AS Level Physics

Chapter 3 – Forces and Motions

3.3.2 Dynamics

Worked Examples

www.tutorpacks.co.uk

@tutorpacks

RESOLVING FORCES

Exam Style Question 1:

State why the equation $'F = ma'$ cannot be applied to particles travelling at speeds very close to the speed of light.

Answer:

The mass of particles increases as the particles speed gets closer to the speed of light. $F = ma$ only works if mass is constant.

Albert Einstein claimed in his theory of special relativity that nothing can accelerate beyond the speed of light. An experiment showed that the kinetic energy and momentum of particles can increase without limit however their speed does not. This can only happen if the mass of a particle increases with its speed. This apparent mass increase becomes significant at speeds approaching light speed – know as 'relativistic speeds'.

RESOLVING FORCES

Exam Style Question 2:

The figure below shows the horizontal forces acting on a car of mass $900\ kg$ when it is travelling at a particular velocity on a level road.

The total forward force between the tyres and the road is $200\ N$ and the air resistance (drag) is $80\ N$.

i) Calculate the acceleration of the car.

ii) Explain why we cannot use the equation $v = u + at$ to predict the velocity of the car at a later time even when the forward force is constant.

Answers:

i) Calculate the acceleration of the car.

Step 1: Calculate the unbalanced (net) force.

$$F_{net} = 200\ N - 80\ N = 120N$$

Step 2: Calculate the acceleration by rearranging $F = ma$

$$a = \frac{F}{m} = \frac{120\ N}{900\ kg} = 0.133\ ... = 0.13\ m\ s^{-2}$$

So, the car's acceleration is $0.13\ m\ s^{-2}$ forwards.

Exam Style Question 2:

Answers:

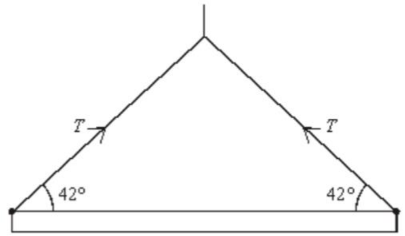
ii) Explain why we cannot use the equation $v = u + at$ to predict the velocity of the car at a later time even when the forward force is constant.

The formula $v = u + at$ only works if acceleration remains constant. However, the drag force changes with speed and therefore acceleration is not constant. So the formula $v = u + at$ is not applicable.

RESOLVING FORCES

Exam Style Question 3:

The figure below shows a uniform stell girder being held horizontally by a crane. Two cables are attached to the ends of the girder and the tension in each of these cables is T.



a) If the tension, T, in each cable is $850\ N$, calculate

i) The horizontal component of the tension in each cable,

ii) The vertical component of the tension in each cable,

iii) The weight of the girder.

b) On the figure draw an arrow to show the line of action of the weight of the girder.

RESOLVING FORCES

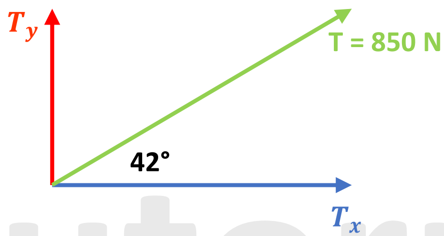
Exam Style Question 3:

Answers:

i) The horizontal component of the tension in each cable,

ii) The vertical component of the tension in each cable.

Step 1: Resolve the force acting on one cable first into its horizontal and vertical components.



Step 2: Use the formulas below:

Horizontal component: $T_x = T\ cos\theta = 850\ cos\ 42 = 631.67 = 632N$

Vertical component: $T_y = T\ sin\theta = 850\ sin\ 42 = 568.76 = 569N$

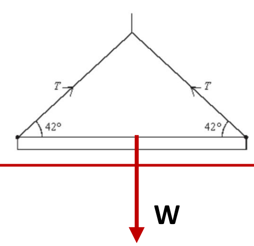
iii) The weight of the girder.

Weight of the girder = $2 \times 569 = 1138\ N$

Two cables hold the girder in place by applying equal upward force and share its weight. Vertical force of one cable is 569 N, therefore to calculate girder weight multiple this number by 2.

b) On the figure draw an arrow to show the line of action of the weight of the girder.

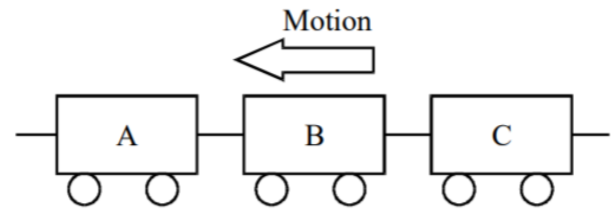
The weight force always acts directly down the object (in this case the girder).



RESOLVING FORCES

Exam Style Question 4:

The diagram shows three trucks which are part of a train. The mass of each truck is $84{,}000\ kg$.



a) The train accelerates uniformly in the direction shown from rest to $16\ m\ s^{-1}$ in a time of 4.0 minutes. Calculate the resultant force on each truck.

b) The force exerted by truck B on truck C is $11{,}200\ N$. Draw a free-body force diagram for truck B, showing the magnitude of all the forces. Neglect any frictional forces on the trucks.

Answers:

a) The train accelerates uniformly in the direction shown from rest to $16\ m\ s^{-1}$ in a time of 4.0 minutes. Calculate the resultant force on each truck.

Step 1: Convert the time from minutes into seconds:

$$t = 4\ min \times 60\ seconds = 240\ seconds$$

Step 2: Calculate the acceleration:

$$a = \frac{v-u}{t} = \frac{16\ m\ s^{-1} - 0\ m\ s^{-1}}{240\ seconds} = 0.0666 \ldots\ ms^{-2}$$

Step 3: Use the formula $F = ma$:

$$F = 84000\ kg \times 0.0666 \ldots\ ms^{-2} = 5600N$$

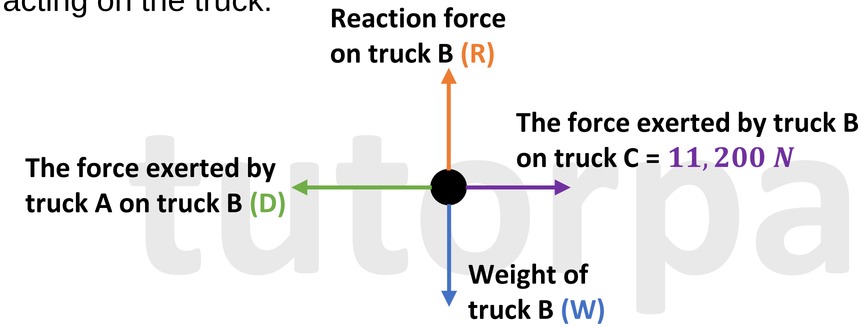
RESOLVING FORCES

Exam Style Question 4:

Answers:

b) The force exerted by truck B on truck C is $11,200\ N$. Draw a free-body force diagram for truck B, showing the magnitude of all the forces. Neglect any frictional forces on the trucks.

Step 1: Represent truck B as just a dot showing all the forces acting on the truck:



Step 2: Calculate the weight (W) and reaction (R) force of truck B:

$$W = mg = 84000\ kg \times 9.81 = 824040\ N$$

As the $W = R$ therefore $R = 824040N$.

Step 3: Calculate force, D:

We know that the resultant force on each truck is 5600 N. Therefore

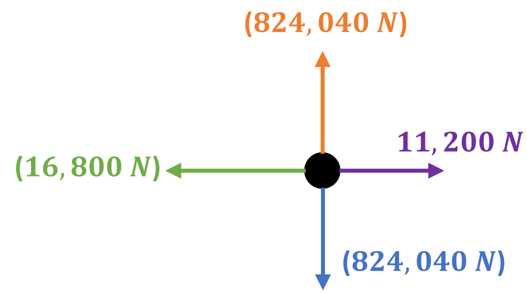
$$D - 11200\ N = 5600\ N$$
$$\therefore D = 16800N$$

RESOLVING FORCES

Exam Style Question 4:

Answers:

Step 4: Redraw the truck B as a dot with all the calculated values:



Elevator Physics (Lift Motion)

Exam Style Question 5:

Fig. 5.1 shows a person standing in a stationary lift.

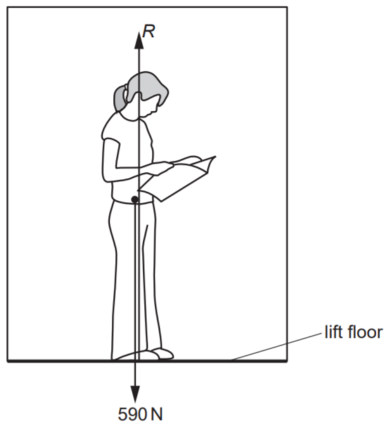


Fig. 5.1

There are only two forces acting on the person. The weight of the person is $590\ N$. The vertical constant force acting on the person from the floor of the lift is R.

a) Show that the mass of the person is $60\ kg$.

b) The lift starts from rest. It has a constant upwards acceleration of $0.50\ ms^{-2}$. Calculate the magnitude of the contact force R.

c) After a short period of acceleration, the lift travels upwards at a constant velocity. Explain why the force R is equal to the weight of the person when the lift travels at a constant velocity.

Elevator Physics (Lift Motion)

Exam Style Question 5:

Answers:

a) Show that the mass of the person is $60\ kg$.
Use the formula: $W = mg$ and rearrange it to find m:

$$\boldsymbol{m = \frac{W}{g} = \frac{590}{9.81} = 60.142 \ldots = 60\ kg}$$

b) The lift starts from rest. It has a constant upwards acceleration of $0.50\ ms^{-2}$. Calculate the magnitude of the contact force R.

Step 1: Calculate the unbalanced (net) force using $F = ma$

$$\boldsymbol{Net\ force = 60 \times 0.50 = 30\ N}$$

Step 2: Form an equation which links net force, R and the weight together:

$$\boldsymbol{R - W = net\ force}$$
$$\boldsymbol{R - 590\ N = 30\ N}$$

Step 3: Rearrange the equation above to find R:

$$\boldsymbol{R = 30\ N + 590\ N}$$
$$\boldsymbol{\therefore R = 620\ N}$$

c) After a short period of acceleration, the lift travels upwards at a constant velocity. Explain why the force R is equal to the weight of the person when the lift travels at a constant velocity.

As the lift travels upwards with a constant velocity all the forces are balanced. This means that the resultant (or net) force is zero.
Using the equation: $R - W = net\ force$ and knowing net force is zero, this means:

$$\boldsymbol{R - W = 0}$$
$$\boldsymbol{\therefore R = W}$$

Elevator Physics (Lift Motion)

Exam Style Question 6:

A lift has a mass of $500\ kg$. It is designed to carry a maximum of 8 people of total mass $560\ kg$. The lift is supported by a steel cable of cross-sectional area $3.8 \times 10^{-4}\ m^2$. When the lift is at ground floor level the cable is at its maximum length of $140\ m$, as shown in Fig 3.1. The mass per unit length of the cable is $3.0\ kg\ m^{-1}$.

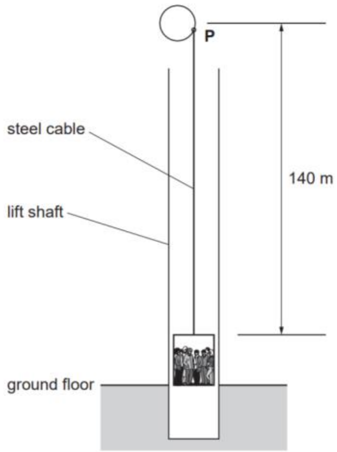


Fig. 3.1

a) Show that the mass of the $140\ m$ long steel cable is $420\ kg$.

b) The lift with its 8 passengers is stationary at the ground floor level. The initial upward acceleration of the lift and the cable is $1.8\ ms^{-2}$. Show that the maximum tension in the cable at point **P** is $1.7 \times 10^4\ N$.

Elevator Physics (Lift Motion)

Exam Style Question 6:

Answers:

a) Show that the mass of the $140\ m$ long steel cable is $420\ kg$.

We already know the mass per unit length of the cable is $3.0\ kg\ m^{-1}$ and the maximum length of the cable is $140\ m$. Therefore, to calculate the mass you do:

$$mass = 140\ m \times 3.0\ kg\ m^{-1} = 420\ kg$$

b) Show that the maximum tension in the cable at point P is $\mathbf{1.7 \times 10^4\ N}$.

Step 1: Calculate the total mass:

$$total\ mass = 500 + 560 + 420 = 1480\ kg$$

Step 2: Calculate the total weight using $W = mg$:

$$total\ weight = 1480 \times 9.81 = 14504\ N$$

Step 3: Calculate the net force using $F = ma$

$$F = 1480 \times 1.8 = 2664\ N$$

$$\therefore net\ force = 2664\ N$$

Step 4: Now we know the downwards force and the net force so we form an equation that links tension, weight and net force:

$$tension - weight = net\ force$$

$$tension - 14504 = 2664$$

$$tension = 14504 + 2664$$

$$\therefore tension = 17168\ N = 1.72 \times 10^4\ N$$

Please see the **'3.3.1 Dynamics notes'** pack for revision notes.

For more revision notes, tutorials, worked examples and more help visit **www.tutorpacks.co.uk.**

tutorpacks.co.uk