1 Immediately after take-off from the surface of the Earth, a rocket of mass 12 000 kg accelerates vertically upwards at 1.4 m s^{-2}

What is the thrust produced by the rocket motor?

A 1.7×10^4 N ⬭

B 1.0×10^5 N ⬭

C 1.3×10^5 N ⬭

D 1.6×10^5 N ⬭

(Total 1 mark)

2 An electric wheelchair, powered by a battery, allows the user to move around independently.

One type of electric wheelchair has a mass of 55 kg. The maximum distance it can travel on level ground is 12 km when carrying a user of mass 65 kg and travelling at its maximum speed of 1.5 m s^{-1}.

The battery used has an emf of 12 V and can deliver 7.2×10^4 C as it discharges fully.

(a) Show that the average power output of the battery during the journey is about 100 W.

(3)

(b) During the journey, forces due to friction and air resistance act on the wheelchair and its user.

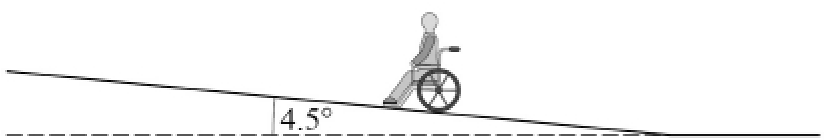
Assume that all the energy available in the battery is used to move the wheelchair and its user during the journey.

Calculate the total mean resistive force that acts on the wheelchair and its user.

total mean resistive force = ____________________ N

(2)

The diagram below shows the wheelchair and its user travelling up a hill. The hill makes an angle of 4.5° to the horizontal.



(c) Calculate the force that gravity exerts on the wheelchair and its user parallel to the slope.

force parallel to the slope = ____________________ N

(1)

(d) Calculate the maximum speed of the wheelchair and its user when travelling up this hill when the power output of the battery is 100 W.

Assume that the resistive forces due to friction and air resistance are the same as in part (b).

maximum speed = ____________________ $m\ s^{-1}$

(2)

(e) Explain how and why the maximum range of the wheelchair on level ground is affected by

- the mass of the user
- the speed at which the wheelchair travels.

Effect of mass ____

____

____

____

____

____

Effect of speed ____

____

____

____

____

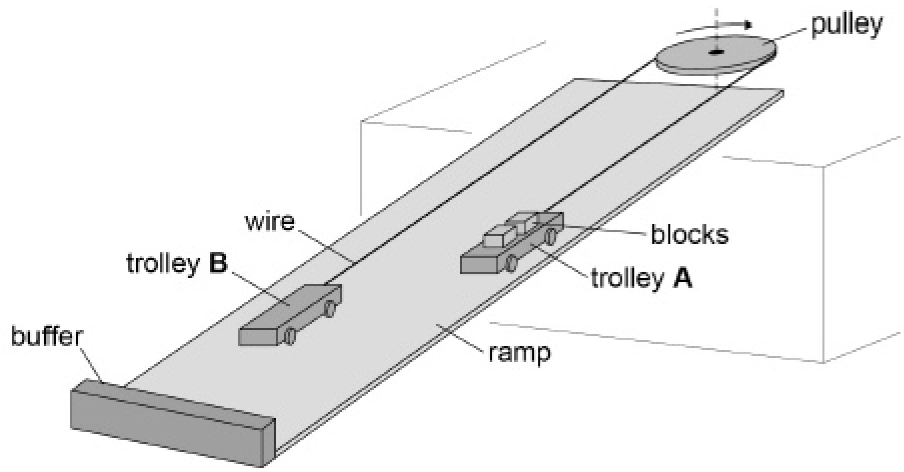
____

(4)

(Total 12 marks)

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

Figure 1

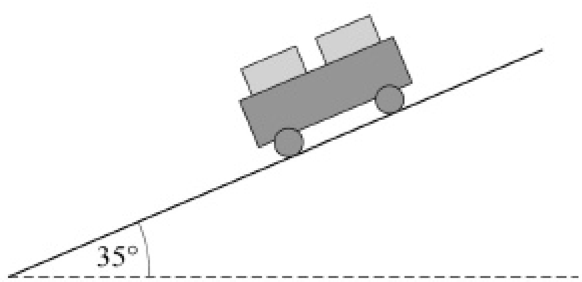


The model consists of two identical trolleys of mass *M* on a ramp which is at 35° to the horizontal. The trolleys are connected by a wire that passes around a pulley of negligible mass at the top of the ramp.

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**.

____

____

____

____

____

____

(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)

4 A car is designed to break the land speed record. The thrust exerted on the car is 230 kN at one instant of its motion. The mass of the car at this instant is 11 000 kg.

(a) The acceleration of the car at this instant is 2.9 m s^{-2}.

Calculate the air resistance acting on the car.

air resistance =__________________ N

(3)

(b) The thrust on the car remains constant as the speed increases.

Explain why the acceleration decreases and eventually reaches zero.

____

____

____

____

____

(2)

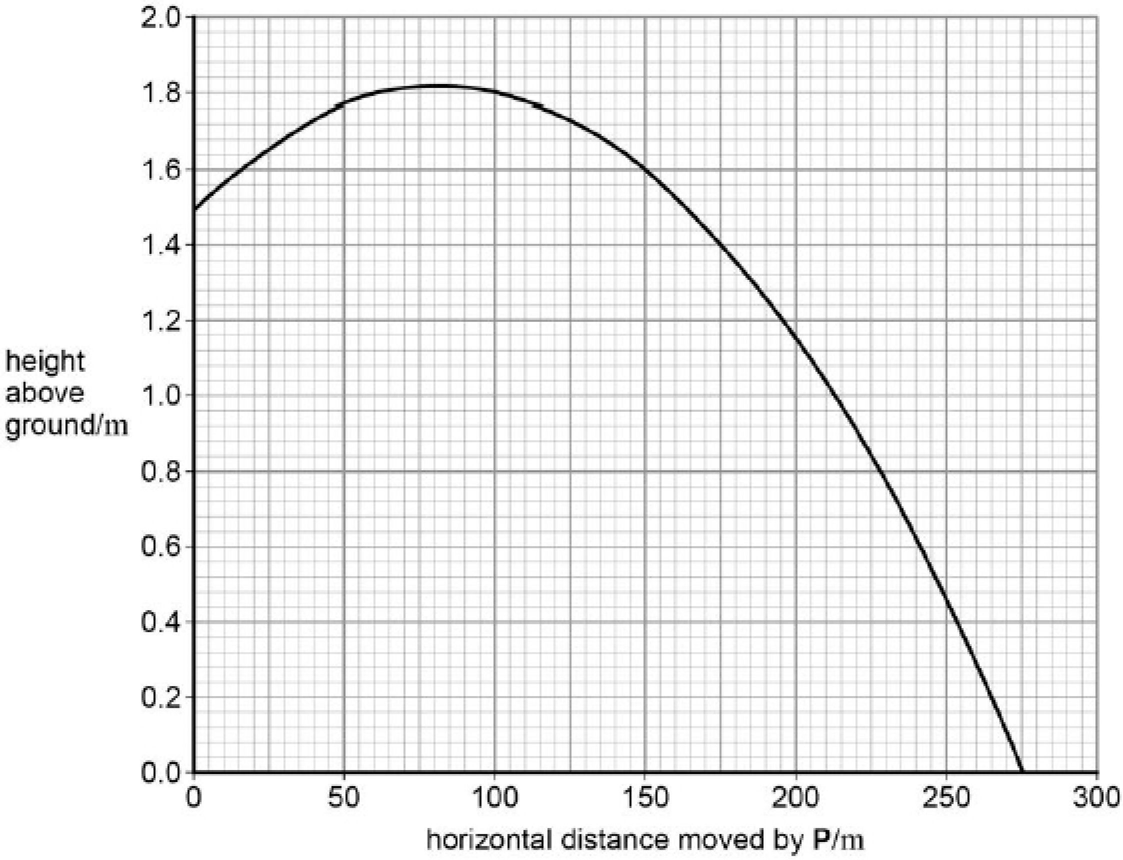
(c) A supersonic car is attempting to break the land speed record on a horizontal track. When it is travelling at 320 m s^{-1}, a small part **P** that is 1.5 m above the ground becomes detached from the car. The initial vertical velocity of **P** is 2.5 m s^{-1} in the upwards direction.

Calculate the time taken for the small part **P** to reach the ground.
Assume that air resistance has a negligible effect on the vertical motion.

time =______________________s

(3)

(d) The graph below shows the path that **P** would follow from the instant that it became detached if there were no air resistance in the horizontal direction.



In practice, air resistance is not negligible in the horizontal direction.

Draw, on the graph, a line to show the path that **P** would follow assuming that air resistance only affects motion in the horizontal direction.

(2)

(e) Explain your answer to part **(d)**, including the reason why air resistance is negligible in the vertical direction.

____

____

____

____

____

(2)

(Total 12 marks)