Forces (Dynamics)

Effects of Forces

Force is a push or pull which can cause an object to rotate or more, it can also change the speed or direction of a body.

Extension in Springs

Hooke's Law

Load applied to a spring is directly proportional to extension within the limit of proportionality.

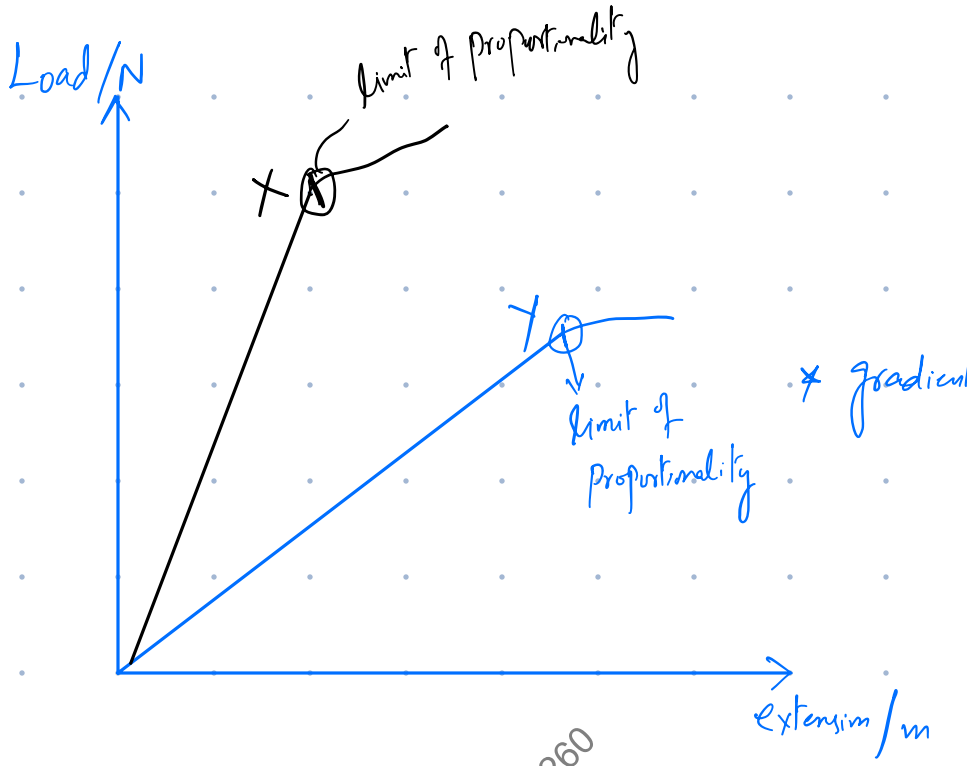
load (Newton) $\propto$ extension (m)

$$F \propto x$$

or $$F = kx$$;

* K is called Spring Constant, its value depends upon the Stiffness of spring.

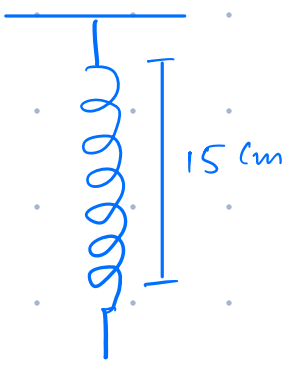
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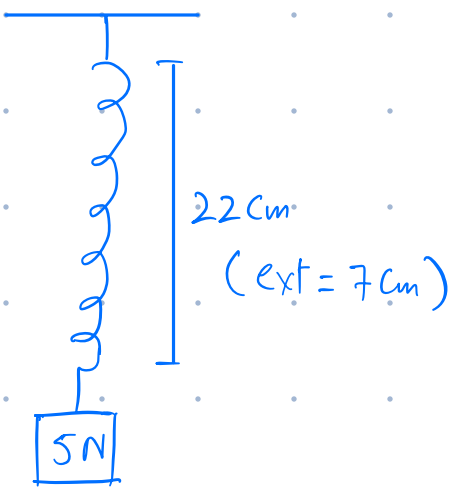


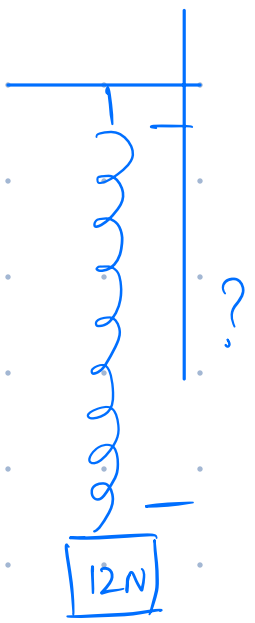
* gradient = spring constant

* Spring X is more stiff as its gradient of load - extension graph is more.

Example







Load		ext.
5	X	7
12		x

$x = \frac{12 \times 7}{5}$

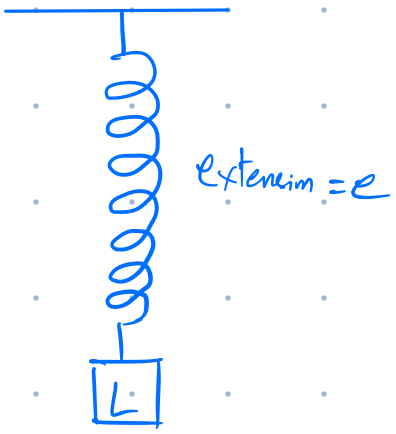
$x = 16.8$ cm

new length of spring = 15 cm + 16.8 cm

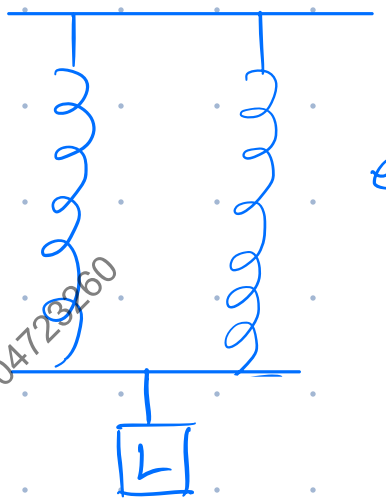
= 31.8 cm

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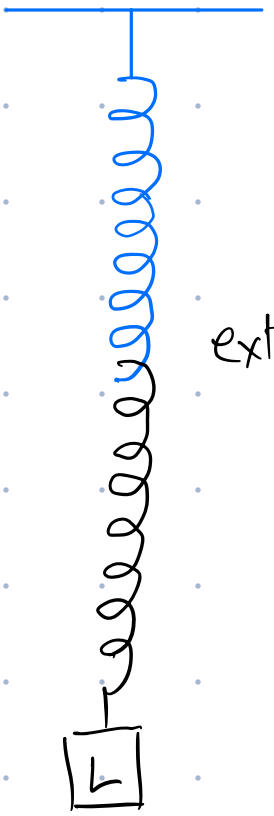
Arrangement of Springs



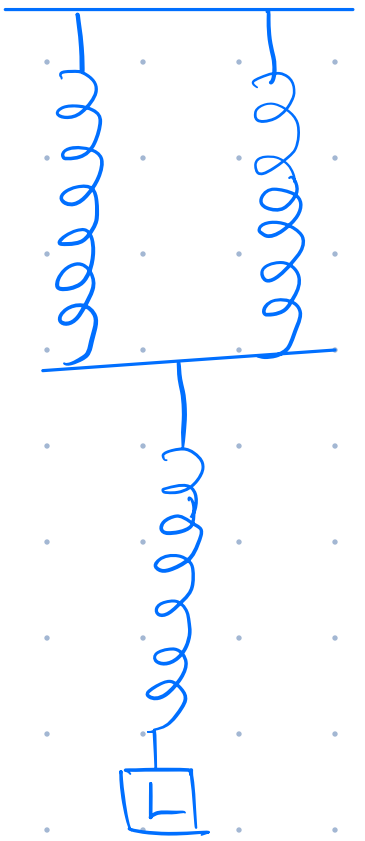
extension = e



extension = $\frac{e}{2}$



extension = $2e$



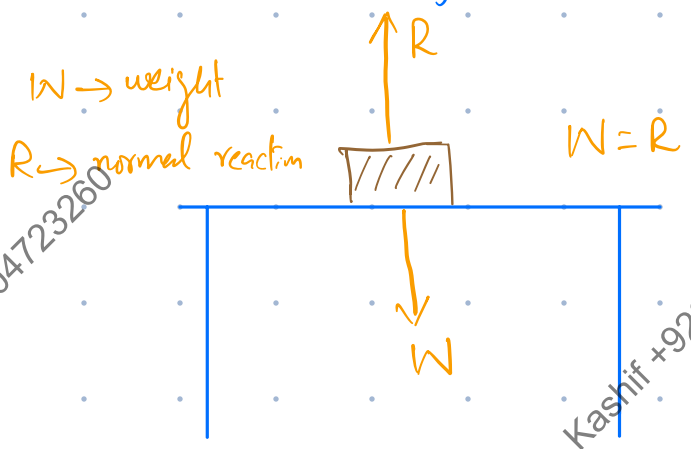
extension = $e + \frac{e}{2}$

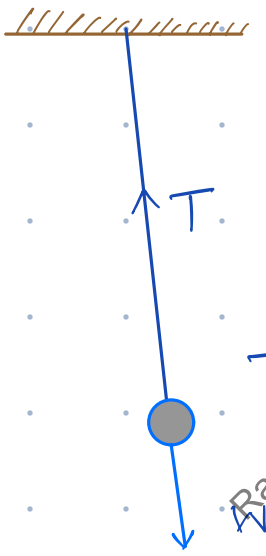
$= \frac{3e}{2}$

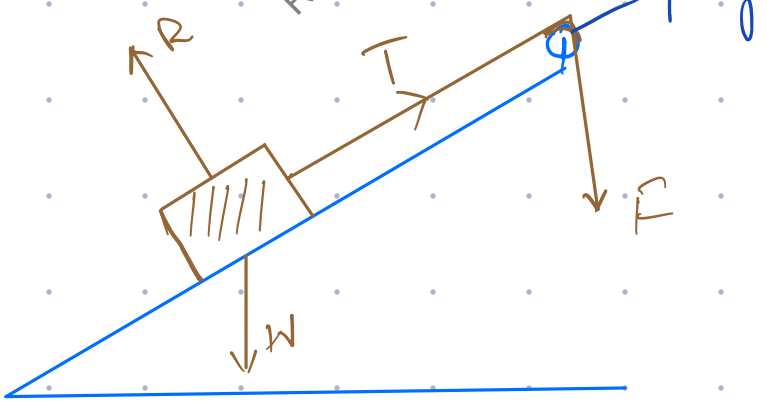
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· Resultant Force

Sum of all the forces acting on an object which has combined effect of all the forces acting on an object.









resultant force = 4 N



resultant force = 10N + 4N − 12N
= 2N

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Addition of Forces (Scale Diagram)

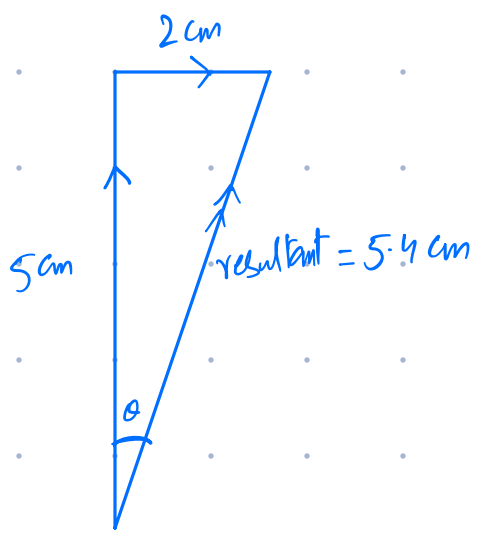
Example:

An aeroplane is flying due North while its engine supplying a constant forward force of 10,000 N. Assume wind is blowing from West to East and exerting a force of 4000 N. Find resultant force on aeroplane by drawing a scale diagram.

Solution:



Scale: 2000 N = 1 cm $\Rightarrow$ 10,000 N = 5 cm, 2000 N = 2 cm



5.4 cm $\approx$ 11000 N

measure angle by protractor to give direction of resultant $\approx 20^\circ$

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Newton's Laws of Motion

First Law

"An object remains in its state of rest or uniform motion unless a net force acts on it"

* First Law is also called Law of Inertia.

Second Law

"Net force is equal to product of mass and acceleration".

$$F = ma$$

* Here F is net force (resultant force)

Example:



net force = 20N − 5N

= 15N

$a = \frac{F}{m} = \frac{15}{2}$

$= 7.5 ms^{-2}$

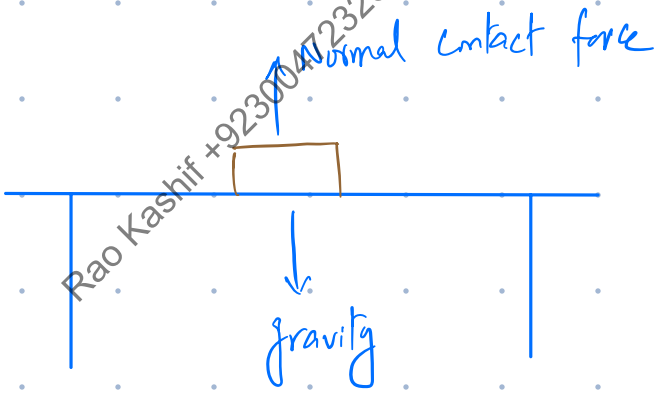
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Third Law

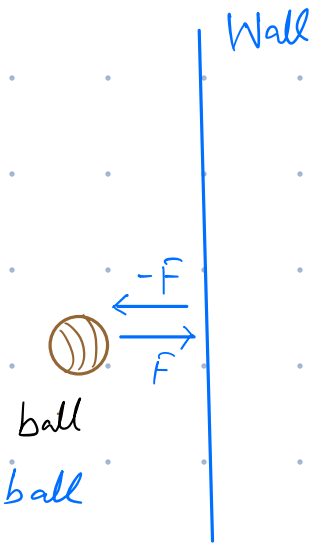
"If object A exerts force F on object B then B will exert force -F on object A"

All balanced forces in nature exhibit Newton's third law pair

Examples



* A ball hitting a wall exerts a force F on wall, as a reaction wall exerts force -F on ball



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* very important Formula

$$F = ma$$

net force = mass × acceleration.

Example



Net force on vehicle = 10,000 N − 6000 N

= 4000 N

From Newton's Second Law:

$$\text{acceleration} = \frac{\text{Net force}}{\text{mass}}$$

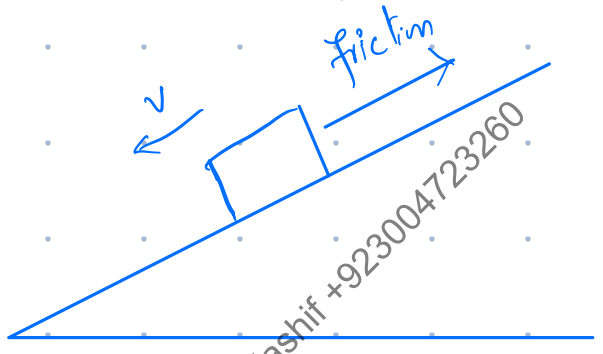
$$a = \frac{4000}{5000} = 0.8\ ms^{-2}$$

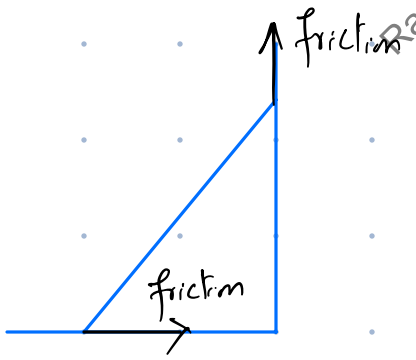
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Friction

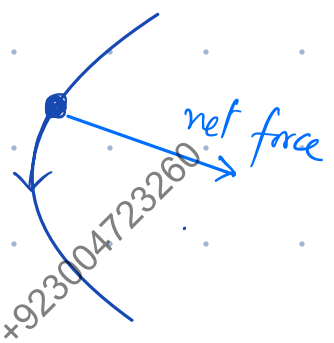
A force that opposes the motion when objects move in contact.

* Friction has always direction opposite to which object is moving or about to move





* Centripetal Force: When an object moves in circle, it has a net force directed towards centre of circle (centripetal force)



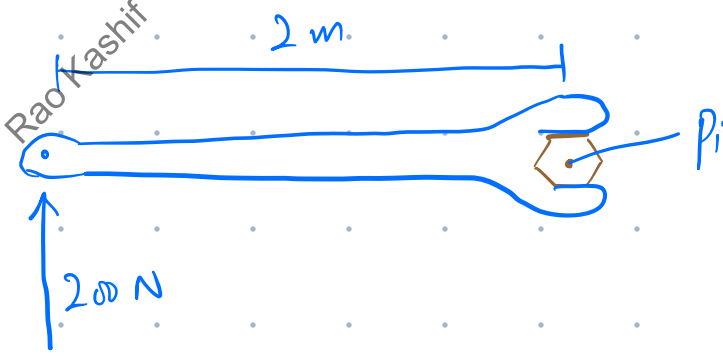
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Turning Effect of Forces

Moment / Torque

Force x perpendicular distance from pivot

* Moment is a vector quantity (can be clock wise or anticlock wise)
* SI unit of Moment is Newton-meter (Nm)



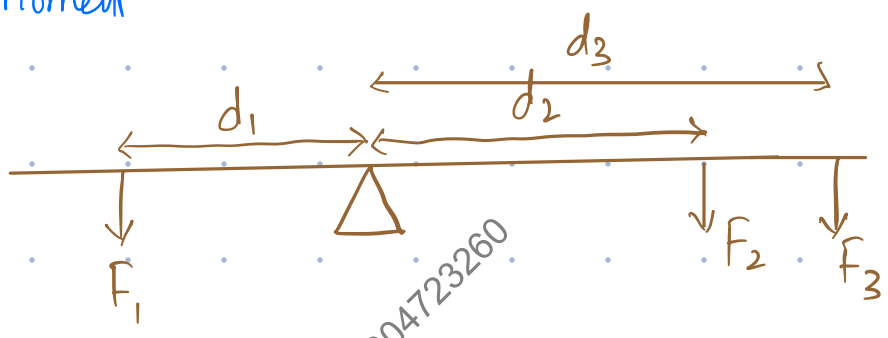
Moment of force about pivot = 200 N x 2 m
= 400 Nm (clock-wise direction)

* Moment / torque is directly proportional to force and perpendicular distance from pivot. We can increase the turning effect either by increasing force or by increasing distance from pivot point

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Principle of Moments

"A body is in equilibrium if total clock wise moment is equal to total anti clock wise moment"



$$F_1 d_1 = F_2 d_2 + F_3 d_3$$

Equilibrium

Conditions of equilibrium

(1) Net force = 0 (no acceleration)

(2) Net moment = 0 (clock wise moment = anticlock wise moment)

Important: A body at rest or a body moving with uniform speed are both equilibrium as they both have zero acceleration.

* If an object suddenly stops by applying brakes it is not equilibrium.

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Centre of Mass

The point where whole mass of an object appears to be concentrated.

Centre of gravity

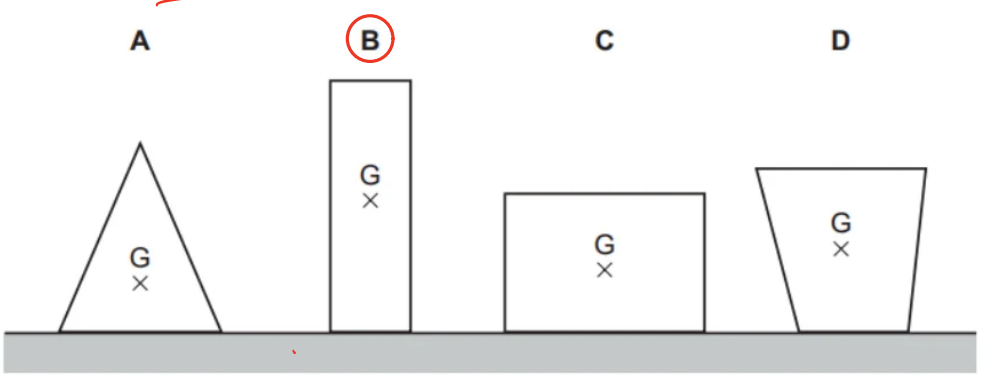
The point where whole weight of an object acts vertically downwards.

* An object which has centre of mass low will be more stable

26.

Four objects of equal mass rest on a table. The centre of mass of each object is labelled G.

Which object is the least stable?



* racing cars have their bodies very close to the ground as they are designed to be more stable

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* Locating Centre of Gravity

For Symmetric objects such as a rectangular card board, a uniform sphere, Centre of gravity will be their geometric centre.

For irregular shaped lamina (card) We use plumb line:

" Make three to ~~four~~ holes in each corner of the card, suspend it with iron nail on a wall. Tie a plumb line (thread attached to metal ball) with the nail and draw a line along the Thread. Repeat this procedure with every hole. The point where all the lines will intersect will be Centre of gravity.

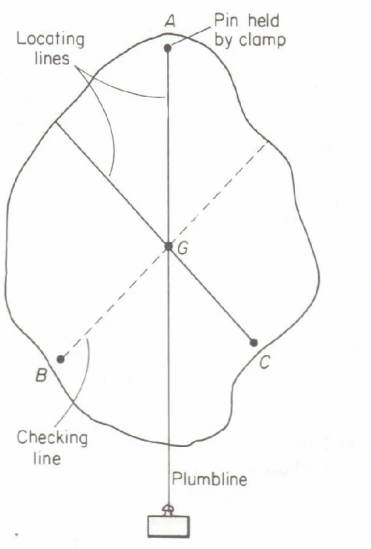


Fig. 6.8. Locating centre of gravity by plumbline

Past Paper Practice

5 A man pulls a sledge of mass 25 kg across level ground with a horizontal force of 60 N. A constant force of friction of 20 N acts on the sledge.

What is the acceleration of the sledge?

A $0.63\,m/s^2$ **(B)** $1.6\,m/s^2$ **C** $2.4\,m/s^2$ **D** $3.2\,m/s^2$

net force $= 60N - 20N = 40N$

$a = \frac{F}{m} = \frac{40}{25} = 1.6\,m/s^2$

7 A satellite is orbiting the Earth in a circular orbit.

Which two quantities are always in the same direction as each other?

A the acceleration of the satellite and the displacement of the satellite

B the acceleration of the satellite and the velocity of the satellite

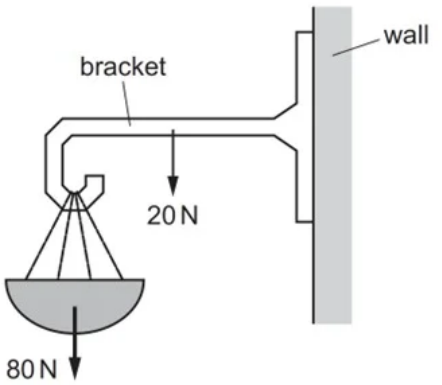
(C) the resultant force on the satellite and the acceleration of the satellite ⇒ directed towards centre

D the resultant force on the satellite and the velocity of the satellite

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6 A hanging basket is fixed to a wall by a bracket.



The weight of the basket is 80 N. The weight of the bracket is 20 N.

What is the size of the upwards force exerted on the bracket by the wall?

A 60 N **B** 70 N **C** 90 N **D** 100 N

* In equilibrium, total downward force must be same as total upward force

7 A train of mass 240 000 kg is travelling at a speed of 60 m/s. The brakes are applied and it decelerates for 10 minutes until it comes to rest.

What is the average resultant force?

A 24 000 N **B** 40 000 N **C** 480 000 N **D** 720 000 N

Sol: find deceleration first

$t = 10\,\text{min} = 600\,\text{sec}$

$$a = \frac{v - u}{t}$$

$$a = -\frac{60}{600} = -0.1\,\text{ms}^{-2}$$

$$F = ma = 240{,}000\,(0.1)$$

$$= 24000\,\text{N}$$

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1 Fig. 1.1 shows the directions of four forces acting on a racing car as it travels in a horizontal straight line.

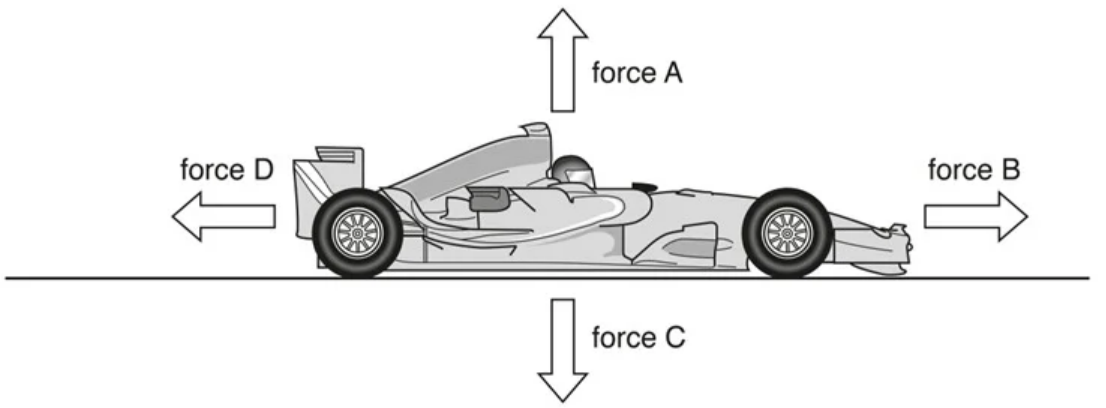


Fig. 1.1

(a) Draw a line from each box on the left to the correct description of each force.

force A	driving force
force B	contact or normal reaction force
force C	air resistance and friction
force D	force of gravity

[1]

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(b) The table shows the sizes of the forces acting on the car at one time.

force A/N	force B/N	force C/N	force D/N
8000	1000	8000	600

The gravitational field strength g is 10 N/kg.

Calculate

(i) the mass of the car,

Weight = 8000N

$\Rightarrow m = \frac{W}{g} = \frac{8000}{10}$

mass = 800 kg [1]

(ii) the resultant force on the car,

forward − backward

= 1000 N − 600N

resultant force = 400 N [1]

(iii) the acceleration of the car.

$a = \frac{F}{m} = \frac{400}{800}$

acceleration = $0.5\ m\,s^{-2}$ [2]

(c) At another time, the car is travelling at speed u. It then accelerates for 5.0 s with an acceleration of 1.6 m/s^2, and reaches a speed of 20 m/s.

Calculate the value of u.

$a = \frac{v-u}{t}$

$1.6 = \frac{20-u}{5}$

$8 = 20 - u$

$\Rightarrow u = 12\ m\,s^{-1}$

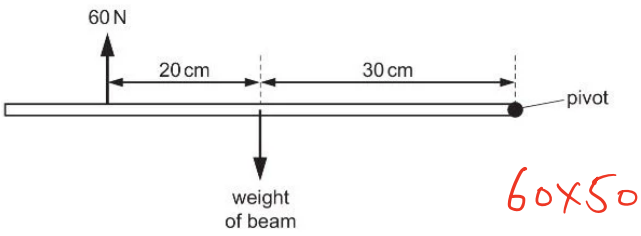
u = $12\ m\,s^{-1}$ [2]

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QUESTION # 1: M/J 16 P11

9 A uniform horizontal beam, pivoted at its right-hand end, is in equilibrium. A force of 60 N acts vertically upwards on the beam as shown.



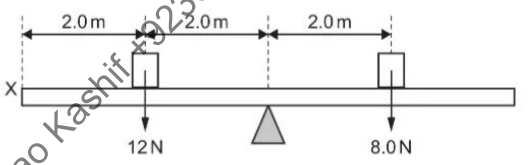
60x50 = Wx30

What is the weight of the beam?

A 36 N **B** 40 N **C** 90 N **D** 100 N

QUESTION # 2: M/J 16 P12

6 A uniform plank is pivoted at its mid-point. Two weights are added to the plank, one weight on each side of the pivot in the positions shown.



A vertical force is applied at point X to balance the plank.

What is the size and direction of this force?

	size / N	direction
A	2.0	downwards
B	2.0	upwards
C	4.0	downwards
D	4.0	upwards

Clock wise moment = 12 x 2 = 24 Nm

anticlock wise moment = 8 x 2 = 16 Nm (lesser than clock wise

* In order to Maintain equilibrium, X should create anticlock wise moment (upward direction)

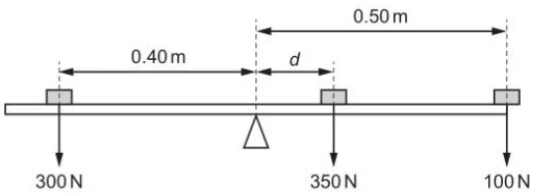
24 − 16 = 8 Nm

X . 4 = 8

X = 2 N upwards

QUESTION # 3: M/J 17 P11

12 A uniform beam is pivoted at its centre. The beam is balanced by three weights in the positions shown.



What is the length *d*?

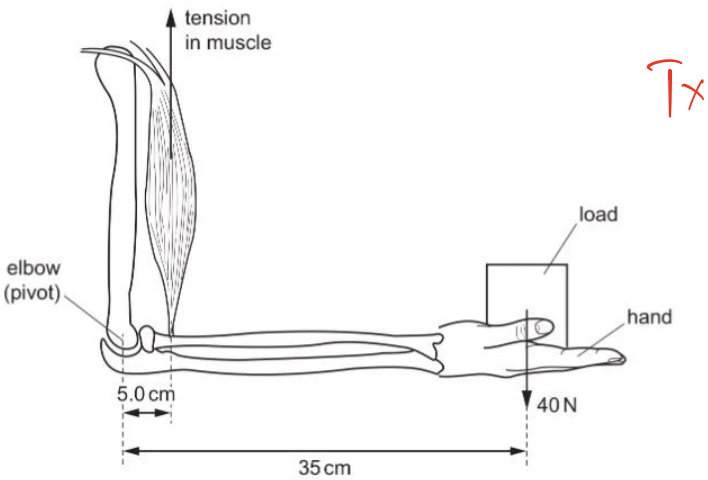
A 0.020 m **B** 0.050 m **C** 0.20 m **D** 0.48 m

$300 \times 0.4 = 350 \times d + 100 \times 0.5$

$\frac{120 - 50}{350} = d$

QUESTION # 4: M/J 18 P11

9 The diagram shows a muscle and bones in a person's arm. The hand holds a load of weight 40 N. The elbow acts as a pivot and the tension in the muscle keeps the lower part of the arm horizontal.



$T \times 5 = 40 \times 35$

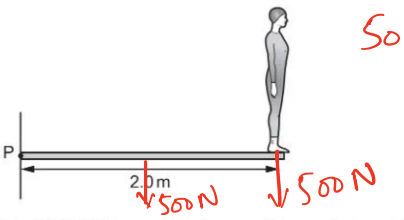
What is the tension in the muscle due to the load?

A 200 N **B** 240 N **C** 280 N **D** 1400 N

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QUESTION # 8: O/N 17 P12

7 A diver of weight 500 N stands at the end of a springboard that is 2.0 m long and is fixed at point P.



500x2+500x1

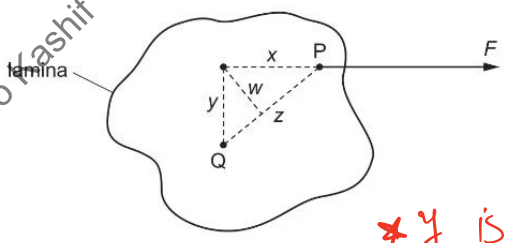
The springboard has a weight of 500 N. The centre of mass of the springboard is in the centre of the board.

What is the total moment about point P of the diver and the board?

A 500 N m **B** 750 N m **C** 1000 N m **D** 1500 N m

QUESTION # 10: O/N 20 P11

10 A length of thread is attached to a lamina at point P, as shown in the diagram.



The lamina is free to rotate about point Q.

The tension in the thread is *F*.

What is the moment of *F* about Q?

A *Fw* **B** *Fx* **C** *Fy* **D** *Fz*

* y is perpendicular to the direction of F

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