Forces and acceleration

121 marks

Hints online, answers free with an account: mathswariz.uk/worksheets/a-level-mechanics-forces-and-acceleration/

Date

A Do Now

Quick questions to start. Some use earlier lessons; some set a slip that costs marks.

A1 Needed today [3 marks]

A cyclist increases her speed uniformly from $3\ \text{m s}^{-1}$ to $15\ \text{m s}^{-1}$ in 4 s. Find her acceleration and the distance she travels in this time.

Answer .....

A2 Last lesson [2 marks]

A box of mass 4 kg rests on a horizontal table. A light string pulls vertically upwards on the box with tension 15 N. Find the normal reaction from the table.

Answer .....

A3 Common slip [2 marks]

A car slows down uniformly from $20\ \text{m s}^{-1}$ to rest in a distance of 50 m. Taking the direction of motion as positive, find the acceleration of the car.

Answer .....

A4 Common slip [2 marks]

A particle of mass 250 g is acted on by a resultant force of 0.6 N. Find its acceleration.

Answer .....

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B Example, then your turn

A-Level

Your teacher works through each example with you. Then try the one beside it.

EXAMPLE 1

A box of mass 8 kg is pushed along a horizontal floor by a horizontal force of 50 N. The resistance to motion is 18 N. Find the acceleration of the box and the normal reaction from the floor.

Hint Draw the four forces and the acceleration arrow. In $F = ma$, F is the RESULTANT force in the direction of the acceleration, not the push alone.

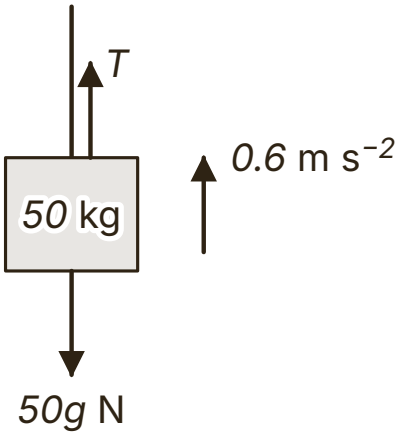
B1 A car of mass 1200 kg moves along a straight horizontal road. The engine gives a constant driving force of 3000 N and the resistance to motion is constant. The speed of the car increases from $4\ \text{m s}^{-1}$ to $16\ \text{m s}^{-1}$ in 8 s. Find the resistance to motion. [4 marks]

Answer .....

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EXAMPLE 2

A load of mass 50 kg is raised by a vertical rope with an upward acceleration of $0.6\ \text{m s}^{-2}$. Find the tension in the rope. Later the load is lowered with a downward acceleration of $0.6\ \text{m s}^{-2}$. Find the tension now.



Hint The weight $50g$ N always acts down. Take the direction of the acceleration as positive and write $F = ma$ with every force in that direction.

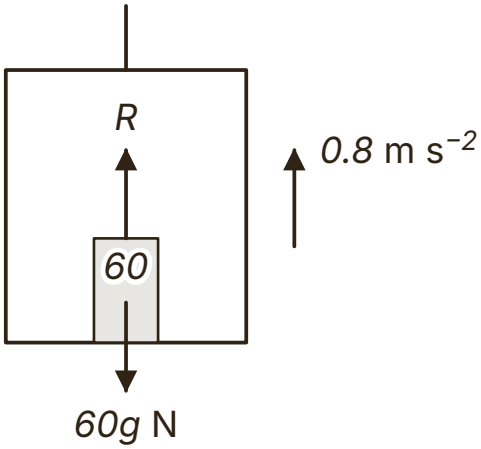
B2 A crate of mass 80 kg is lowered on a vertical rope. It starts from rest and moves down 4.5 m in 3 s with constant acceleration. Find the tension in the rope. [5 marks]

Answer .....

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EXAMPLE 3

A woman of mass 60 kg stands in a lift. Find the force exerted on her by the floor when the lift (a) moves upwards with acceleration $0.8\ \text{m s}^{-2}$, (b) moves upwards and slows down with deceleration $0.5\ \text{m s}^{-2}$.



Hint Write the equation of motion for the WOMAN only: her weight down and the reaction R up. The lift's cable does not act on her.

B3 A man stands on weighing scales in a lift. When the lift accelerates upwards at $1.2\ \text{m s}^{-2}$ the scales show a force of 880 N. Find the mass of the man. Find the force shown by the scales when the lift is moving downwards and slowing down at $0.6\ \text{m s}^{-2}$. [5 marks]

Answer .....

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EXAMPLE 4

A particle of mass 2 kg is pulled from rest across a horizontal floor by a horizontal force of 14 N. The resistance to motion is a constant 4 N. After 3 s the pulling force is removed. Find the total distance the particle travels.

Hint Two stages, two accelerations. Find the speed at the end of stage 1: it is the initial speed of stage 2. In stage 2 only the resistance acts.

B4 A sledge of mass 25 kg is pulled from rest across horizontal ice by a horizontal rope with tension 75 N. The resistance to motion is a constant 30 N. After 10 s the rope is released. Find the total distance the sledge travels. [6 marks]

Answer .....

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EXAMPLE 5

A ball of mass 0.5 kg is thrown vertically upwards with speed $14\ \text{m s}^{-1}$. Air resistance is modelled as a constant force of 1.1 N. Find the greatest height the ball reaches above the point of projection, and its speed when it returns to that point.

Hint Air resistance opposes the motion: down while the ball rises, up while it falls. So the accelerations up and down are different.

B5 A stone of mass 0.4 kg is thrown vertically upwards with speed $21\ \text{m s}^{-1}$. Air resistance is modelled as a constant force of 0.56 N. Find the greatest height the stone reaches above the point of projection, and the total time until it returns to that point. [7 marks]

Answer .....

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C1 A bucket of mass 6 kg is raised by a vertical rope with an upward acceleration of $0.4\ \text{m s}^{-2}$. Ravi writes $T = 6 \times 0.4 = 2.4$ N. Explain his mistake and find the tension. [4 marks]

Answer .....

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C2 A man of mass 70 kg stands in a lift that is moving downwards and slowing down at $0.7\ \text{m s}^{-2}$. Pia says: "The lift is going down, so the floor pushes on him with less than his weight." Explain why Pia is wrong and find the force the floor exerts on him. [4 marks]

Answer .....

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C3 A van of mass 2000 kg moves on a straight horizontal road. The engine gives a driving force of 5000 N and the resistance to motion is 1400 N. Ben writes $a = \dfrac{5000}{2000} = 2.5\ \text{m s}^{-2}$. Correct his working, and find the time the van takes to increase its speed from $5\ \text{m s}^{-1}$ to $23\ \text{m s}^{-1}$. [4 marks]

Answer .....

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C4 A boat of mass 1500 kg moves at a constant speed of $6\ \mathrm{m\ s^{-1}}$ in a straight line. The engine gives a forward force of 2400 N. Zoe writes $2400 - R = 1500 \times 6$. Explain her mistake and find the resistance R. The engine force is then increased to 3000 N with the resistance unchanged. Find how far the boat travels while its speed increases to $10\ \mathrm{m\ s^{-1}}$. [5 marks]

Answer .....

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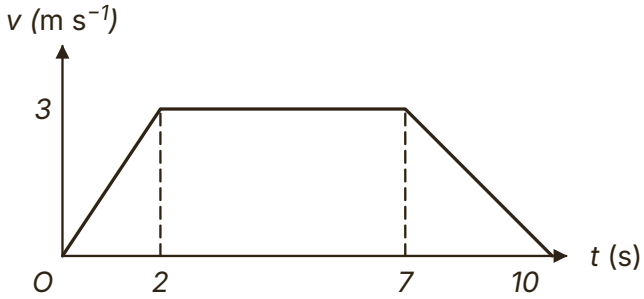
C5 A box is pulled along a horizontal floor by a horizontal force. The resistance to motion is a constant F N. When the force is 40 N the acceleration is $3\ \mathrm{m\ s^{-2}}$, and when the force is 64 N the acceleration is $5\ \mathrm{m\ s^{-2}}$. Find the mass of the box and F. [4 marks]

Answer .....

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D1 A lift of mass 500 kg carries a woman of mass 65 kg. The lift is raised by a vertical cable. The velocity-time graph shows its motion: it starts from rest, moves upwards with constant acceleration for 2 s, moves at a constant speed of $3\ \text{m s}^{-1}$, then slows down at a constant rate and comes to rest at $t = 10$ s. The cable is modelled as light and inextensible.

(a) Find the tension in the cable during the first 2 s. [3 marks]



Answer .....

(b) Find the force exerted on the woman by the floor of the lift during the last 3 s. [3 marks]

Answer .....

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(c) Find the total distance the lift rises. [2 marks]

Answer .....

(d) Explain why the mass 565 kg is used in part (a) but the mass 65 kg is used in part (b). [2 marks]

Total for D1: 10 marks

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D2

A stone of mass 0.25 kg is thrown vertically upwards with speed $18\ \text{m s}^{-1}$. Air resistance is modelled as a constant force of 0.7 N. Kim writes: "Going up, $0.25a = 0.25g - 0.7$, so the deceleration is $7\ \text{m s}^{-2}$."

Kim is wrong.

(a) Explain Kim's mistake. [2 marks]

(b) Find the greatest height of the stone above the point of projection. [3 marks]

Answer .....

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(c) Find the total time for which the stone is more than 5 m above the point of projection. [5 marks]

Answer .....

Total for D2: 10 marks

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D3 A stone of mass 0.6 kg is dropped from rest from a point 2.5 m above soft ground. It falls freely, hits the ground and sinks 4 cm into the ground before it comes to rest. The ground is modelled as giving a constant resistance to the motion of the stone, and air resistance is ignored. Find the magnitude of the resistance from the ground. [7 marks]

Answer .....

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D4 A crate of mass 120 kg is raised from rest on the ground by a vertical cable. For the first 4 s the tension in the cable is 1296 N. The cable is modelled as light and inextensible and air resistance is ignored.

(a) Find the acceleration of the crate during the first 4 s. [2 marks]

Answer .....

(b) Find the speed of the crate and its height above the ground at $t = 4$ s. [2 marks]

Answer .....

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(c) The tension is then changed so that the crate rises at constant speed. Find the new tension. [2 marks]

Answer .....

(d) After rising at constant speed for 3 s, the cable breaks. Find the time from the moment the cable breaks until the crate hits the ground. [4 marks]

Answer .....

Total for D4: 10 marks

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D5 A particle P of mass 3 kg is pulled from rest across a horizontal floor by a constant horizontal force of 21 N. The resistance to motion is a constant F N. In the first 4 s, P moves 16 m.

(a) Find F. [4 marks]

Answer .....

(b) At $t = 4$ s the pulling force is removed. Find the time P takes to come to rest and the total distance it moves. [3 marks]

Answer .....

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(c) Sketch a velocity-time graph for the motion of P from $t = 0$ until it comes to rest, showing the values where the lines meet the axes and the greatest speed. [2 marks]

Total for D5: 9 marks

D6 A firework of mass 0.5 kg is launched vertically upwards from rest on the ground. For the first 2 s the engine gives a constant upward thrust of 9 N. After 2 s the thrust stops. The firework is modelled as a particle of constant mass and air resistance is ignored.

(a) Find the acceleration of the firework while the engine works. [2 marks]

Answer .....

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(b) Find the speed and the height of the firework at $t = 2$ s. [2 marks]

Answer .....

(c) Find the greatest height of the firework above the ground. [3 marks]

Answer .....

(d) State one way in which the model of constant mass is not realistic, and its effect on the answer to part (c). [2 marks]

Total for D6: 9 marks

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E Extension

Stretch

No route is given. The hints are at the end of the sheet. Use one at a time.

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E1 A woman stands on weighing scales in a lift. When the lift moves upwards with acceleration $a\ \mathrm{m\ s^{-2}}$ the scales show 693 N. When the lift moves upwards and slows down with deceleration $a\ \mathrm{m\ s^{-2}}$ the scales show 483 N. Find the mass of the woman and the value of a. On one journey the lift starts from rest, accelerates at $a\ \mathrm{m\ s^{-2}}$ for T s, moves at constant speed, then slows down at $a\ \mathrm{m\ s^{-2}}$ for T s and comes to rest. The journey takes 10 s and the lift rises 28 m. Find T and the greatest speed of the lift. [9 marks]

Answer .....

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Extension hints

Cover these with paper. Uncover one at a time.

E1

Hint 1 Write two equations of motion for the woman: $693 - mg = ma$ and $483 - mg = -ma$. Add them.

Hint 2 Sketch the velocity-time graph. The greatest speed is aT and the time at constant speed is $10 - 2T$. The area is 28.

Hint 3 The equation in T is a quadratic with two roots. Check each against the fact that the two slowing and speeding stages fit inside 10 s.

How did it go?

Colour one circle on each line: not yet, nearly, yes.

I can write an equation of motion F = ma using the resultant force, with the weight mg when the motion is vertical.	○ ○ ○
I can find the tension in a rope or the reaction of a lift floor when the load accelerates up or down.	○ ○ ○
I can combine F = ma with the constant acceleration formulae, including when a force changes part way.	○ ○ ○
I can solve problems where air resistance gives different accelerations going up and coming down.	○ ○ ○

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