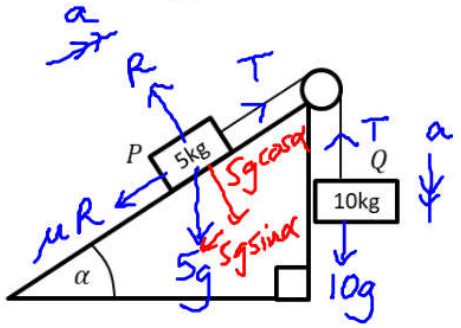
# Friction - including connected particles on slopes

Two particles $P$ and $Q$ of masses 5kg and 10kg respectively are connected by a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a rough inclined plane. $P$ rests on the inclined plane and $Q$ hangs on the edge of the plane with the string vertical and taut. The plane is inclined to the horizontal at an angle $\alpha$ where $\tan\alpha = 0.75$, as shown in the diagram. The coefficient of friction between $P$ and the plane is 0.2. The system is released from rest.

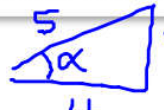
(a) Find the acceleration of the system.

(b) Find the tension in the string.




$\mu = 0.2$

$\tan\alpha = \frac{3}{4}$




$\sin\alpha = \frac{3}{5}$

$\cos\alpha = \frac{4}{5}$

**For P**

(R ↕)

$R = 5g\cos\alpha$

$R = 5g \times \frac{4}{5} = 4g$

**Equation of motion for Q**

$F = ma \downarrow$

$10g - T = 10a$ (1)

**For P**

$T - 5g\sin\alpha - \mu R = 5a$

$T - 5g \times \frac{3}{5} - 0.2 \times 4g = 5a$

$T - 3.8g = 5a$ (2)

(1) + (2) $10g - 3.8g = 15a$

$\frac{6.2g}{15} = a$ $a = 4.05\ ms^{-2}$ (3sf)

Use (2) $T = 5a + 3.8g$

$= 57.5\ N$ (3sf)

# Resultant force acting on pulley

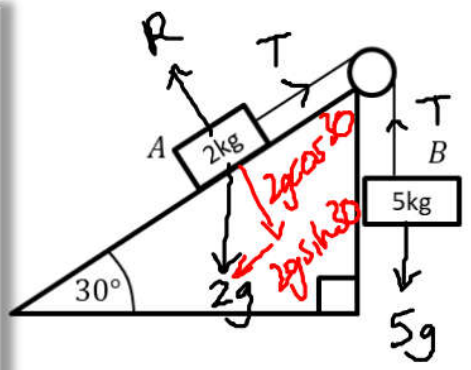
One end of a light inextensible string is attached to a block $A$ of mass 2kg. The block $A$ is held at rest on a **smooth** fixed plane which is inclined to the horizontal at an angle of $30°$. The string lies along the line of greatest slope of the plane and passes over a smooth light pulley which is fixed at the top of the plane. The other end of the string is attached to a block $B$ of mass 5kg. The system is released from rest. By modelling the blocks as particles and ignoring air resistance,

(a)(i) show that the acceleration of block $B$ is $\frac{4}{7}g$

(ii) find the tension in the string.

(b) State how you have used the fact that the string is inextensible in your calculations.

(c) Calculate the magnitude of the force exerted on the pulley by the string.




*Part (c) on next slide*

$F=ma \downarrow$ (B)

$5g - T = 5a$ (1)

$F=ma \nearrow$ (A).

$T - 2g\sin 30 = 2a$ (2)

(1) + (2) $\times \frac{1}{2}$

$5g - 2g\sin 30 = 7a$

$4g = 7a$

$\frac{4}{7}g = a$

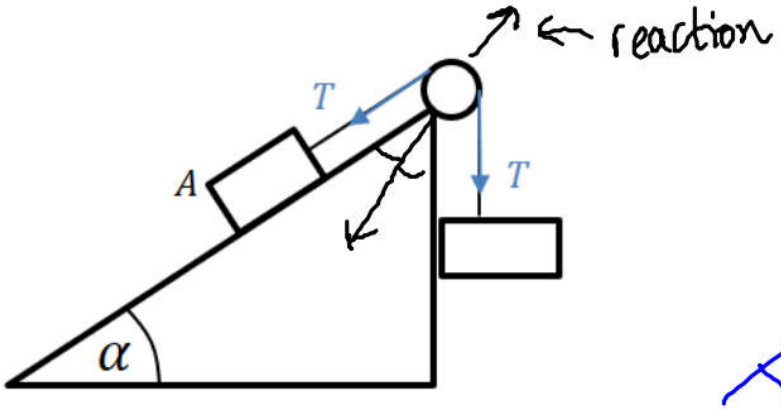
$T = 2a + 2g\sin 30$

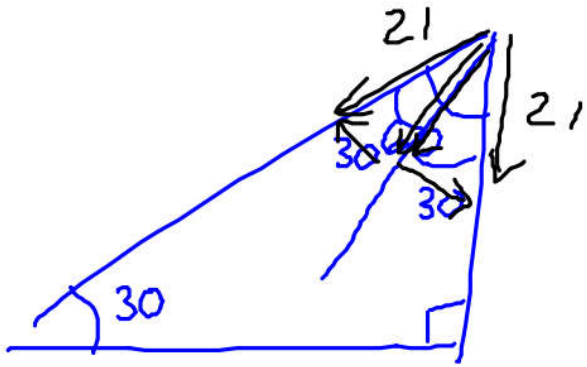
$= \frac{8}{7}g + g = \frac{15}{7}g = 21\text{N}$

b) We modelled both particles as having the same acceleration.

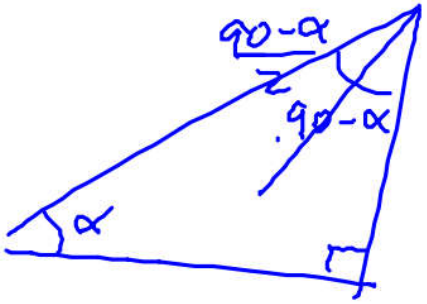
Resultant force is

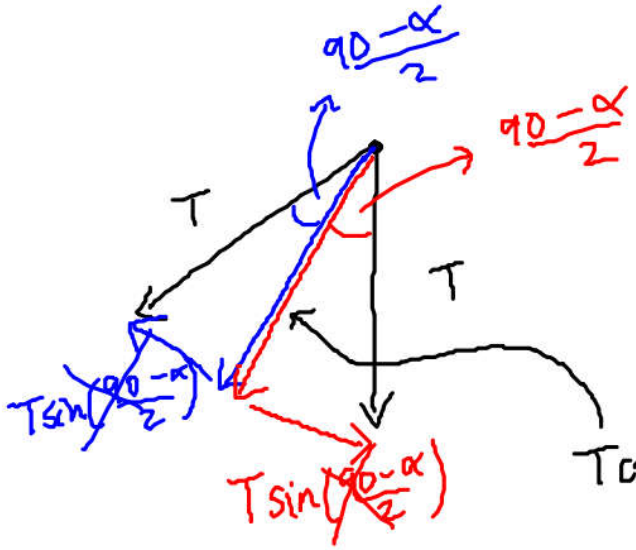
$$2T\cos\left(\frac{90-\alpha}{2}\right)$$




$2 \times 21\cos 30$




$T\cos\left(\frac{90-\alpha}{2}\right) \times 2$

Resultant $= 2T\cos\left(\frac{90-\alpha}{2}\right)$

c) $2T\cos(30)$

$= 2 \times 21\cos 30$

$= 42 \times \frac{\sqrt{3}}{2}$

$= 21\sqrt{3}$

$= 36.4\text{N}$.

Ex 7F
odd

# Edexcel M1(Old) May 2013(R) Q3

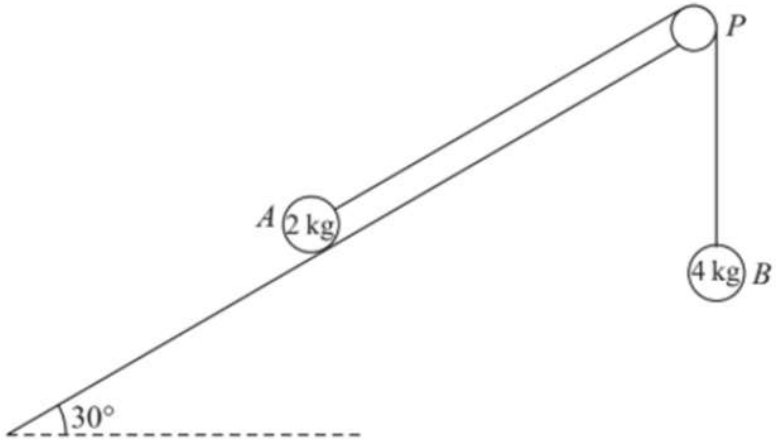
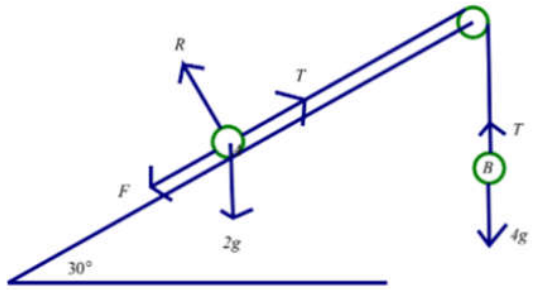



**Figure 2**

A fixed rough plane is inclined at 30° to the horizontal. A small smooth pulley $P$ is fixed at the top of the plane. Two particles $A$ and $B$, of mass 2 kg and 4 kg respectively, are attached to the ends of a light inextensible string which passes over the pulley $P$. The part of the string from $A$ to $P$ is parallel to a line of greatest slope of the plane and $B$ hangs freely below $P$, as shown in Figure 2. The coefficient of friction between $A$ and the plane is $\frac{1}{\sqrt{3}}$. Initially $A$ is held at rest on the plane. The particles are released from rest with the string taut and $A$ moves up the plane.

Find the tension in the string immediately after the particles are released.

**(9)**




| | |
|---|---|
| Equation of motion of $B$: $4g - T = 4a$ | M1A1 |
| Equation of motion of $A$: $T - F - 2g\sin 30 = 2a$ | M1A2 |
| OR: $4g - F - 2g\sin 30 = 6a$ | |
| Resolve perpendicular to the plane at $A$: $R = 2g\cos 30$ | B1 |
| Use of $F = \mu R$ : $F = \frac{1}{\sqrt{3}} \times 2g\cos 30 (= g)$ | M1 |
| $T - g - g = T - 2g = 2a$ | |
| $2T - 4g = 4g - T$, $3T = 8g$, $T = \frac{8g}{3} (\approx 26)$ 26.1(N) | **DM1**A1 |

**7** Two particles $P$ and $Q$ of equal mass are connected by a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a fixed wedge. One face of the wedge is smooth and inclined to the horizontal at an angle of 30° and the other face of the wedge is rough and inclined to the horizontal at an angle of 60°. Particle $P$ lies on the rough face and particle $Q$ lies on the smooth face with the string connecting them taut. The coefficient of friction between $P$ and the rough face is 0.5.

**a** Find the acceleration of the system.

**b** Find the tension in the string.