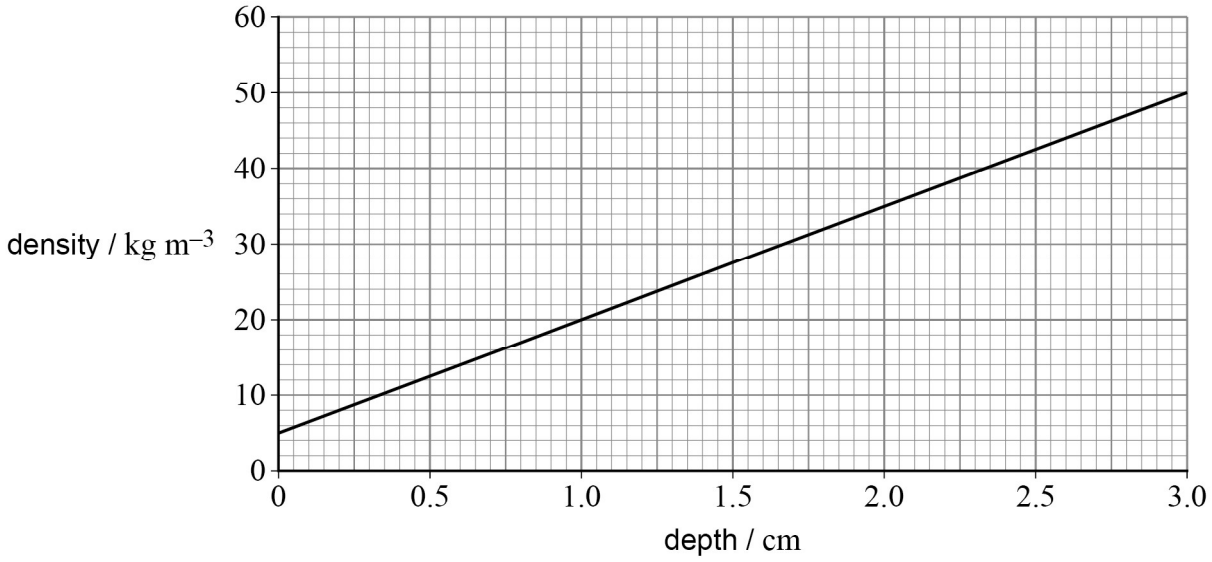
0 3 . 3 The block is rectangular with an area of cross-section of $8.0\ \text{cm}^2$ and a thickness of $3.0\ \text{cm}$.

Figure 6 shows how the density of the block varies with depth up to its maximum thickness.

Figure 6



Calculate the mass of the block.

[4 marks]

mass = _____ kg

Question 3 continues on the next page

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0 3 . 4 In another test, a spherical particle **Q** is fired at a right angle to the surface of an identical block.

Q has the same mass as **P** and is travelling at the same speed as **P** when it strikes the surface of the block.
Q is made from a less dense material than **P**.

Compare the distance travelled by **Q** with that travelled by **P** as they are brought to rest.

[3 marks]

10

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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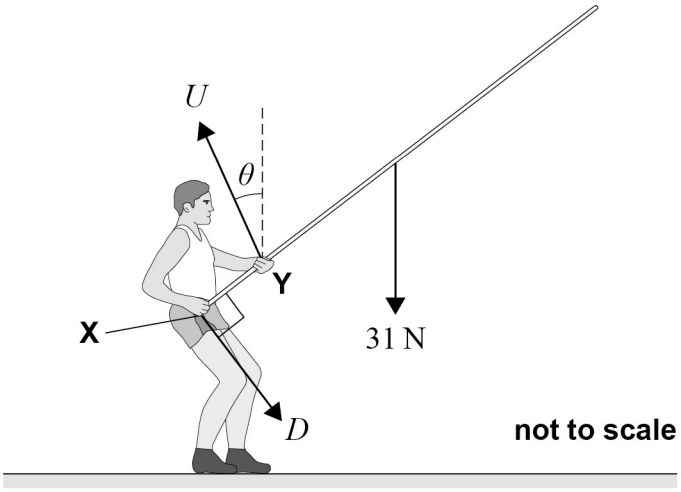
0 4 **Figure 7** shows an athlete holding a vaulting pole at an angle of $40°$ to the horizontal.

Figure 7

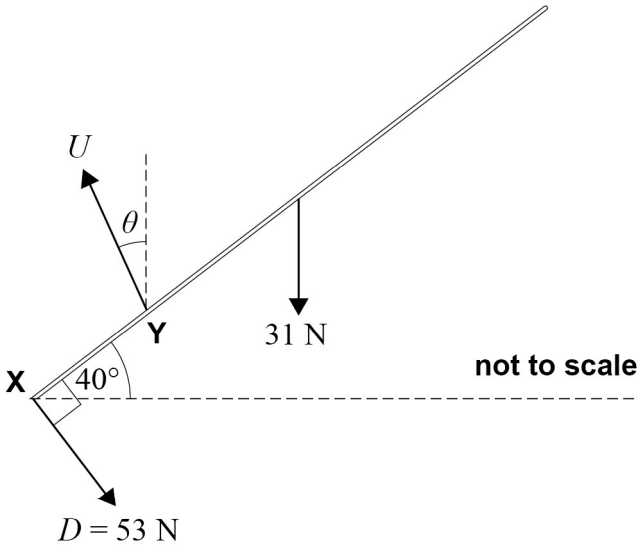


Forces D and U are exerted on the pole by the athlete's right and left hands respectively.
U is applied at point **Y** at an angle θ to the vertical.
The magnitude of D is 53 N and is applied at $90°$ to the pole at **X**.

The uniform pole is in equilibrium. It has a weight of 31 N.

Figure 8 shows the forces acting on the pole.

Figure 8



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0 4 . 1 Determine, using a scale diagram, θ and the magnitude of U.

[4 marks]

$\theta =$ _____ °

magnitude of $U =$ _____ N

Question 4 continues on the next page

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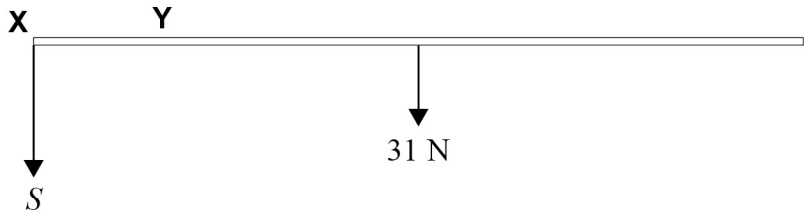
0 4 . 2 The athlete now moves the pole to a horizontal position. The pole is held stationary in this position.
The athlete's right hand applies a force S vertically downwards at **X** as shown in **Figure 9**. The athlete's left hand applies a force V at **Y**.

Figure 9

not to scale



Discuss the differences between the magnitudes and directions of force U in **Figure 7** and force V applied at **Y** in **Figure 9**.

[3 marks]

7

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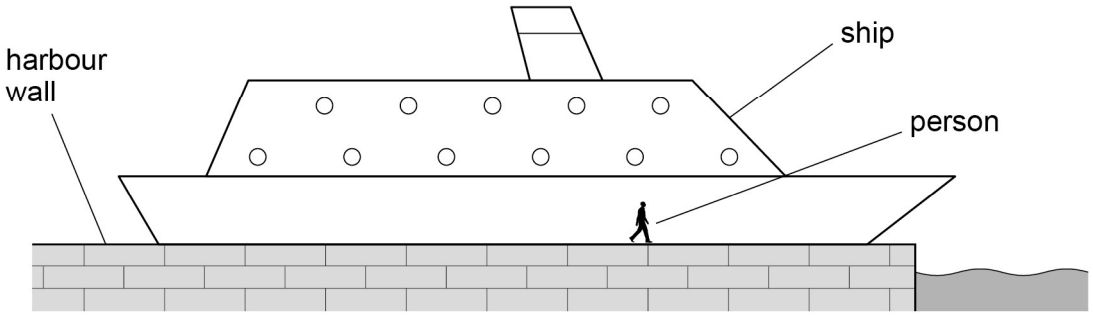
0 5 . 1 **Figure 10** shows a ship leaving a harbour at a constant velocity.
The ship moves at the same velocity as a person walking on the harbour wall alongside the ship.

Figure 10



The momentum of the ship is approximately 1×10^7 N s.

Estimate the mass of the ship.

[2 marks]

mass of ship = _____ kg

Question 5 continues on the next page

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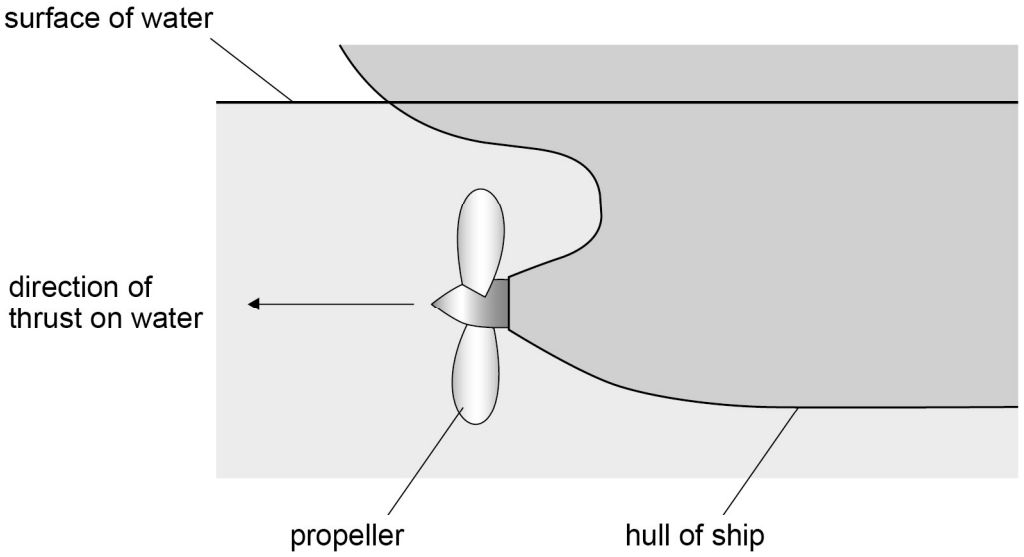
0 5 . 2 **Figure 11** shows the direction of the thrust exerted by the ship's propeller as the propeller rotates. The ship's engine makes the propeller rotate. When more water is accelerated, more work is done by the engine.

Figure 11



Explain, using Newton's laws of motion, how the thrust of the propeller on the water enables the ship to maintain a constant momentum.

[4 marks]

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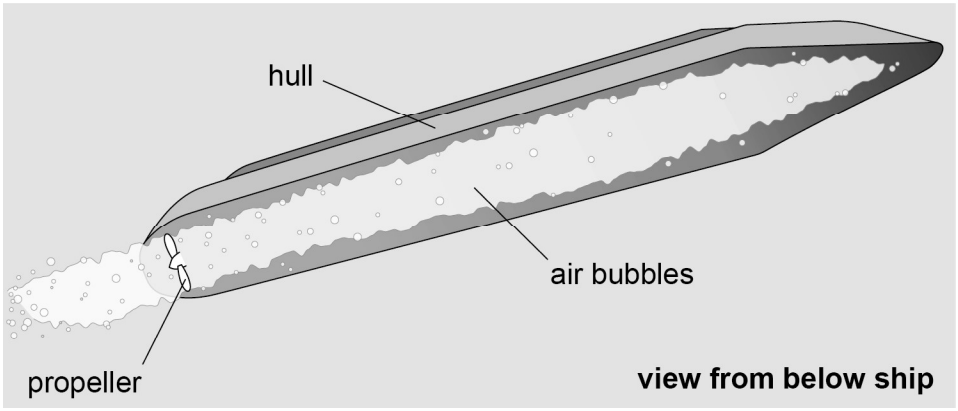
0 5 . 3 **Figure 12** shows the bottom of the hull with a drag reduction system in operation. Air bubbles are introduced into the water below the hull. This reduces the work done per second against the drag on the hull at any given speed.

However, when the air bubbles reach the propeller they decrease the mass of water being accelerated by the propeller every second. This decreases the thrust produced by the propeller at a given speed of rotation.

Figure 12



The system enables the ship to save fuel while maintaining the same momentum.

Explain why the system delivers this fuel saving.
In your answer, consider the effects of the introduction of the system on

- the thrust
- the drag on the hull.

[3 marks]

9

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Section B

Answer **all** questions in this section.

0 4 **Figure 10** shows a conveyor used to raise concrete blocks on a building site. The blocks do not slip on the belt at any time.

Figure 10

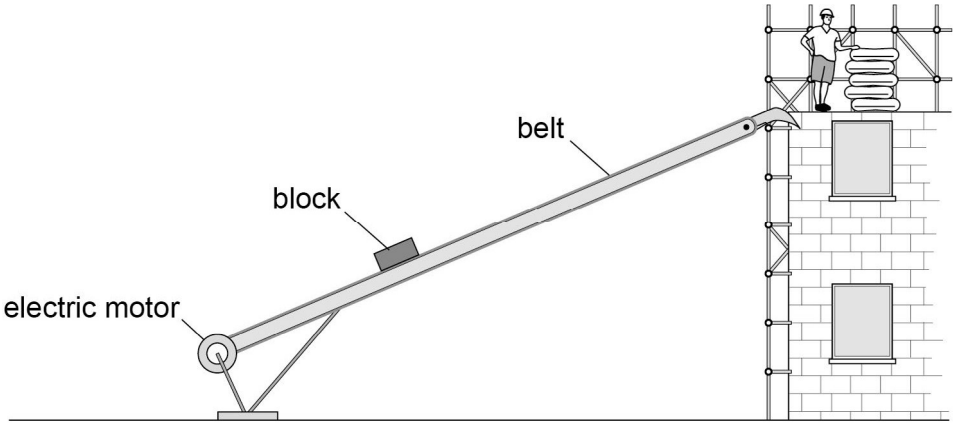
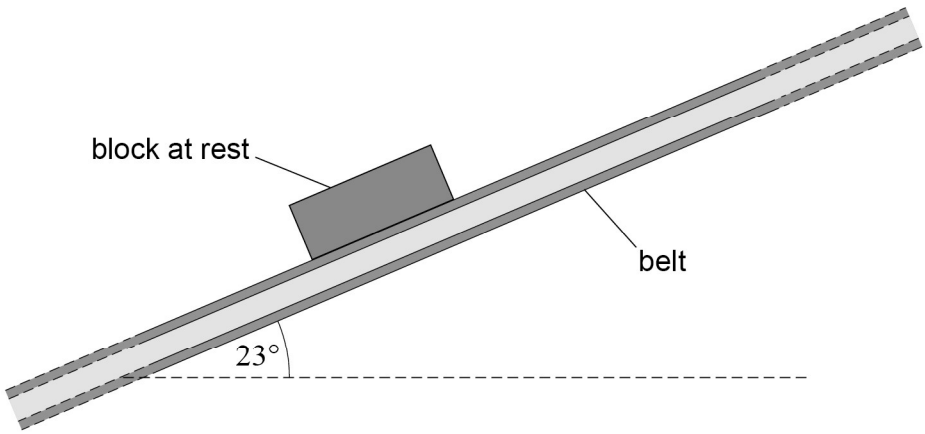


Figure 11 shows an enlarged view of one block on the belt. The belt is inclined at $23°$ to the horizontal. The mass of the block is $19\ \text{kg}$.

Figure 11



The belt exerts a frictional force F on the block when the block is at rest.

0 4 . 1 Draw an arrow on **Figure 11** to show the line of action of F.

[1 mark]

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0 4 . 2 Show that the magnitude of F is approximately $70\ \text{N}$.

[1 mark]

0 4 . 3 The belt is driven by an electric motor. When the motor is switched on, the belt and the block accelerate uniformly from rest to a speed of $0.32\ \text{m s}^{-1}$ in a time of $0.50\ \text{s}$.

Calculate the magnitude of the frictional force of the belt on the block during this acceleration.

[3 marks]

frictional force = _____ N

Question 4 continues on the next page

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0 4 . 4 The motor is connected to a $110\ \text{V}$ dc supply that has negligible internal resistance. The maximum operating current in the motor is $5.0\ \text{A}$.

The efficiency of the motor and drive system of the conveyor is 28%. The belt travels at $0.32\ \text{m s}^{-1}$ and is $8.0\ \text{m}$ long.

Deduce the maximum number of blocks that can be moved on the belt at one time.

[4 marks]

maximum number of blocks = _____

9