Access Tuition

A-Level Physics

Newtons Laws of Motion

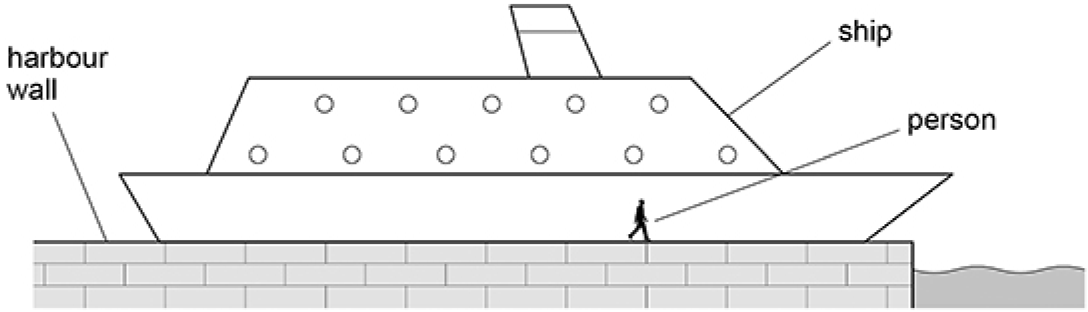
Question Paper

Time available: 65 minutes
Marks available: 49 marks

1. (a) **Figure 1** 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 1



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

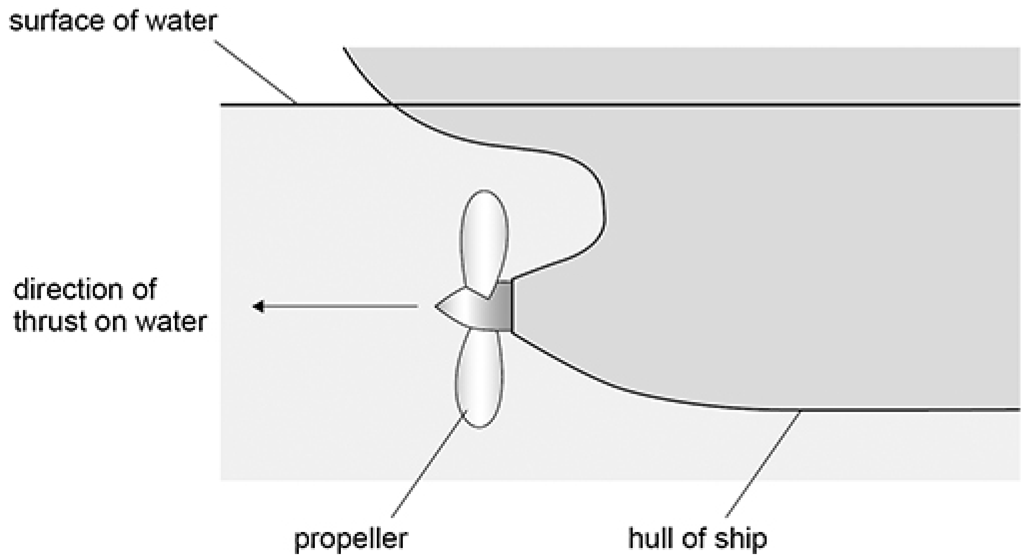
Estimate the mass of the ship.

mass of ship = ________________ kg

(2)

(b) **Figure 2** 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 2



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

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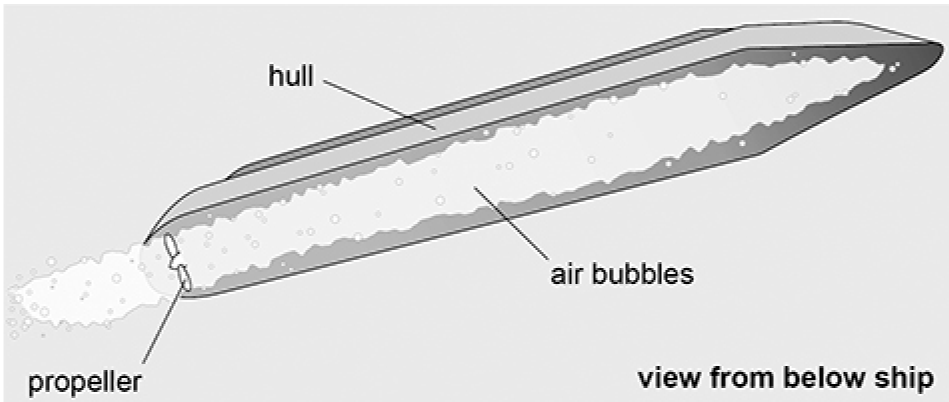
(4)

(c) **Figure 3** 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 3



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.

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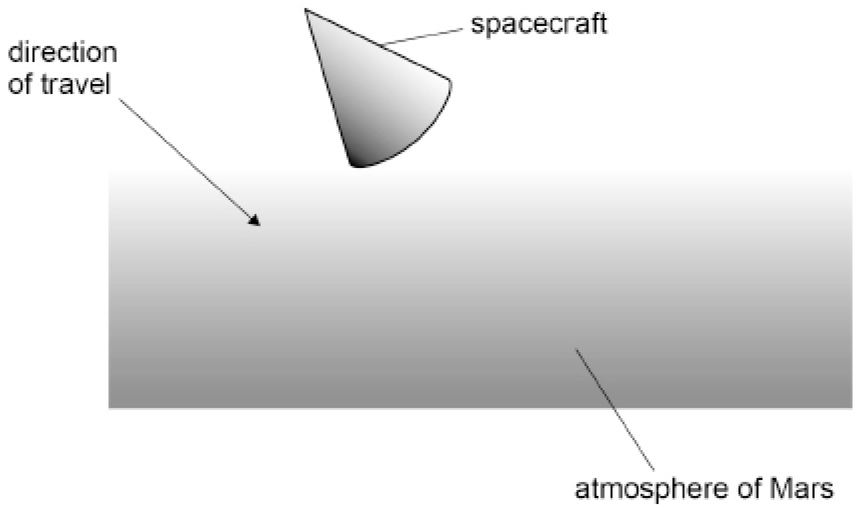
(3)
(Total 9 marks)

2. A spacecraft entering the atmosphere of Mars must decelerate to land undamaged on the surface.

Figure 1



(a) **Figure 1** shows the spacecraft of total mass 610 kg entering the atmosphere at a speed of 5.5 km s^{-1}.

Calculate the kinetic energy of the spacecraft as it enters the atmosphere. Give your answer to an appropriate number of significant figures.

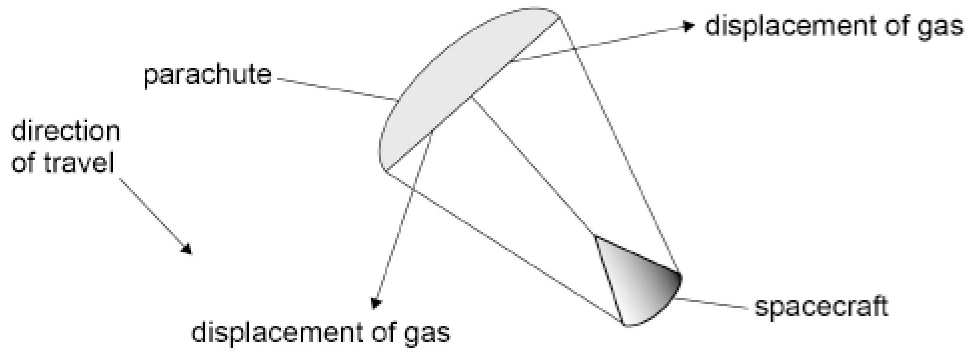
kinetic energy = ________________ J

(3)

(b) A parachute opens during the spacecraft's descent through the atmosphere.

Figure 2 shows the parachute–spacecraft system, with the open parachute displacing the atmospheric gas. This causes the system to decelerate.

Figure 2



Explain, with reference to Newton's laws of motion, why displacing the atmospheric gas causes a force on the system **and** why this force causes the system to decelerate.

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(4)

(c) As the parachute–spacecraft system decelerates, it falls through a vertical distance of 49 m and loses 2.2×10^5 J of kinetic energy.
During this time, 3.3×10^5 J of energy is transferred from the system to the atmosphere.
The total mass of the system is 610 kg.

Calculate the acceleration due to gravity as it falls through this distance.

acceleration due to gravity = _______________ m s^{-2}

(3)

(d) Dust from the surface of Mars can enter the atmosphere. This increases the density of the atmosphere significantly.

Deduce how an increase in dust content will affect the deceleration of the system.

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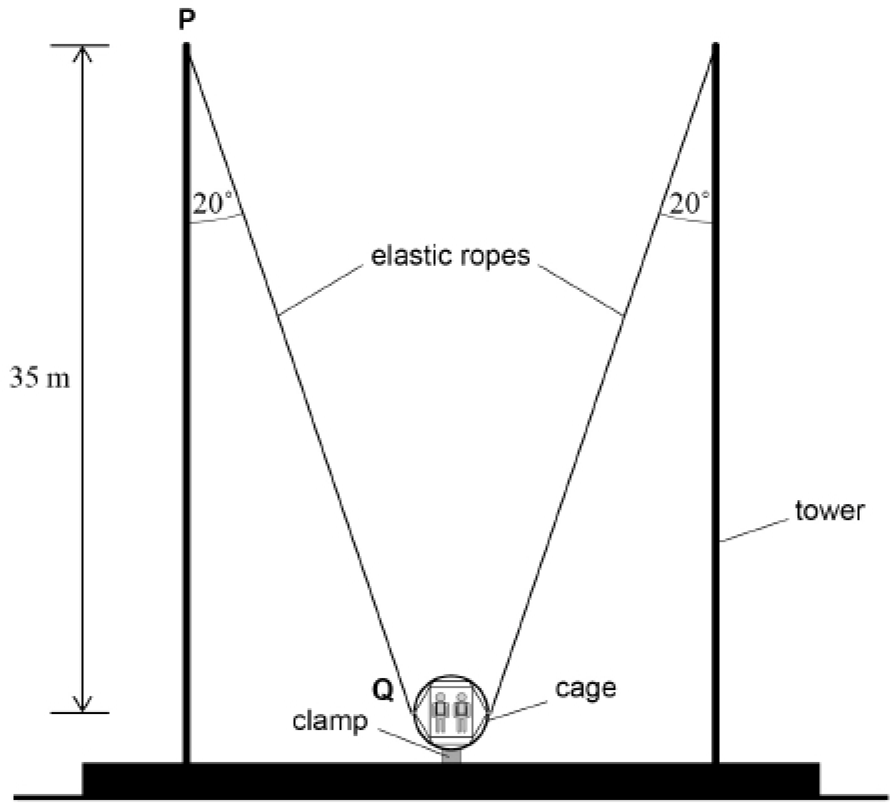
(3)
(Total 13 marks)

3. The diagram shows a fairground ride called a 'reverse bungee'.



Two identical stretched elastic ropes are fixed to a cage with passengers inside. The loaded cage is held in place by a clamp. When the clamp is released the elastic ropes accelerate the loaded cage vertically into the air.

P is the point where the rope attaches to the top of the vertical tower.
Q is the point where the rope attaches to the cage. **Q** is level with the centre of mass of the loaded cage.

Before release, the tension T in each elastic rope is 3.7×10^4 N and each rope makes an angle of 20° with the vertical tower.

The total mass M of the loaded cage is 1.2×10^3 kg and the mass of the elastic ropes is negligible.

(a) Show that the downward force F exerted by the clamp on the loaded cage is about 6×10^4 N.

(4)

(b) Calculate the initial acceleration of the loaded cage when the clamp is released.

acceleration = ____________________ m s^{-2}

(2)

(c) The unstretched length of each elastic rope is 24 m. The ropes obey Hooke's Law for all extensions used in the ride.
The **vertical** distance between points **P** and **Q** on the diagram above is 35 m.

Show that the total elastic potential energy stored in both ropes before the loaded cage is released is about 5×10^5 J.

(4)

(d) The designers of the ride claim that the loaded cage will reach a height of 50 m above **Q**.

Deduce whether this claim is justified.

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(3)

(e) The designers also claim that the loaded cage reaches a maximum speed of at least 90 km h^{-1}.

Calculate, in J, the kinetic energy of the loaded cage when it travels at 90 km h^{-1}.

kinetic energy = ____________________ J

(3)

(f) Deduce without further calculation whether the maximum speed claim is justified.

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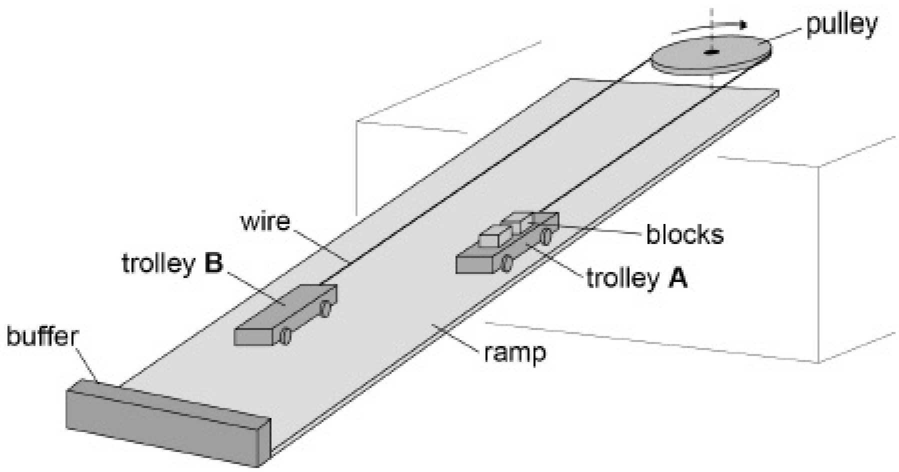
(1)

(Total 17 marks)

4. **Figure 1** shows a model of a system being designed to move concrete building blocks from an upper to a lower level.

Figure 1

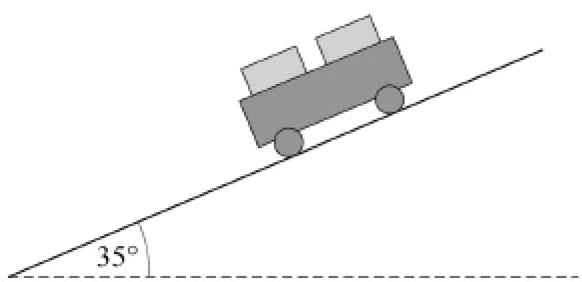


The model consists of two identical trolleys of mass *M* on a ramp which is at 35° to the horizontal. The trolleys are connected by a wire that passes around a pulley of negligible mass at the top of the ramp.

Two concrete blocks each of mass *m* are loaded onto trolley **A** at the top of the ramp. The trolley is released and accelerates to the bottom of the ramp where it is stopped by a flexible buffer. The blocks are unloaded from trolley **A** and two blocks are loaded onto trolley **B** that is now at the top of the ramp. The trolleys are released and the process is repeated.

Figure 2 shows the side view of trolley **A** when it is moving **down** the ramp.

Figure 2



(a) The tension in the wire when the trolleys are moving is T.

Draw and label arrows on **Figure 2** to represent the magnitudes and directions of any forces and components of forces that act on trolley **A** parallel to the ramp as it travels down the ramp.

(1)

(b) Assume that no friction acts at the axle of the pulley or at the axles of the trolleys and that air resistance is negligible.

Show that the acceleration a of trolley **B** along the ramp is given by

$$a = \frac{mg \sin 35^\circ}{M + m}$$

(2)

(c) Compare the momentum of loaded trolley **A** as it moves downwards with the momentum of loaded trolley **B**.

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(2)

(d) In practice, for safety reasons there is a friction brake in the pulley that provides a resistive force to reduce the acceleration to 25% of the maximum possible acceleration.

The distance travelled for each journey down the ramp is 9.0 m.

The following data apply to the arrangement.

Mass of a trolley M = 95 kg

Mass of a concrete block m = 30 kg

Calculate the time taken for a loaded trolley to travel down the ramp.

time = ____________________ s

(3)

(e) It takes 12 s to remove the blocks from the lower trolley and reload the upper trolley.

Calculate the number of blocks that can be transferred to the lower level in 30 minutes.

number = ____________________

(2)

(Total 10 marks)