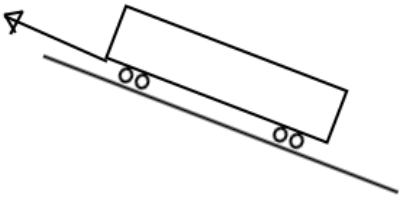
Section 2: Newton's second law

Exercise level 3 (Extension)

1. The Great Orme Tramway in North Wales is Britain's only remaining cable-operated street tramway. It takes passengers from Llandudno to the summit of the Great Orme. The cars are permanently fixed to the cable so are controlled by stopping and starting the cable winding mechanism. It has gradients as steep as 1 in 3.8.



(i) Assuming a particle model for a tram car, that the cable is parallel to the track on a straight section of maximum gradient, that the car has mass 20 tonnes, and that there is no resistance to motion, find the force in the cable necessary to hold the tram car at a stop at the maximum gradient. Take $g = 9.8$.

(ii) What is the normal reaction force from the track under such circumstances?

(iii) If the cable were to break what would be the acceleration of a tramcar and what would be its speed when it had travelled 100 metres down the hill? Again assume that there is no resistance to motion, and that no emergency brake is applied.

2. Two students are investigating the most efficient way to pull a heavy stone up a rough slope along the line of greatest slope. The mass of the stone is 200 kg and the slope is a plane inclined at 15^o to the horizontal. Take $g = 9.8$.

(i) Their first technique is to pull alongside each other, each with a separate rope attached to the stone. This constrains them to pull with their ropes at an angle of 60^o but the plane defined by their two ropes is inclined at 20^o to the slope. They find that they must pull at 1200 N each to achieve a steady speed. How great is the frictional resistance on the stone?

(ii) They then investigate pulling in turn so that the puller's rope and the motion are in the same vertical plane, although the rope is still inclined to the slope at 20^o. What force is required from the one who is pulling to manage that?

3. A tractor is pulling a load of 500 kg up a slope inclined at 15^o to the horizontal. It is attached to the load by a rope which is parallel to the line of slope.

(i) When the tractor is pulling with a force of 3000 N, it and the load accelerate at 0.5 ms^{-2} up the slope. Take $g = 9.8$. What is the resistance to motion?

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(ii) When the load and tractor have reached a speed of 0.75 ms^{-1} the rope is released. How long does it take the load to stop? How far does it travel in that time?

(iii) Once the load has stopped will it start to slide down the slope? (Assume that the resistance to downward motion has potentially the same magnitude as upward motion.)

On another occasion the load is placed on light sledge which reduces the resistance (both up and down) by 80%; the towing arrangement is as before.

(iv) How long does it take the load to stop if the traction is removed at 0.75 ms^{-1}? How long after that does it take to reach the same speed *down* the slope?