Newton's Laws 2i

A Level

A trailer of mass $500\,\mathrm{kg}$ is attached to a car of mass $1250\,\mathrm{kg}$ by a light rigid horizontal tow-bar. The car and trailer are travelling along a horizontal straight road. The resistance to motion of the trailer is $400\,\mathrm{N}$ and the resistance to motion of the car is $900\,\mathrm{N}$. Find both the tension in the tow-bar and the driving force of the car in each of the following cases.

Part A Driving force 1

The car and trailer are travelling at constant speed.

What is the driving force?

Part B Tension 1

What is the tension in the tow-bar?

Part C Driving force 2

The car and trailer have acceleration $0.6\,\mathrm{m\,s^{-2}}$.

What is the driving force of the car? Give your answer to 4 significant figures.

Part D Tension 2

What is the tension in the tow-bar?

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Normal Reaction 2i

A Level

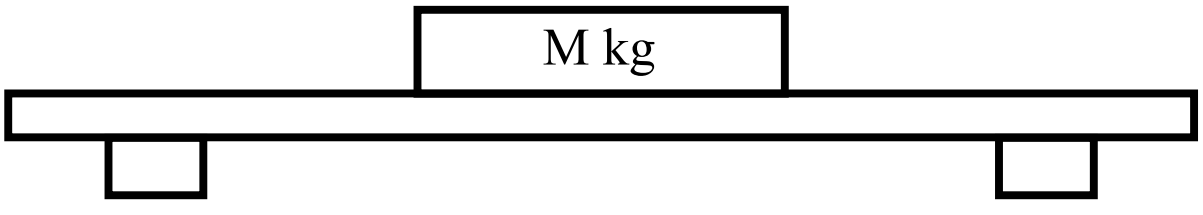

Figure 1: Diagram showing a block of mass $M\,\mathrm{kg}$ on a platform which is raised by a hoist.

A box of mass $M\,\mathrm{kg}$ is loaded onto a platform which can be raised by a hoist. The platform, which consists of 2 vertical supports and a horizontal plate, has a total mass of $30\,\mathrm{kg}$. Before the hoist is attached, the box and platform are on horizontal ground and the thrust in each support is $350\,\mathrm{N}$.

Part A Mass of box

Find the mass of the box to 3 significant figures.

Part B Normal reaction 1

The platform is now connected to the hoist cable, raised slowly by a short distance so that it leaves the ground, and brought to a halt.

Find the normal reaction on the box in this stationary position to 3 significant figures.

Part C Tension

Find the tension in the hoist cable.

Part D Normal reaction 2

The hoist suddenly jerks the platform upwards, with an initial acceleration of $1.5\,\mathrm{m\,s^{-2}}$.

Find the normal reaction on the box to 3 significant figures.

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Gameboard:

STEM SMART Double Maths 21 - Forces and Friction

Analysing Systems and Forces 2i

A Level

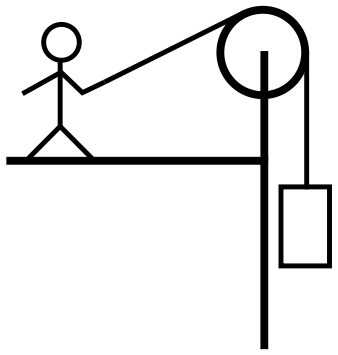

Figure 1: Man preparing to lower a box down a cliff.

A man is preparing to lower a box down a cliff. He sets up a fixed pulley with a rope as shown in **Figure 1**. He pulls on the rope with a force $-(100\,\underline{\boldsymbol{i}} + 75\,\underline{\boldsymbol{j}})\,\mathrm{N}$ and the box settles into a stationary position with the rope between the box and pulley vertical.

Part A Force in rope

The force **on the man's hand from the rope** can be written as

$$\underline{\boldsymbol{F}} = \begin{pmatrix} F_1 \\ F_2 \end{pmatrix}$$

Find F_1.

Find F_2.

Part B Magnitude of tension

What is the magnitude of the tension in the rope?

Part C Force diagrams

Draw a labelled diagram showing the forces acting in the rope at the pulley.

Easier question?

Draw a labelled diagram showing the forces on the box.

Easier question?

Part D Assumptions

In order to model the system mathematically, it is necessary to make assumptions. Give one assumption you need to make about the pulley and two assumptions about the rope.

Easier question?

Part E Mass of box

Find the mass of the box to 3 significant figures.

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Gameboard:

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Analysing Systems and Forces 1i

A Level

A small, smooth pulley is suspended from a fixed point by a light chain. A light inextensible string passes over the pulley. Particles P and Q, of masses $0.30\,\mathrm{kg}$ and m respectively, are attached to the opposite ends of the string. The particles are released from rest at a height of $0.20\,\mathrm{m}$ above horizontal ground with the string taut; the portions of the string not in contact with the pulley are vertical. P strikes the ground with speed $1.4\,\mathrm{m\,s^{-1}}$. Subsequently P remains on the ground and Q does not reach the pulley.

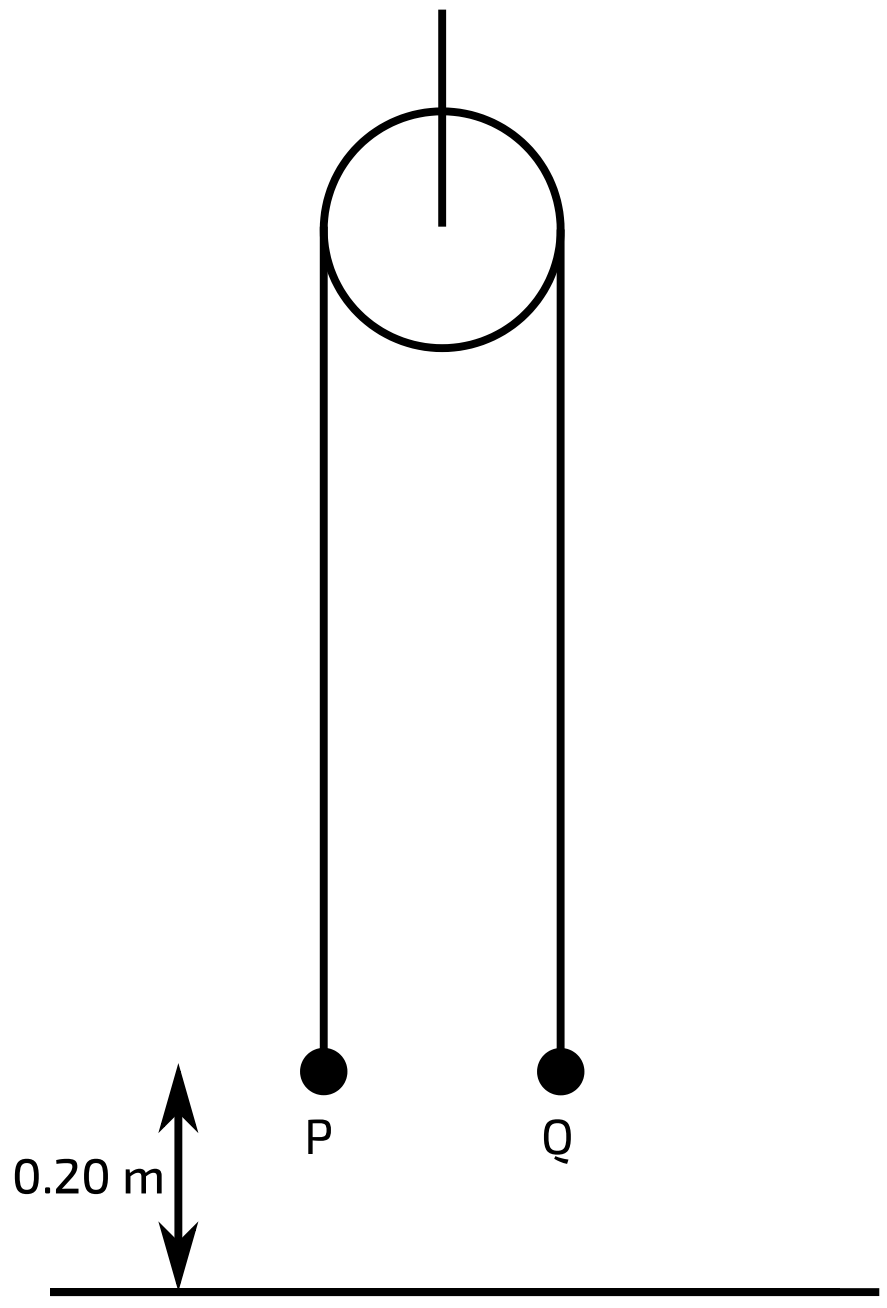

Figure 1: Diagram showing string with P and Q on either end passing over a pulley.

Part A Acceleration of P

Calculate the acceleration of P while it is in motion to 2 significant figures.

Part B Tension in the string

Calculate the tension in the string to 2 significant figures.

Part C Mass of Q

Find the mass of Q.

Part D Height of Q

Calculate the greatest height of Q above the ground.

Part E Tension in the chain

It is given that the mass of the pulley is $0.50\,\mathrm{kg}$.

State the magnitude of the tension in the chain which supports the pulley when P **is in motion**. Give your answer to 2 significant figures.

Part F Tension when Q moving upwards

State the magnitude of the tension in the chain which supports the pulley when P **is at rest on the ground and** Q **is moving upwards**. Give your answer to 2 significant figures.

Used with permission from UCLES, A Level Maths, June 2010, OCR M1, Question 7

Gameboard:
STEM SMART Double Maths 21 - Forces and Friction

2D Vectors & NII 1i

A Level

P P P

Three horizontal forces, acting at a single point have magnitudes $12\,\mathrm{N}$, $14\,\mathrm{N}$ and $5\,\mathrm{N}$ and act along bearings $000\,^\circ$, $090\,^\circ$, and $270\,^\circ$ respectively.

Part A Force diagram

Show these forces on a diagram.

Easier question?

Part B Base vector form

Express the $12\,\mathrm{N}$ force using ijk notation.

The following symbols may be useful: `i, j, k`

Express the $14\,\mathrm{N}$ force using ijk notation.

The following symbols may be useful: `i, j, k`

Express the $5\,\mathrm{N}$ force using ijk notation.

The following symbols may be useful: `i, j, k`

Part C Magnitude and bearing

Find the magnitude of the resultant force to 2 significant figures.

Find the bearing of the resultant force.

Part D Mass

The three forces are applied to a small particle producing an acceleration of $(45\underline{\underline{\boldsymbol{i}}} + 60\underline{\underline{\boldsymbol{j}}})\,\mathrm{m\,s^{-2}}$.

Find the mass of the particle.

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Resolving Forces 2i

A Level

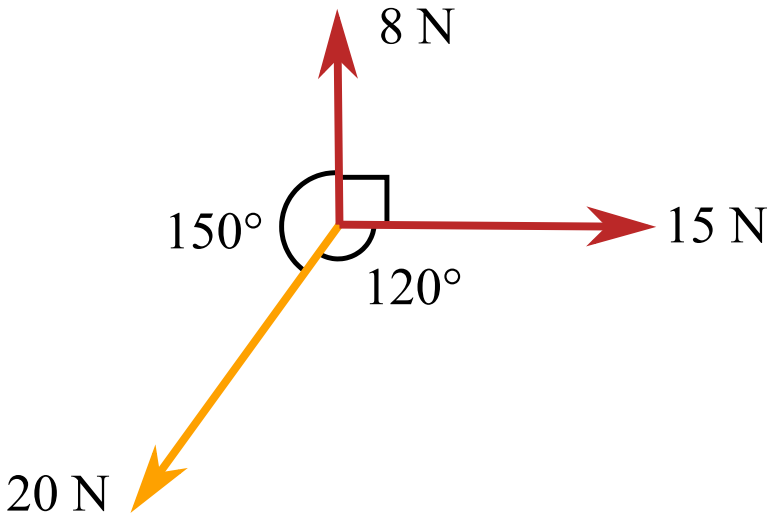

Figure 1: Three horizontal forces of magnitudes $8\,\mathrm{N}$, $15\,\mathrm{N}$ and $20\,\mathrm{N}$ acting at a point

Three horizontal forces of magnitudes $8\,\mathrm{N}$, $15\,\mathrm{N}$ and $20\,\mathrm{N}$ act at a point. The $8\,\mathrm{N}$ and $15\,\mathrm{N}$ forces are at right angles. The $20\,\mathrm{N}$ force takes an angle of 150° with the $8\,\mathrm{N}$ force and an angle of 120° with the $15\,\mathrm{N}$ force.

Part A Resultant force

Calculate the component of the resultant of the three forces, along the direction of the $15\,\mathrm{N}$ force.

Calculate the component of the resultant of the three forces, along the direction of the $8\,\mathrm{N}$ force. Give your answer to 3 significant figures.

Part B Magnitude and angle

Calculate the magnitude of the resultant force to 3 significant figures.

Calculate the angle it makes with the direction of the $8\,\mathrm{N}$ force to 3 significant figures.

Part C Greatest and least

The directions in which the three horizontal forces act can be altered.

State the greatest possible magnitude of the resultant force to 2 significant figures.

State the least possible magnitude of the resultant force.

Gameboard:

STEM SMART Double Maths 21 - Forces and Friction

General Contact Force 1ii

A Level

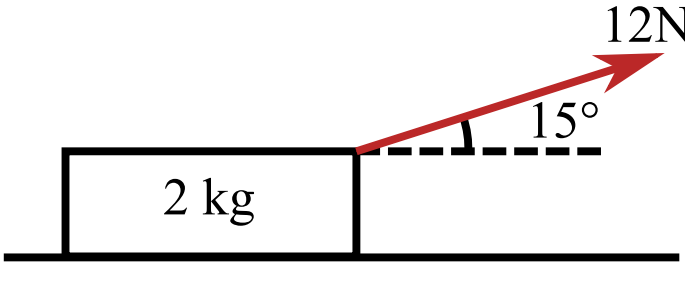

Figure 1: A block resting on a rough horizontal plane acted on by a force of $12\,\mathrm{N}$ at an angle of $15\,^\circ$ to the horizontal.

A block of mass $2\,\mathrm{kg}$ is at rest on a rough horizontal plane, acted on by a force of magnitude $12\,\mathrm{N}$ at an angle of $15\,^\circ$ upwards from the horizontal.

Part A Frictional component

Find the frictional component of the contact force exerted on the block by the plane. Give your answer to 3 significant figures.

Part B Magnitude of normal component

Find the magnitude of the normal component of the contact force exerted on the block by the plane, correct to 3 significant figures.

Part C Coefficient of friction

It is given that the block is on the point of sliding.

Find the coefficient of friction between the block and the plane.

Part D Acceleration of block

The force of magnitude $12\,\mathrm{N}$ is now replaced by a horizontal force of magnitude $20\,\mathrm{N}$. The block starts to move.

Assuming that the frictional force due to the rough plane has the same coefficient of friction as that found in Part C, find the acceleration of the block correct to 3 significant figures.

Gameboard:

STEM SMART Double Maths 21 - Forces and Friction

Motion on Inclined Planes 1i

A Level

A and B are two points on a line of greatest slope of a plane inclined at $45\,^\circ$ to the horizontal and $AB = 2.0\,\mathrm{m}$. A particle P of mass $0.40\,\mathrm{kg}$ is projected from A towards B with speed $5.0\,\mathrm{m\,s^{-1}}$. The coefficient of friction between the plane and P is 0.20.

Part A Speed of P

Given that the level of A is above the level of B, calculate the speed of P when it passes through the point B.

Part B Time taken by P

What is the time taken for P to travel from A to B?

Part C P reaching B

Given instead that the level of A is below that of B, will P reach B?

- Yes, it reaches B with a speed of $2\,\mathrm{m\,s^{-1}}$.
- No, it does does not reach B. It only travels $1.5\,\mathrm{m}$ up the incline.
- No, it does not reach B. It only travels $0.5\,\mathrm{m}$ up the slope.
- Yes, it just reaches B, but no further.

Gameboard:

STEM SMART Double Maths 21 - Forces and Friction

Friction on Inclined Planes 3i

A Level

A sledge of mass $25\,\mathrm{kg}$ is on a plane inclined at $30\,^\circ$ to the horizontal. The coefficient of friction between the sledge and the plane is 0.2.

Part A Tension in cable

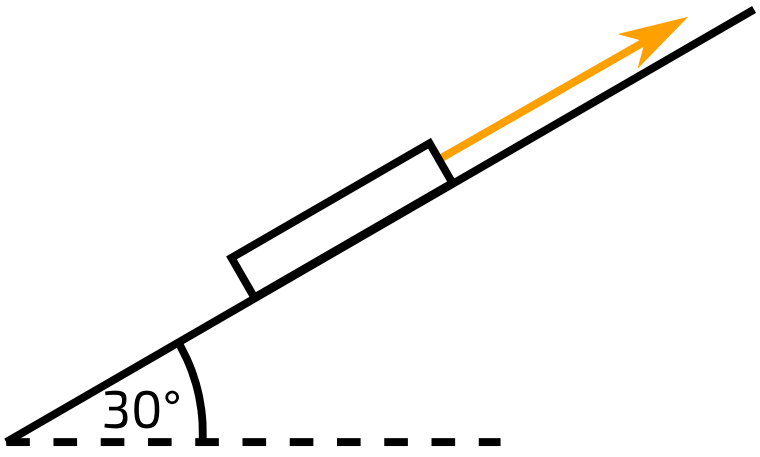

Figure 1: A sledge being pulled up an inclined plane.

The sledge is pulled up the plane, with constant acceleration, by means of a light cable which is parallel to a line of greatest slope. The sledge starts from rest and acquires a speed of $0.8\,\mathrm{m\,s^{-1}}$ after being pulled for $10\,\mathrm{s}$.

Ignoring air resistance, find the tension in the cable correct to 3 significant figures.

Part B Least value of P

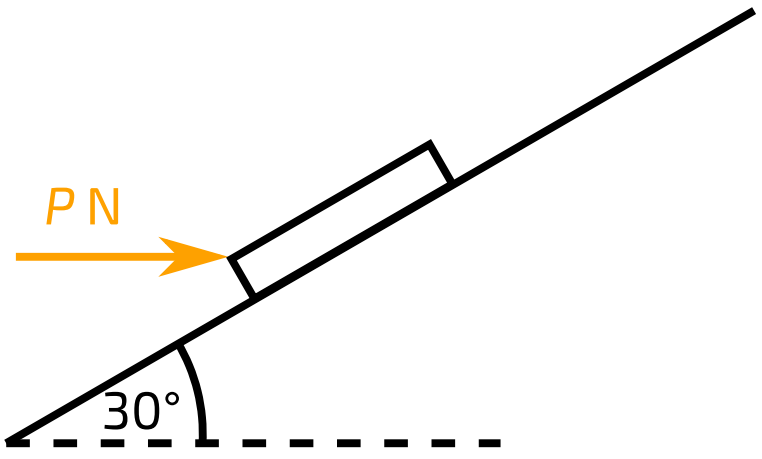

Figure 2: A sledge held at rest by a horizontal force on an inclined plane.

On a subsequent occasion the cable is not in use and two people of total mass $150\,\mathrm{kg}$ are seated in the sledge. The sledge is held at rest by a horizontal force of magnitude P newtons, as shown in Fig. 2.

Find the least value of P which will prevent the sledge from sliding down the plane. Give your answer correct to 3 significant figures.
