Further Maths A-Level Starter Activity

Topic: Kinematic Modelling

Chapter Reference: Mechanics 2, Chapter 7

12 minutes

1. A cyclist and her bicycle have a combined mass of 78 kg. While riding on level ground and using her greatest driving force, she is able to accelerate uniformly from rest to 10 ms -1 in 15 seconds against constant resistive forces that total 60 N.

a. Show that her maximum driving force is 112N **(4)**

The cyclist begins to ascend a hill, inclined at an angle α to the horizontal, riding with her maximum driving force and against the same resistive forces. In this case, she can maintain a steady speed.

b. Find the angle α, giving your answer to the nearest degree. (4 marks) **(4)**

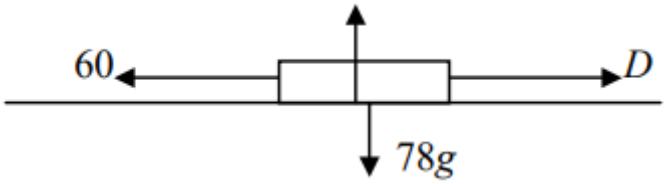
c. Comment on the assumption that the resistive force remains constant

(i) in the case when the cyclist is accelerating,

(ii) in the case when she is maintaining a steady speed. **(2)**

Solutions

1a.

	
Acceleration = $\frac{10-0}{15}$	**M1**
$a = \frac{2}{3}\ ms^{-2}$	**A1**

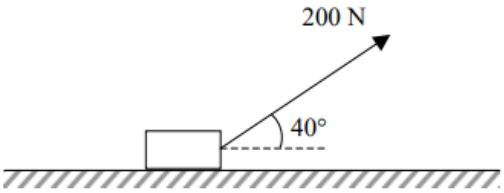
1b.

Equation of motion is 112 – 60 – 78 g sin α = 0	**M1** **A1**
sin $\alpha = \frac{52}{78g} = \frac{2}{3}g$	**M1**
$\alpha = 3.901$ $\alpha = 4^{o}$ to the nearest degree	**A1**

1c.

In (a) unlikely as increase in speed will cause increase in air resistance	**B1**
In (b) more reasonable as speed is constant	**B1**

1.



The figure above shows a large block of mass 50 kg being pulled on rough horizontal ground by means of a rope attached to the block. The tension in the rope is 200 N and it makes an angle of 40° with the horizontal. Under these conditions, the block is on the point of moving. Modelling the block as a particle,

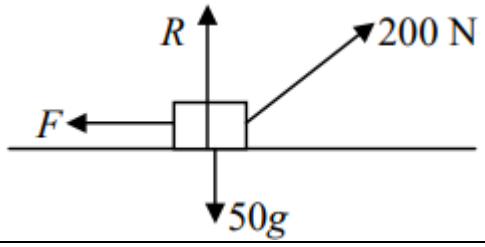
a. Show that the coefficient of friction between the block and the ground is 0.424 correct to 3 significant figures. **(6)**

The angle with the horizontal at which the rope is being pulled is reduced to 30°. Ignoring air resistance and assuming that the tension in the rope and the coefficient of friction remain unchanged,

b. Find the acceleration of the block **(6)**

Solutions

1a.

	
Resolve (V): R + 200 sin 40 – 50g = 0	**M1**
R = 50g – 200 sin 40	**A1**
Resolve (H): 200 cos 40 – F = 0	**M1**
F = 200 cos 40	**A1**
F = μR	**M1**
$\mu = \frac{200\cos 40}{50g - 200\sin 40} = 0.424\ (3sf)$	**A1**

1b.

Resolve (V): R + 200 sin 30 – 50g = 0	**M1**
R = 50g – 200 sin 30 = 390	**A1**
Resolve (H): 200 cos 30 – $\mu R = 50a$	**M1**
$50a = 100\sqrt{3} - 0.424$	**M1**
a = 0.16 ms^{-2}	**A1**

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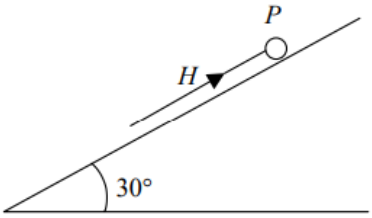
15 minutes

1.



A particle P, of mass 2 kg, lies on a rough plane inclined at an angle of 30° to the horizontal. A force H, whose line of action is parallel to the line of greatest slope of the plane, is applied to the particle as shown in the figure. The coefficient of friction between the particle and the plane is $\frac{1}{\sqrt{3}}$.

Given that the particle is on the point of moving up the plane,

a. Draw a diagram showing all the forces acting on the particle **(2)**

b. Show that the ratio of the magnitude of the frictional force to the magnitude of H is equal to 1 : 2 **(7)**

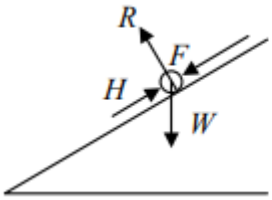
The force H is now removed but P remains at rest.

c. Use the principle of friction to explain how this is possible. **(2)**

Solutions

1a.

(a)



B2

1b.

resolve perp. to plane: $R - 2g\cos30° = 0 \quad \therefore R = g\sqrt{3}$	M1 A1
$F = \mu R = \frac{1}{\sqrt{3}} g\sqrt{3} = g$	M1 A1
resolve // to plane: $H - F - 2g\sin30° = 0$	M1
$H - g - g = 0 \quad \therefore H = 2g$	A1
$F : H = g : 2g = 1 : 2$	A1

1c.

friction varies between μR up plane (to prevent movement down plane)
and μR down plane (to prevent movement up plane) B2

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18 minutes

1. A car of mass 1.25 tonnes tows a caravan of mass 0.75 tonnes along a straight, level road. The total resistance to motion experienced by the car and the caravan is 1200 N. The car and caravan accelerate uniformly from rest to 25 ms^{-1} in 20 seconds.

a. Calculate the driving force produced by the car's engine. **(4)**

Given that the resistance to motion experienced by the car and by the caravan are in the same ratio as their masses,

b. Find these resistances and the tension in the towbar. **(4)**

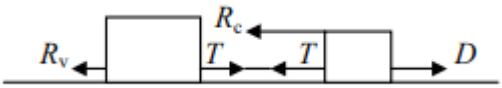
When the car and caravan are travelling at a steady speed of 25 ms -1, the towbar snaps. If the caravan experiences the same resistive force as before,

c. Calculate the distance travelled by the caravan before it comes to rest, **(5)**

d. Give a reason why your answer to (c) may be unrealistic. **(2)**

Solutions

1.



1a.

acc^n $= \frac{25-0}{20} = \frac{5}{4}$ ms^{-2}	M1 A1
for car and van, eqn. of motion is $D - 1200 = 2000 \times \frac{5}{4}$	M1
$D = 3700$ N	A1

1b.

1200 divided in ratio 1.25 : 0.75 i.e. 5 : 3	M1
car resistance $= \frac{5}{8} \times 1200 = 750$ N, so caravan resistance is 450 N	A1
for car, eqn. of motion is $3700 - 750 - T = 1250 \times \frac{5}{4}$	M1
$T = 1387.5$ N	A1

1c.

for van, $^-450 = 750a$ $\therefore a = {}^-\frac{3}{5}$ ms^{-2}	M1A1
$u = 25$, $v = 0$, $a = {}^-\frac{3}{5}$ use $v^2 = u^2 + 2as$	M1
$0 = 625 - \frac{6}{5}s$ $\therefore s = 520.8$ m	M1 A1

1d.

e.g. caravan may nose down at front, may not stay in a straight line	B1
so dist. likely to be less than that calculated in *(c)*	B1