Q1

1

A communications satellite with a mass of 3600 kg orbits the earth in a circular orbit at an altitude of 1400 km. The satellite moves at a constant speed. State, with a reason, whether there is any resultant force acting on the satellite.

[3]

The speed is constant, so the magnitude of the velocity is constant. But the orbit is circular, so the direction of the velocity is changing. Therefore the velocity is not constant.

By Newton's First Law there must be a non-zero resultant force acting on the satellite.

Newton's First Law of Motion

An object at rest will stay at rest, and an object moving with constant velocity will continue to move with constant velocity, unless an unbalanced force acts on the object.

Q2

2

A tourist with a weight of 1246 N is riding in a lift to the top of the Empire State Building in New York City. On his back he has a backpack full of 'I Love New York' souvenirs, with a total weight of 352 N. The lift is moving vertically upwards at a constant speed of 6.1 m s^{-1}, and the tourist is standing still on the horizontal floor of the lift waiting for it to reach the top.

State, with a reason, the magnitude and direction of the total normal reaction force exerted on the tourist by the floor of the lift.

[3]

The combined weight of the tourist and souvenirs is 1246 + 352 = 1598 N, which is directed vertically downwards.

Because the tourist is moving upwards at a constant speed, Newton's First Law says that forces in the vertical direction must be balanced.

Therefore the normal reaction force of the floor of the lift on the tourist is 1598 N vertically upwards.

Newton's First Law of Motion

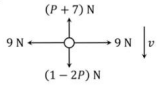
An object at rest will stay at rest, and an object moving with constant velocity will continue to move with constant velocity, unless an unbalanced force acts on the object.

Q3

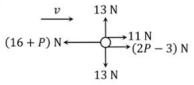
3

Given that the particle in each of the following diagrams is moving with constant velocity, v, work out the value of P:

(i)



(ii)



[3]

Newton's First Law of Motion

An object at rest will stay at rest, and an object moving with constant velocity will continue to move with constant velocity, unless an unbalanced force acts on the object.

constant velocity $\Rightarrow$ total force in any direction is zero (by Newton's 1st Law)

(i) take 'up' as positive vertical direction

$$(P+7)-(1-2P)=0$$

$$3P+6=0$$

$$\boxed{P=-2}$$

(ii) take 'right' as positive horizontal direction

$$(11)+(2P-3)-(16+P)=0$$

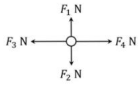
$$P-8=0$$

$$\boxed{P=8}$$

Q4

4

The following force diagram depicts a particle at equilibrium:



Given that $5F_4 = 9F_2$ and $3F_1 + 5F_3 = 450$, determine the values of F_1, F_2, F_3 and F_4.

[4]

Because the particle is at equilibrium,

$$F_1 = F_2 \quad \text{and} \quad F_3 = F_4$$

So

$$5F_4 = 9F_2 \Rightarrow 5F_3 = 9F_1 \Rightarrow F_3 = \frac{9}{5}F_1$$

Then

$$3F_1 + 5F_3 = 450$$

$$3F_1 + 5\left(\frac{9}{5}F_1\right) = 450$$

$$12F_1 = 450$$

$$\boxed{F_1 = F_2 = 37.5}$$

And

$$F_3 = \frac{9}{5}F_1 = \frac{9}{5}(37.5)$$

$$\boxed{F_3 = F_4 = 67.5}$$

Q5a

5a

In a slate quarry a load of slates is being raised to the surface for processing. The total weight of the slates and the platform on which they rest is 21000 N, and to make sure that the platform remains level while it is being raised, the same tension, T, is maintained in each of the two lifting cables. Other than the weight of the platform and slates, and the tension in the cables, all other influences on the motion of the platform can be ignored.

(a) Given that the platform is moving vertically upwards at a constant speed of 0.25 m s^{-1}, work out the tension, T, in each cable.

[2]

As it passes one of the levels in the quarry, two workers with a combined weight of 1600 N jump onto the centre of the slow-moving platform, hoping to catch a ride to the surface at the end of their shift.

(b) Given that the tension in the cables stays the same, and that the platform remains perfectly level, describe the resulting motion of the platform after the workers jump onto it. Consider both the time immediately after they jump on as well as the longer term implications for the motion of the platform. Be sure to explain the physical reasoning behind your answer.

[3]

Because the platform is moving upwards at a constant speed, Newton's First Law says that forces in the vertical direction must be balanced.

Therefore

$$2T = 21000$$

$$T = 10500 \text{ N}$$

Q5b

5b

In a slate quarry a load of slates is being raised to the surface for processing. The total weight of the slates and the platform on which they rest is 21000 N, and to make sure that the platform remains level while it is being raised, the same tension, T, is maintained in each of the two lifting cables. Other than the weight of the platform and slates, and the tension in the cables, all other influences on the motion of the platform can be ignored.

(a) Given that the platform is moving vertically upwards at a constant speed of 0.25 m s^{-1}, work out the tension, T, in each cable.

[2]

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(b) Given that the tension in the cables stays the same, and that the platform remains perfectly level, describe the resulting motion of the platform after the workers jump onto it. Consider both the time immediately after they jump on as well as the longer term implications for the motion of the platform. Be sure to explain the physical reasoning behind your answer.

[3]

After the workers jump on, there will be a resultant force in the downward direction.

At first this means that the platform will begin to decelerate, with its upward velocity decreasing.

Eventually the upward velocity will reach zero, and then the platform will begin to accelerate in the downward direction.

Q6a

6a

A monorail train is moving along a horizontal level track. The train's engine provides a forward thrust of T N. The total resistance is modelled by a constant force of F N.

(a) Modelling the train as a particle, draw a force diagram to show the forces acting on the train.

[3]

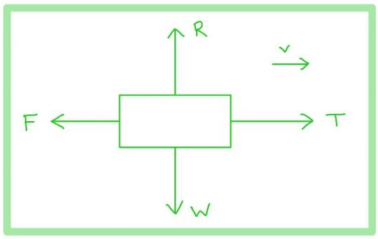
(b) Given that

- the train's speed is increasing in its direction of motion
- the resultant force acting on the train is 4200 N
- of T and F, 9 times the magnitude of the smaller force is equal to 2 times the magnitude of the larger force

find the values of T and F.

[3]

a) W = weight
R = normal reaction force
(W and R are equal and opposite)
v = velocity in horizontal direction



Q6b

6b

A monorail train is moving along a horizontal level track. The train's engine provides a forward thrust of T N. The total resistance is modelled by a constant force of F N.

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[3]

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- the train's speed is increasing in its direction of motion
- the resultant force acting on the train is 4200 N
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find the values of T and F.

[3]

b) Because speed is increasing in direction of motion, we know $T > F$.

Therefore

$9F = 2T \Rightarrow F = \frac{2}{9}T$

and

$T - F = 4200$

$T - \frac{2}{9}T = 4200$

$\frac{7}{9}T = 4200$

$T = 5400$

$F = \frac{2}{9}(5400)$

$F = 1200$

W = weight
R = normal reaction force
(W and R are equal and opposite)
v = velocity in horizontal direction