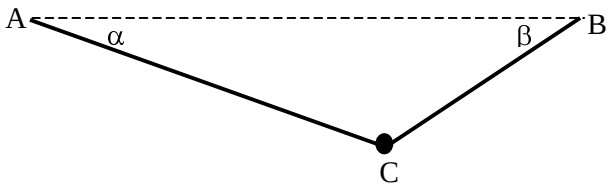
## STATICS, FRICTION & NEWTON'S SECOND LAW

*Take g as 9.8 $ms^{-2}$ when required*

**1.** A heavy bead of weight 10 N is threaded onto a smooth string of length 20 cm. The ends of the rope are attached to two horizontal pegs A and B where AB = 16 cm and the bead is at rest at C.
$\angle BAC = \alpha$ and $\angle ABC = \beta$.




a) Prove that $\alpha = \beta$

[3]

b) Find the tension in the string

[4]

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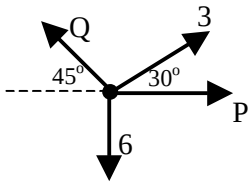
**2.** A particle is in equilibrium under the action of the four forces shown in the diagram.




Find the values of P and Q [6]

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**3.** A microphone is being suspended at a point M by two wires attached at A and B to a horizontal beam. The wire AM makes an angle of $30^0$ with the horizontal and wire BM an angle of $40^0$ with the horizontal. The weight of the microphone is 0.2 N. Find the tensions in the wires, giving your answers to 3 decimal places.

[7]

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**4.** A man is pushing a supermarket trolley of weight W to his car, which is parked on rough horizontal ground. The shopping in the trolley weighs 2W. The force exerted by the man is of magnitude P and is at $30^0$ with the horizontal. The trolley is moving at a steady speed. The coefficient of friction between the trolley and the ground is $\frac{1}{\sqrt{3}}$.

a) Find the value of P in terms of W.

[6]

After unloading the shopping the man pushed the trolley back to the store. Again the trolley moved at a constant speed but now the force exerted by the man makes an angle of $20^0$ with the horizontal.

b) Find the magnitude of the force the man is exerting. [5]

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## STATICS, FRICTION & NEWTON'S SECOND LAW

**5.** A block of weight 150 N is being pulled along at a steady speed on a rough horizontal table by a horizontal force of 100 N.

a) Find the coefficient of friction between the block and the table.

[6]

b) The force on the block changes magnitude and direction, so that it now acts at $30^o$ to the vertical. The block continues to move at a constant speed. Find the new magnitude of the force, giving your answer correct to 3 significant figures.

[5]

c) State one assumption you have used in your modelling.

[1]

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**6.** A particle of mass 3 kg is at rest on a rough horizontal plane inclined at $30^o$ to the horizontal. It is held in position by a force of P newtons parallel to the plane acting along the line of greatest slope of the plane. The coefficient of friction between the particle and the plane is $\frac{2}{3}$. The particle is about to move up the plane.

Find the value of P, giving your answer to 3 significant figures.

[6]

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**7.** A particle of mass 5kg is placed on a rough inclined plane which makes an angle of $\theta$ with the horizontal, where $\sin\theta = \frac{3}{5}$. The particle is in limiting equilibrium. Find the value of $\mu$, the coefficient of friction between the particle and the plane.

[6]

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**8.** A particle of mass 5kg is placed on a rough plane inclined at angle $\theta$ to the horizontal, where $\sin\theta = \frac{3}{5}$.
A force of X newtons acts parallel to the plane up the line of greatest slope of the plane to prevent the particle from moving. The coefficient of friction between the particle and the plane is 0.25.
Find X if:

a) the particle is about to slip down the plane

[7]

b) the particle is about to slip up the plane

[5]

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## STATICS, FRICTION & NEWTON'S SECOND LAW

**9.** a) A particle of mass 5 kg is in equilibrium under the forces

$\mathbf{F}_1 = (3\mathbf{i} + 2\mathbf{j})$ N  $\mathbf{F}_2 = (7\mathbf{i} - 5\mathbf{j})$ N  and $\mathbf{F}_3 = (a\mathbf{i} + b\mathbf{j})$ N

Find the values of a and b

[3]

b) The force $\mathbf{F}_1$ is now replaced by the force $\mathbf{F}_4 = (-\mathbf{i} + 6\mathbf{j})$ N
Find the magnitude of the acceleration of the particle

[4]

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**10.** A box of mass 5kg is held at rest on a rough inclined plane by a rope which is parallel to the line of greatest slope of the plane. The plane makes an angle of $\cos^{-1}\left(\frac{3}{5}\right)$ with the horizontal.
The coefficient of friction between the box and the plane is 0.6.
Find the range of possible values of T, the tension in the string, giving your answer in terms of g.

[11]

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**11.** A particle of weight 6N is placed on a rough plane inclined at an angle of $\sin^{-1}\left(\frac{5}{13}\right)$ to the horizontal.
The particle is held in equilibrium by a horizontal force of 3N.

a) Find the frictional force acting on the particle and the normal reaction between the particle and the plane.

[6]

b) State what can be deduced about the value of $\mu$, the coefficient of friction between the particle and the plane.

[2]

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**12.** A boy of mass 20kg stands in a lift of mass 50kg. The lift is suspended from a cable.
The tension in the cable is T. The lift is accelerating upwards at 0.1 $ms^{-2}$.

a) Find the magnitude of the reaction force between the boy and the lift.

[3]

b) Find the value of T.

[3]

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**13.** A car of mass 1000kg is towing a trailer of mass 400kg up a hill inclined at $\sin^{-1}(0.1)$ to the horizontal.
The resistances to motion of the car and the trailer are proportional to their masses, with the total resistance being 700N. The driving force of the car is of magnitude 3kN.
Find:

a) the acceleration of the car and trailer

[7]

b) the tension in the tow bar.

[2]

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**STATICS, FRICTION & NEWTON'S SECOND LAW**

**14.** Two particles A and B are connected by a light inelastic string. The particle A is on a smooth wedge inclined at an angle $\theta$ to the horizontal. The string passes over a smooth pulley at the top of the wedge and the particle B hangs freely. The mass of A is 3m kg and of B is m kg. The system is at rest.

Find the angle $\theta$.

[6]

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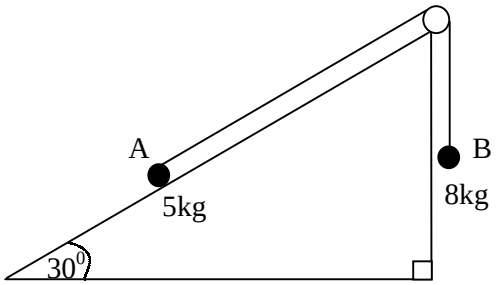
**15.**




The diagram shows a particle A of mass 5 kg on a rough inclined plane that makes an angle of $30^o$ with the horizontal. A light inextensible string is attached to A, lies along the line of greatest slope of the plane and passes over a smooth pulley at the top. A particle B of mass 8 kg hangs vertically from the string. The coefficient of friction between the particle A and the inclined plane is 0.7. Find the acceleration of the system giving your answer to 3 significant figures.

[8]

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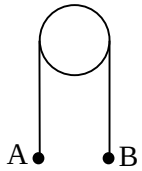
**16.**




The diagram shows particles A and B, of masses 2m and 3m respectively. A and B are connected by a light, inextensible string of length 1.5 metres, which passes over a smooth pulley. A and B are held at the same level, then released.

a) Find the acceleration of particle A, giving your answer in terms of g

[4]

b) Given that the particles were initially 25cm above the floor, find the time taken for B to hit the floor, giving your answer correct to 3 significant figures.

[3]

c) Find the greatest height above the floor to which A rises.

[7]

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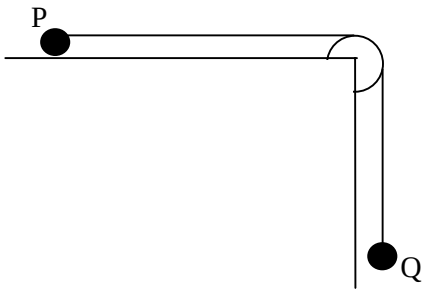
**17.**




Particles P and Q are each of mass m kg. They are connected by a string of length 120cm. P is held at rest on a smooth horizontal table, 110cm from its edge. The string passes over a smooth pulley which is fixed to the edge of the table. Q hangs freely.

a) Find the acceleration of particle P when it is released, giving your answer in terms of g. [4]

b) Given that the table is 100cm high, find the time required for Q to hit the ground. [3]

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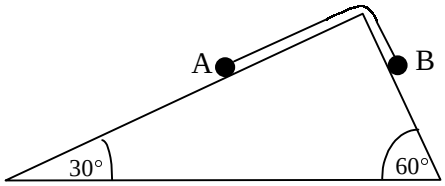
**18.** The particles A and B have masses 5kg and 2kg respectively. They are connected by a light inextensible string. The particles are held at rest on a wedge as shown in the diagram; the string passes over a smooth pulley at the apex of the wedge




The coefficient of friction between each particle and the wedge is $\mu$.

a) Given that the particles accelerate at $\frac{1}{20}$ g ms$^{-2}$ when released from rest, find the value of $\mu$, giving your answer to 3 decimal places. [11]

b) Explain how you have used the assumption that the pulley is smooth. [1]

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## STATICS, FRICTION & NEWTON'S SECOND LAW

**19.** Two particles A and B are connected by a light inextensible string. The particle A rests on a rough horizontal table. The string passes over a smooth pulley attached to the edge of the table and B hangs vertically. The masses of A and B are m kg and 2m kg respectively. The coefficient of friction between A and the table is $\frac{1}{2}$.

The system is released from rest when A is 64cm from the pulley. Assuming that B does not reach the floor before A reaches the table edge, find the following, giving your answers in terms of g:

a) the magnitude of the acceleration of A

[7]

b) the speed of A when it reached the table edge.

[2]

c) When A reaches the edge of the table, the string breaks. Given that the table is 1 metre high, find the time between B hitting the floor and A hitting the floor, giving your answer correct to 3 decimal places.

[10]

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**20.** A crate of weight 6N is at rest on a rough horizontal plane inclined at $30^0$ to the horizontal. It is held in position by a rope which is at an angle of $45^0$ to the horizontal. The coefficient of friction between the crate and the plane is $\frac{1}{\sqrt{3}}$. The crate is in limiting equilibrium, about to move up the plane.

a) Find the tension in the string.

[7]

b) The force being applied to the crate is increased so that it begins to move up the plane. It travels a distance of 1 m in 4 seconds. Find the new tension in the rope.

[8]

c) State two assumptions you have made in your calculations.

[2]

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