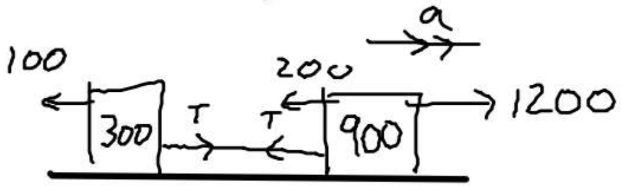
9 A car of mass 900 kg pulls a trailer of mass 300 kg along a straight horizontal road using a light tow-bar which is parallel to the road. The horizontal resistances to motion of the car and the trailer have magnitudes 200 N and 100 N respectively. The engine of the car produces a constant horizontal driving force on the car of magnitude 1200 N.

a Show that the acceleration of the car and trailer is $0.75\,\mathrm{m\,s^{-2}}$. **(2 marks)**

b Find the magnitude of the tension in the tow-bar. **(3 marks)**

The car is moving along the road when the driver sees a set of traffic lights have turned red. He reduces the force produced by the engine to zero and applies the brakes. The brakes produce a force on the car of magnitude F newtons and the car and trailer decelerate.

c Given that the resistances to motion are unchanged and the magnitude of the thrust in the towbar is 100 N, find the value of F. **(7 marks)**



a)

whole system

$R\rightarrow,\ F=ma$

$1200 + \cancel{T} - \cancel{T} - 100 - 200 = 1200a$

$900 = 1200a$

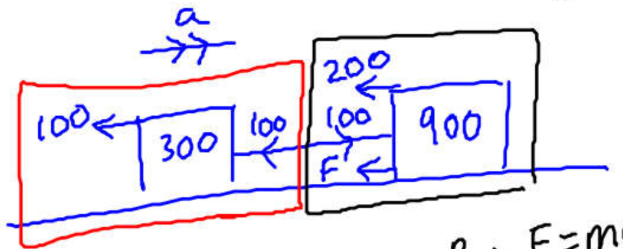
$a = 0.75$

b) Trailer, $R\rightarrow,\ F=ma$

$T - 100 = 300\times 0.75$

$\underline{\underline{T = 325\text{ N}}}$

c)



$R\rightarrow,\ F=ma$

$-100-100 = 300a$

$-200 = 300a$

$a = -\frac{2}{3}$

$R\rightarrow,\ F=ma$

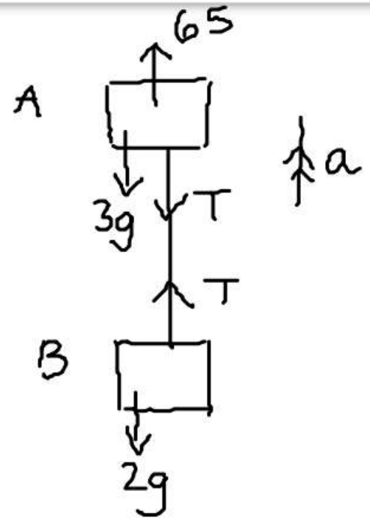
$100 - 200 - F = 900\times -\frac{2}{3}$

$-100 - F = -600$

$\underline{\underline{F = 500}}$

Connected Particles - hanging strings

Two particles *A* and *B* of masses 3kg and 2kg respectively are connected by a light inextensible string. Particle *B* hangs directly below particle *A*.
A force of 65N is applied vertically upwards causing the particles to accelerate.
Find:
i) The magnitude of the acceleration
ii) The tension in the string.



i) whole system R↑, F=ma

$$65 + T - T - 3g - 2g = 5a$$

$$\frac{65 - 5g}{5} = a$$

$$a = 3.2 \text{ ms}^{-2}$$

$g = 9.8$

ii) A, R↑, F=ma

$$65 - T - 3g = 3 \times 3.2$$

$$35.6 - T = 9.6$$

$$T = 26 \text{ N}$$

(B, R↑, F=ma

$$T - 2g = 2 \times 3.2$$

$$T = 26 \text{ N}$$)

Connected Particles - lifts/boxes on boxes

Edexcel M1 May 2013 Q2

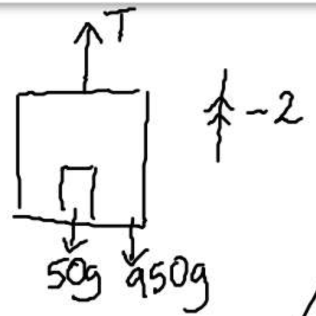
A woman travels in a lift. The mass of the woman is 50 kg and the mass of the lift is 950 kg. The lift is being raised vertically by a vertical cable which is attached to the top of the lift. The lift is moving upwards and has constant deceleration of 2 m s^{-2}. By modelling the cable as being light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

(a) the tension in the cable, **(3)**

"zoom in" on the woman

(b) the magnitude of the force exerted on the woman by the floor of the lift. **(3)**

a)



$R\uparrow$, $F = ma$

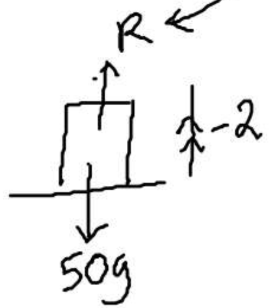
$$T - 50g - 950g = 1000 \times (-2)$$

$$T - 1000g = -2000$$

$$T = -2000 + 1000g$$

$$T = \underline{\underline{7800\text{ N}}}$$

b)



$(50g = 490\text{N})$

woman, $R\uparrow$, $F = ma$

$$R - 50g = 50 \times (-2)$$

$$R - 50g = -100$$

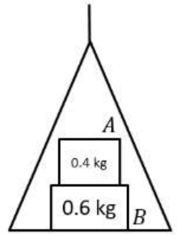
$$R = -100 + 50g$$

$$R = \underline{\underline{390}}\text{ N}$$

Newton's 3rd Law: For every action there is an equal and opposite reaction.

Therefore when two bodies A and B are in contact, if body A exerts a force on body B, then body B exerts a force on body A that is equal in magnitude and acts in the opposite direction.

A light scale-pan is attached to a vertical light inextensible string. The scale-pan carries two masses A and B. The mass of A is 400g and the mass of B is 600g. A rests on top of B, as shown in the diagram.
The scale-pan is raised vertically, using the string, with acceleration 0.5 ms^{-2}.
(a) Find the tension in the string.
(b) Find the force exerted on mass B by mass A. = exerted on A by B
(c) Find the force exerted on mass B by the scale-pan.



Tip: We can use Newton's 3rd Law to reverse "force of A on B" to "force of B on A" and vice versa.

a)

$\uparrow 0.5$

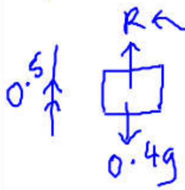
R↑, F=ma

$T - 0.4g - 0.6g = 1 \times 0.5$

$T - g = 0.5$

$T = \underline{10.3\text{N}}$.

b) Look at particle A



this is the force exerted on A by B

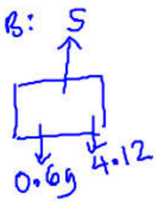
R↑, F=ma

$R - 0.4g = 0.4 \times 0.5$

$R = \underline{4.12\text{N}}$

Look at B:

c)



$\uparrow 0.5$

R↑, F=ma

$S - 0.6g - 4.12 = 0.6 \times 0.5$

$S = \underline{10.3}$ N

Ex 10E
Q4, 6, 7

Scale pan

$\uparrow 0.5$

R↑, F=ma

$T - 10.3 = 0 \times 0.5$

$\underline{T = 10.3}$

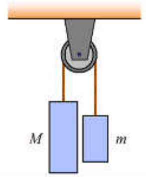
Connected Particles - pulleys

Why can't we just model both particles as a single particle as before?

They are moving in different directions.

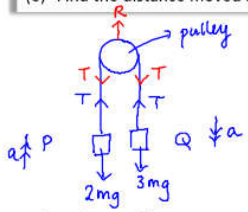
Under what conditions is the tension in each part of the string the same?

When the pulley is smooth.



Particles P and Q, of masses $2m$ and $3m$, are attached to the ends of a light inextensible string. The string passes over a small smooth fixed pulley and the masses hang with the string taut. The system is released from rest. $F=ma$

(a) Write down an equation of motion for P and for Q.
(b) Find the acceleration of each mass.
(c) Find the tension in the string.
(d) Find the force exerted on the pulley by the string.
(e) Find the distance moved by Q in the first 4 s, assuming that P does not reach the pulley.



m=1 2kg 3kg

m=1000 2000kg 3000kg

a) P R↑, $F=ma$

$\boxed{T-2mg=2ma}$ ① → equation of motion for P

Q R↓, $F=ma$

$\boxed{3mg-T=3ma}$ ② → equation of motion for Q.

b) ① + ②

$T-2mg+3mg-T=2ma+3ma$

$\cancel{m}g=5\cancel{m}a$

$a=\frac{1}{5}g=\frac{g}{5}=1.96\,ms^{-2}$

c) ① $T=2ma+2mg$

$=2m\times\frac{1}{5}g+2mg$

$=\frac{2}{5}mg+2mg$

$T=\frac{12}{5}mg$ → this is perfectly fine to have the tension in terms of m.

d) Look at the forces on the pulley

Force exerted on the pulley by the string is $2T=2\times\frac{12}{5}mg=\frac{24}{5}mg$

$(R=2T=\frac{24}{5}mg)$

e) SUVAT for Q

$a=1.96$
$t=4$
$u=0$
$s=?$

$s=ut+\frac{1}{2}at^2$

$s=0\times4+\frac{1}{2}\times1.96\times4^2$

$s=15.68$

$=15.7m$ (3sf)