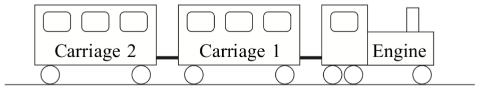
AS#65 FORCE DIAGRAMS

AEM questions are taken from past exam papers - they have been carefully chosen to represent a typical exam question at each level of difficulty. If you can do these questions, you're ready to move onto past papers for this topic.

APPRENTICE

A small train at an amusement park consists of an engine and two carriages connected to each other by light horizontal rods, as shown in the diagram. The engine has mass $2000\,\text{kg}$ and each carriage has mass $500\,\text{kg}$.

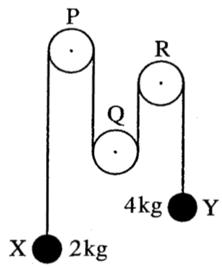


The train moves along a straight horizontal track. A resistance force of magnitude 400 Newtons acts on the engine, and resistance forces of magnitude 300 Newtons act on each carriage. The train is accelerating at $0.5\,\text{ms}^{-2}$.

Draw a diagram to show the **horizontal** forces acting on Carriage 2.

EXPERT

Particles of mass $2\,\text{kg}$ and $4\,\text{kg}$ are attached to the ends X and Y of a light, inextensible string. The string passes round fixed, smooth pulleys at P, Q and R, as shown in the diagram. The system is released from rest with the string taut.



The tension in the string is T N and the magnitude of the acceleration of the particles is $a\,\text{ms}^{-2}$.

Draw a diagram showing the forces acting at X and a diagram showing the forces acting at Y.

MASTER

A man of weight X N stands in a lift of weight M N which is moving upwards and slowing down.

a. Draw a force-acceleration diagram for the man

b. Draw a force-acceleration diagram for the lift

c. Draw a force acceleration diagram for the lift and man combined.

AS#66 NEWTON'S SECOND LAW

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APPRENTICE

A car of mass 1400 kg is travelling along a straight horizontal road. It is moving at $14\ \mathrm{ms}^{-1}$ when it starts to accelerate due to a horizontal forward driving force of $1600\ \mathrm{N}$. It accelerates at $0.8\ \mathrm{ms}^{-2}$ for 12 seconds.

a. Draw a diagram showing the forces acting on the car

b. Find the magnitude of the resistance force that acts on the car.

EXPERT

An air balloon of mass 1400 kg is descending vertically with an acceleration of $2\ \mathrm{ms}^{-2}$

a. Draw a diagram showing the forces acting on the balloon

b. Find the upward force being exerted on the balloon by the atmosphere

MASTER

A rope with a bucket attached is used to draw water from a well. The mass of the empty bucket is 1.2 kg and it can raise 10 kg of water when full.

Find the tension in the rope when

a. the empty bucket is being lowered with an acceleration of $2\ \mathrm{ms}^{-2}$

b. the empty bucket is being lowered at a constant speed

c. the full bucket is being raised with an acceleration of $0.3\ \mathrm{ms}^{-2}$

AS#67 PULLEY PROBLEMS

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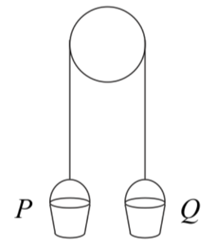
APPRENTICE

A builder ties two identical buckets, P and Q, to the ends of a light inextensible rope. He hangs the rope over a smooth beam so that the buckets hang in equilibrium, as shown in the diagram. The buckets are each of mass 0.6 kg.



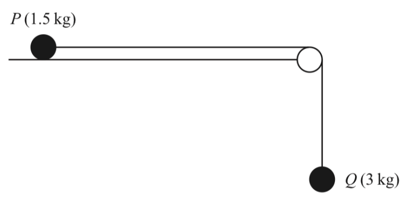
a. i. State the magnitude of the tension in the rope.
   ii. State the magnitude and direction of the force exerted on the beam by the rope.

The bucket Q is held at rest while a stone, of mass 0.2 kg, is placed inside it. The system is then released from rest and, in the subsequent motion, bucket Q moves vertically downwards with the stone inside.

b. By forming an equation of motion for each bucket, show that the magnitude of the tension in the rope during the motion is 6.72 Newtons, correct to three significant figures.

EXPERT

Two particles P and Q have masses 1.5 kg and 3 kg respectively. The particles are attached to the ends of a light inextensible string. Particle P is held at rest on a fixed rough horizontal table. P moves against a resistance of 2.94 N.



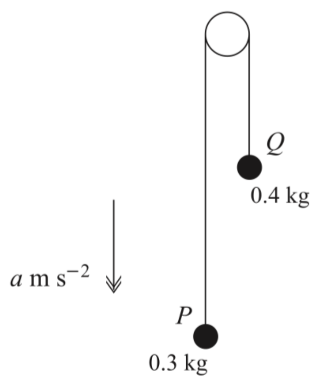
The string is parallel to the table and passes over a small smooth light pulley which is fixed at the edge of the table. Particle Q hangs freely at rest vertically below the pulley which is fixed at the edge of the table. Particle Q hangs freely at rest vertically below the pulley, as shown in the diagram. Particle P is released from rest with the string taut and slides along the table.

Assuming that P has not reached the pulley, find:

a. the tension in the string during the motion,
b. the magnitude and direction of the resultant force exerted on the pulley by the string.

MASTER

Particles P and Q, of masses 0.3 kg and 0.4 kg respectively, are attached to the ends of a light inextensible string. The string passes over a smooth fixed pulley. The system is in motion with the string taut and with each of the particles moving vertically. The downward acceleration of P is $a\text{ ms}^{-2}$ (see diagram).



a. Show that $a = -1.4$.

Initially P and Q are at the same horizontal level. P's initial velocity is vertically downwards and has magnitude 2.8 ms^{-1}.

b. Assuming that P does not reach the floor and that Q does not reach the pulley, find the time taken for P to return to its initial position.

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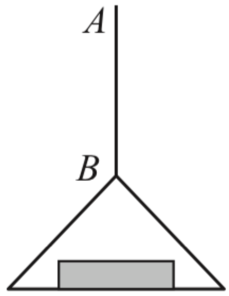
APPRENTICE

A vertical rope AB has its end B attached to the top of a scale pan. The scale pan has mass $0.5\,\mathrm{kg}$ and carries a brick of mass $1.5\,\mathrm{kg}$, as shown in the diagram. The scale pan is raised vertically upwards with constant acceleration $0.5\,\mathrm{ms^{-2}}$ using the rope AB. The rope is modelled as a light inextensible string.



a. By considering the forces on the whole system (scale pan and brick together), find the tension in the rope AB.

b. By considering the forces on the scale pan, find the magnitude of the force exerted on the scale pan by the brick.

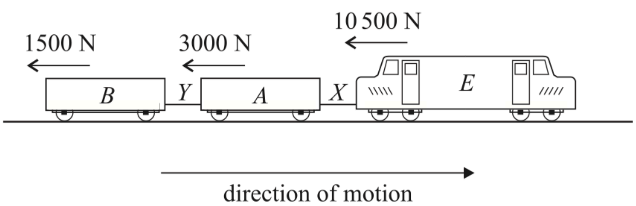
EXPERT

A woman travels in a lift. The mass of the woman is $50\,\mathrm{kg}$ and the mass of the lift is $950\,\mathrm{kg}$. The lift is being raised vertically by a vertical cable which is attached to the top of the lift. The lift is moving upwards and has constant deceleration of $2\,\mathrm{ms^{-2}}$. By modelling the cable as being light and inextensible, find

a. the tension in the cable,
b. the magnitude of the force exerted on the woman by the floor of the lift.

MASTER

A train of total mass $80000\,\mathrm{kg}$ consists of an engine E and two trucks A and B. The engine E and truck A are connected by a rigid coupling X, and trucks A and B are connected by another rigid coupling Y. The couplings are light and horizontal. The train is moving along a straight horizontal track. The resistances to motion acting on E, A and B are $10500\,\mathrm{N}$, $3000\,\mathrm{N}$ and $1500\,\mathrm{N}$ respectively (see diagram).



a. By modelling the whole train as a single particle, show that it is decelerating when the driving force of the engine is less than $15000\,\mathrm{N}$.
b. Show that when the magnitude of the driving force is $35000\,\mathrm{N}$ the acceleration of the train is $0.25\,\mathrm{ms^{-2}}$.
c. Hence find the mass of E, given that the tension in the coupling X is $8500\,\mathrm{N}$ when the magnitude of the driving force is $35000\,\mathrm{N}$.

The driving force is replaced by a breaking force of magnitude $15000\,\mathrm{N}$ acting on the engine. The force exerted by the coupling Y is zero.

d. Find the mass of B.
e. Show that the coupling X exerts a forward force of magnitude $1500\,\mathrm{N}$ on the engine.

AS#69 CHANGE IN MOTION

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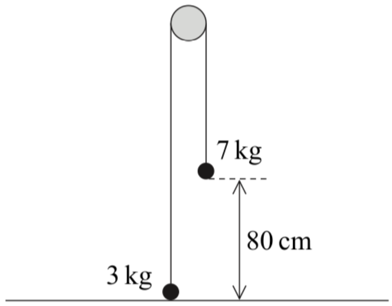
APPRENTICE

Two particles, of masses $3\,\mathrm{kg}$ and $7\,\mathrm{kg}$ are connected by a light inextensible string that passes over a smooth peg. The $3\,\mathrm{kg}$ particle is held at ground level with the string above it taut and vertical. The $7\,\mathrm{kg}$ particle is at a height of $80\,\mathrm{cm}$ above ground level, as shown in the diagram. The $3\,\mathrm{kg}$ particle is then released from rest.



a. By forming two equations of motion, show that the magnitude of the acceleration of the particles is $3.92\,\mathrm{ms}^{-2}$.

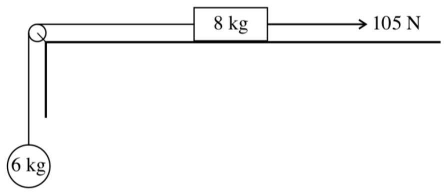
b. Find the speed of the $7\,\mathrm{kg}$ particle just before it hits the ground.

When the $7\,\mathrm{kg}$ particle hits the ground, the string becomes slack and in the subsequent motion the $3\,\mathrm{kg}$ particle does not hit the peg.

c. Find the maximum height above the ground reached by the $3\,\mathrm{kg}$ particle.

EXPERT

The diagram shows the box of mass $8\,\mathrm{kg}$ on a long, rough, horizontal table. A sphere of mass $6\,\mathrm{kg}$ is attached to the box by means of a light inextensible string that passes over a smooth pulley. The section of the string between the pulley and the box is parallel to the table. The constant frictional force of $11.2\,\mathrm{N}$ opposes the motion of the box. A force of $105\,\mathrm{N}$ parallel to the table acts on the box in the direction shown, and the acceleration of the system is in that direction.



a. By drawing two separate diagrams, one showing all the horizontal forces acting on the box and the other showing all the forces acting on the sphere, show that the magnitude of the acceleration of the system is $2.5\,\mathrm{ms}^{-2}$ and find the tension in the string.

The system is stationary when the sphere is at point P. When the sphere is $1.8\,\mathrm{m}$ above P the string breaks, leaving the sphere moving upwards at a speed of $3\,\mathrm{ms}^{-2}$.

c. i. Write down the value of the acceleration of the sphere after the string breaks.
   ii. The sphere passes through P again at time T seconds after the string breaks. Show that T is the positive root of the equation $4.9T^2 - 3T - 1.8 = 0$.

MASTER

Two particles P and Q are connected by a light inextensible string passing over a smooth pulley.
The mass of P is m kg, the mass of Q is $2m$ kg. The particles are held such that they are both 3 m below the pulley.
The system is released from rest and after 1 second, the string breaks.

Find, in terms of m and g, the minimum distance reached between P and the pulley

AS#70 F=ma VECTORS

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APPRENTICE

Three forces $(15\mathbf{i} + \mathbf{j})$ N, $(5q\mathbf{i} - p\mathbf{j})$ N and $(-3p\mathbf{i} - q\mathbf{j})$ N, where p and q are constants, act on a particle.

Given that the particles in equilibrium, find the value of p and the value of q.

EXPERT

Forces of $(15\mathbf{i} + \mathbf{j})$ N and $(15\mathbf{i} + \mathbf{j})$ N act on a body of mass 10 kg.

a. Find the acceleration of the body

b. Find the velocity of the body 2 seconds after starting from rest

MASTER

Three forces, of magnitude 40 N, P N and Q N, all act in a horizontal plane.

These forces are in equilibrium. The diagram shows the forces.

a. Find P

b. Find Q