For "a **car is designed to break the land speed record**"
see my youtube walk through

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?

thrust has to overcome weight and supply upwards accel

thrust = 12000X9.8 + (12000X1.4)

A 1.7×10^4 N ☐

B 1.0×10^5 N ☐

C ☐

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)

$s = \frac{d}{t}$ ∴ $t = 8000$ s $Q = It$ so $I = 9$ A

∴ $P = VI = 108$ W

(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.

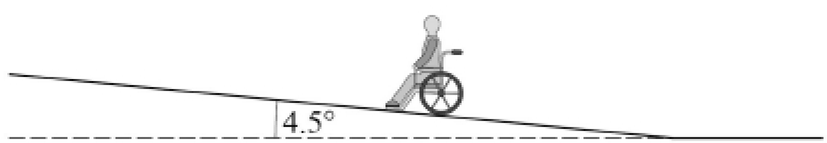
Calculate the total mean resistive force that acts on the wheelchair and its user.

$WD = F \times d \Rightarrow \frac{108\ J/s}{1.5\ m}$

total mean resistive force = 72 N

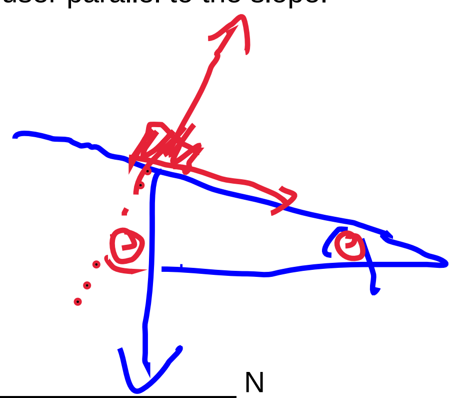
(2)

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.

total mass = 120Kg
So weight = 120 x 9.8 = 1176N
reaction = 1176cos
force parallel to slope = 1176sin



92N

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).

total resistive force = ans b+ ans c
so 165N.
100W = 100 J/S
P=E/t P=Fxd/t set t=1

$P = \frac{F \times d}{t} \Rightarrow \frac{P \times t}{F} = \frac{100 \times 1}{165}$

maximum speed = 0.61 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

range will drop if mass up. Lots of reasons - eg more friction in wheels/tyres to road, more energy to accel etc

Effect of speed

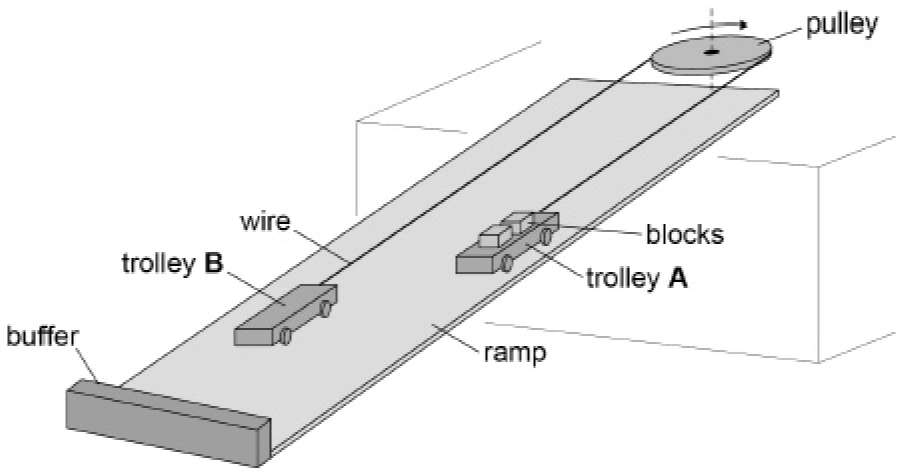
range will drop, More energy need to get to a higher speed since KE is v^2, also more air resistance

(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

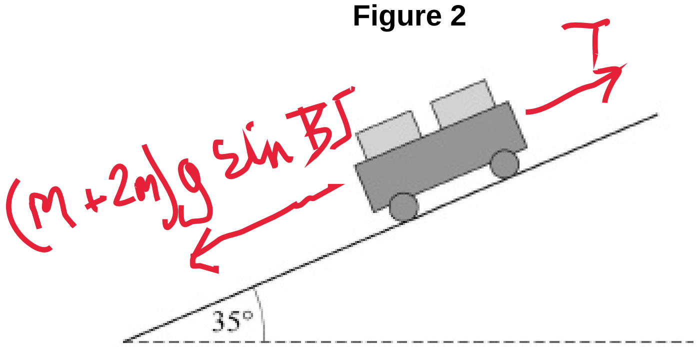


The model consists of two identical trolleys of mass *M* on a ramp which is at 35° to the horizontal. The trolleys are connected by a wire that passes around a pulley of negligible mass at the top of the ramp.

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**.

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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)

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.

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(2)

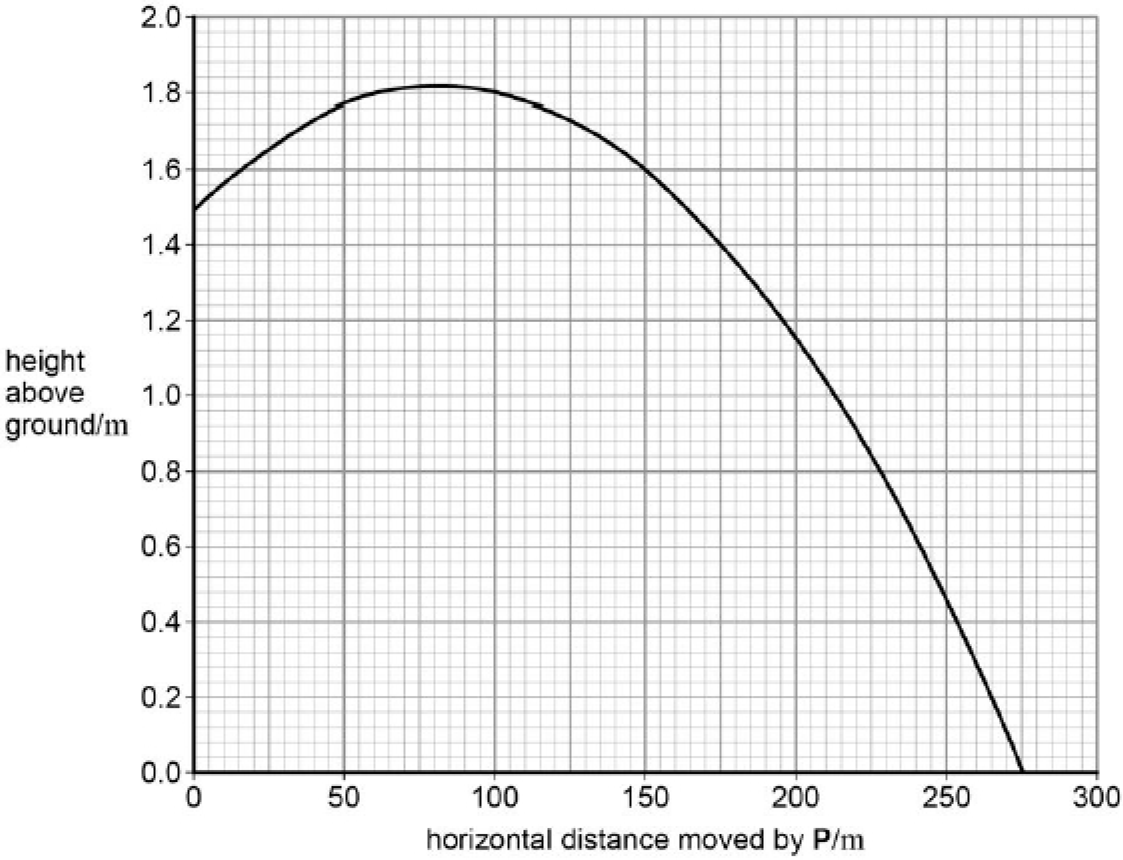
(c) A supersonic car is attempting to break the land speed record on a horizontal track. When it is travelling at 320 m s^{-1}, a small part **P** that is 1.5 m above the ground becomes detached from the car. The initial vertical velocity of **P** is 2.5 m s^{-1} in the upwards direction.

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.

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(2)
(Total 12 marks)

Mark schemes

1 **C**

[1]

2 (a) Calculation of energy = $12 \times 7.2 \times 10^4 = 8.64 \times 10^5$ J

Or time = 12000 / 1.5 = 8000 s ✓

Calculation of other quantity and substitution in power = useful energy / time taken ✓

Power = 110 (108 W) ✓

Or

Time = 8000 s ✓

Allow ecf for current or time

Current = charge / time = 9 A ✓

Power = VI = 108 (W) ✓

3

(b) Attempt to use Power / velocity ✓

Allow use of 100W for P

73 N ✓

Ignore inclusion of KE in calculation

If 108 used then answer is 72 N

If 100 used then answer is 67 N

or

work done = $F \times 12000$ ✓

equates to 110 × 8000 so F = 73 N ✓

allow ecf from 3.1

2

(c) Force parallel to slope = 120 × 9.81 × sin 4.5 = 92 N ✓

1

(d) Total resistive force = ans to (c) + ans to **(b)** (= 165 N) ✓

Allow ecf for incorrect F

Speed $= \left(\frac{100}{165} = \right) 0.61 \text{ m s}^{-1}$

Allow 0.66 / 0.67 if 108 W or 110 W used

2

(e) **Increasing the mass**

Reward discussion of compression of tyres

Reduces the range ✓

increases the friction on the bearings/tyres

OR More energy / power is used accelerating the user to the final speed

OR user and wheelchair have higher KE/ more energy to move ✓

Increasing the speed

Reduces the range ✓

Air resistance increases with speed ✓

Treat as independent parts

If not explicit about increasing / decreasing lose the first mark in each part

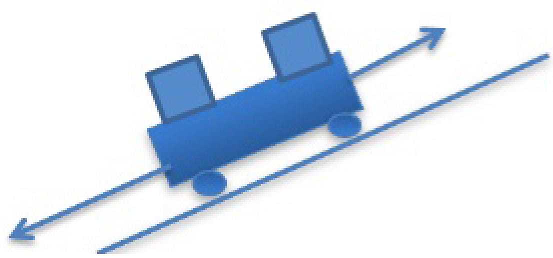
Within each part, second mark is dependent on the first

Allow opposite answers for decreasing mass / speed

4

[12]

3 (a) arrow parallel to slope labelled (M+2m)gsin35 and label parallel to slope labelled tension OR T ✓



Ignore arrows not parallel to ground e.g. weight

Ignore friction

W not acceptable for (M +2m)g

1

(b) T – Mgsin35 = Ma
AND (M+2m)gsin35 – T = (M+2m)a ✓

add two equations

(M + 2m)gsin35 – Mg sin35 = Ma + (M +2m)a ✓

HENCE
(a= mgsin35 / (M+m))

OR
(M +2m)gsin35 – Mgsin35 ✓ (= (2M+2m)a)

a = 2mgsin35 /(2M +2m) ✓

HENCE
(a= mgsin35 / (M+m))

1
1

(c) SECOND MARK CONDITIONAL ON FIRST
mass / impulse / acceleration (of trollies) is the same ✓
momenta (trolley A and B) the same

SECOND MARK CONDITIONAL ON FIRST

both have same *<u>speed / magnitude of velocity</u>* *but different masses* ✓

(hence) momentum of A is greater / momenta in opposite directions ✓

1
1

(d) $\text{acceleration} = \frac{1}{4} \times \frac{30 \times 9.81 \times \sin 35^\circ}{(30 + 95)} = 0.338$ ✓

(use of $v^2 = 2as$)

$v = \sqrt{(2 \times 0.338 \times 9.0)} = 2.47$ ✓

$t = \frac{2.47}{0.338} = 7.3\text{s}$ ✓

OR
(use of $s = 1/2at^2$)
$9 = ½ \times 0.338 \times t^2$ ✓
$t = 7.3$ s ✓

CE from acceleration calculation

If used g for acceleration then no marks awarded

1
1
1

(e) number of journeys = (1800/(12 + 7.3) = 93 or 94 ✓

number of blocks = 2 × 93 = 186 or 2 × 94 = 188 ✓

Allow CE from 06.4

Allow between 93 to 94

Allow CE from incorrect number of journeys

Allow 186 to 188

1
1

[10]

4 (a) resultant force = 11 000 × 2.9 = 31900 (N) ✓

resultant force = thrust − air resistance

OR

31 900 = 230 000 – air resistance✓

198 000 (N) ✓

3

(b) Air resistance increases with speed so resultant force decreases with speed ✓

Eventually air resistance = thrust (so no acceleration)✓

2

(c) Time to reach maximum height = 2.5/9.8=0.255 s✓

maximum height = 1.5 + 4.9 × 0.255^2 = 1.82 m✓

Time to reach ground from maximum height = 0.61 s giving total time = 0.87 s✓

OR

$-1.5 = 2.5t - 0.5 \times 9.8 \times t^2$✓

rearrange quadratic gives $4.9t^2 - 2.5t - 1.5 = 0$ and

solution $t = \dfrac{2.5 \pm \sqrt{2.5^2 + 4 \times 4.9 \times 1.5}}{2 \times 4.9}$ ✓

Giving solutions 0.86 or − 0.35 hence time = 0.86 s✓

Allow credit for alternative routes

3

(d) Starts at 2.5 m s^{-1} and maximum height same but reached earlier✓

Maximum range no more than 175 m✓

2

(e) Motion unchanged vertically / maximum height of P is unchanged: air resistance decelerates P horizontally so less distance travelled. (both points needed) ✓

Air resistance increases with speed: speed is low vertically but very high horizontally (both points needed) ✓

2

[12]