POLITEKNIK MALAYSIA
SULTAN SALAHUDDIN ABDUL AZIZ SHAH

DBS10012 ENGINEERING SCIENCE

FORCE

VOLUME 1

LEE TEN TEN
DIANA MALINI BINTI JARNI
MASLINDA BINTI SUKRI

JABATAN MATEMATIK, SAINS DAN KOMPUTER
POLITEKNIK SULTAN SALAHUDDIN ABDUL AZIZ SHAH

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eISBN No:

e ISBN 978-967-0032-95-5

9 789670 032955

Published by :

Politeknik Sultan Salahuddin Abdul Aziz Shah (online),
Persiaran Usahawan,
Seksyen U1,
40150 Shah Alam,
Selangor.

Telephone No : +603 5163 4000
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First published in 2023

Synopsis

Welcome to your Force eBook.

This eBook consists of notes and examples of calculation in topic of Force which is developed and revise based on Engineering Science for polytechnics (DBS10012). The goal of this eBook is to provides students an understanding of force in physics through a simple and easy understanding methods.

Preface

We would like to dedicate special thanks to our head of department, Pn Nariman Binti Hj Daud for giving the opportunity and trust in producing this eBook.

Special thanks to eLearning team, CRI units and everyone who involved directly or indirectly at Politeknik Sultan Salahuddin Abdul Aziz Shah, who help develop this eBook successfully.

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Introduction of Force

Force is a push or pull that can change the shape of an object or change the shape or size of an object, or change the way an object moves.

For instant, when a ball hits the ground, a force changes its shape, speed and direction.

Force is a vector quantity

SI unit : Newton (N) or $kgms^{-2}$

Formula : $F = \frac{m}{a}$

$m = mass\ (kg)$

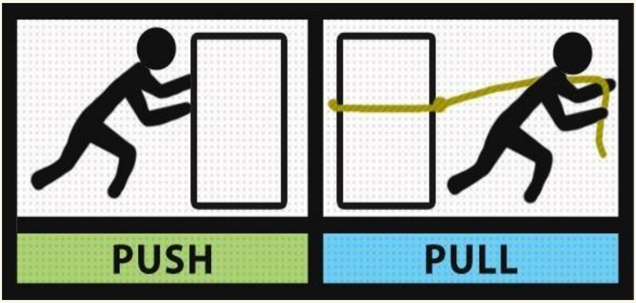
$a = ms^{-2}$

Definition of Term

Definition

Force is a push or pull action that will change the state of rest or motion of an object.

Symbol : F



Effects of Force

Can change the **size or shape** of an object

Can **move a stationary** object

Can **stop a moving** object

Can change the **direction of a moving** object

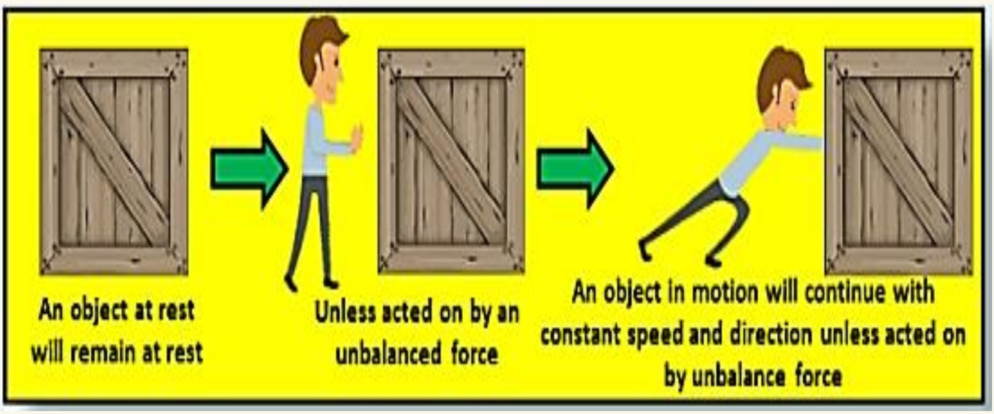
Can **accelerate or decelerate a moving** object

Difference between Mass and Weight :

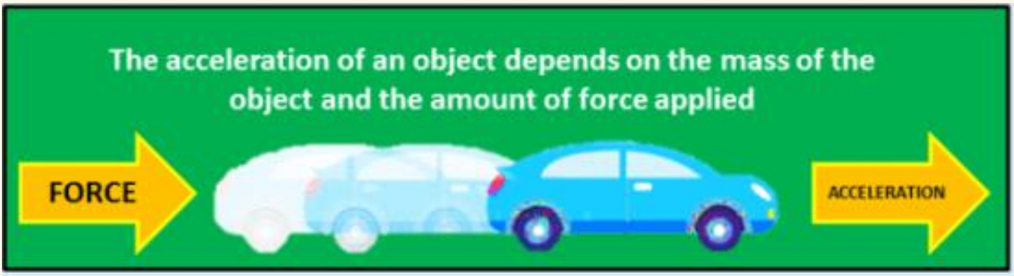
	Mass	Weight
Definition	Defined as the amount of matter in an object	Defined as the force of gravity
Effect of gravity	Mass always constant at any place and any time	Weight change according to the gravity
Type of Q	Base quantity , Scalar quantity	Derived quantity, Vector quantity
Formula	m=F/a m=W/g	W= mg
SI Unit	kilogram (kg)	Newton (N)

Newton's First Law

Newton's First Law of motion states that an object will remain at rest or uniform motion in a straight line unless acted upon by an external force



Newton's Second Law



When the net external force acts on an object,
the acceleration of the object is directly proportional to the net force and inversely proportional to its mass.

$$a = \frac{F}{m} \quad \rightarrow \quad F = ma$$

The second law can also be stated in terms of an object's acceleration, thus

$$\sum F = m\left(\frac{dv}{dt}\right) = ma$$

Newton's Second Law : Calculation

Case 1

Two forces are applied to a toy car with a mass of 10kg as shown below. What is the acceleration of the car?

F_1 = 20N

F_2 = 60N

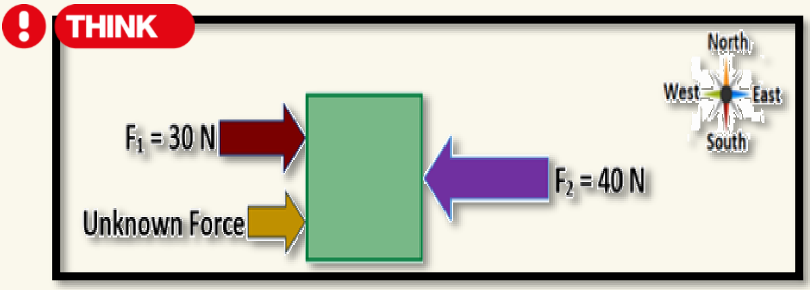
! THINK

Solution :

$$a = \frac{F_{net}}{m} = \frac{F_2 - F_1}{m} = \frac{60 - 20}{10} = \mathbf{4\ m/s^2}$$

Case 2

A wooden block with mass of 4kg accelerates $6m/s^2$ to the East when forces are applied to it as shown below. What is the amount of the unknown force?



Solution :

$$F_{net} = m \cdot a$$

$$F_1 + unknown\ force - F_2 = m \times a$$

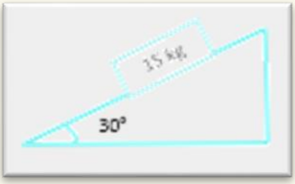
$$30 + unknown\ force - 40 = 4 \times 6$$

$$unknown\ force = 34N$$

Case 3

A friction force of magnitude 25N acts on an object of mass 15kg, which is placed on a rough inclined plane as shown in figure. Determine the **acceleration** of the object moving down the plane ($g = 9.81\ m/s^2$).

THINK



(June 2013 Final Exam Question)

Solution :

Finding W ,

$$\boldsymbol{W = mg}$$
$$= (15)(9.81) = 147.15\ N$$

Finding F ,

$$\boldsymbol{F = F}\sin\boldsymbol{30°}$$
$$= (147.15)\sin 30° = 73.575\ N$$

Finding F_{net} ,

$$\boldsymbol{F_{net} = F - F_R}$$
$$= 73.575 - 25 = 48.575\ N$$

Therefore ,

$$\boldsymbol{F = ma}$$
$$48.575 = (15)(a)$$
$$\therefore a = \frac{48.575}{15} = \boldsymbol{3.24\ ms^{-2}}$$

Newton's Third Law

For any action, there is a reaction which has the same magnitude but acts in the opposite direction.

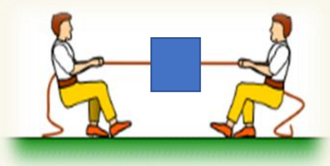
Force in Equilibrium

An object is in equilibrium if the object is at rest or is moving with a constant velocity in a straight line. The force that act on the object are balanced in all directions, the resultant force acting on it is zero. Just like tug-of-wall when the size and direction of the forces acting on an object are exactly balance, then there is no net force acting on the object.

Conditions for equilibrium :

1. The resultant of the forces must be zero. $\Sigma Fnet = 0$

$F_1 = 10N$ ⟵



⟶ $F_2 = 10N$

The resultant force $= F_1 + F_2 = (-10N) + 10N = 0\ N$

An object is in equilibrium if :

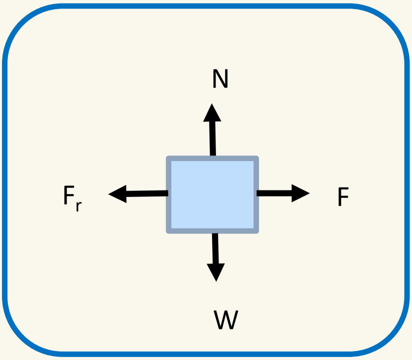
F_r (friction) = F (force) or $\sum f_x = 0$

N (normal) = W (weight) or $\sum f_y = 0$

Conditions for equilibrium :

2. The resultant force along any two mutually perpendicular axes is zero.

$\Sigma Fx = 0$ and $\Sigma Fy = 0$
Pendicular axes is zero.
$\Sigma Fx = 0$ and $\Sigma Fy = 0$



If the forces acting on an object are balanced, then its motion will not change :

- If it is not moving it will stay still
- If it is moving it will keep moving at a steady speed.

If the forces on an object are not equal, then they are unbalanced, then the motion of the object will change :

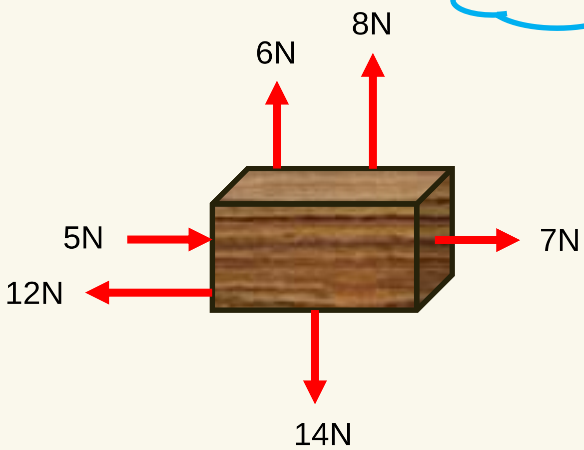
- If it is not moving it will start moving.
- If it is moving it will speed up (accelerate), slow down (decelerate), or change direction.

Example

$$\sum f_x = 5 + 7 - 12 = 0$$

$$\sum f_y = 6 + 8 - 14 = 0$$

Net force = 0



All forces which act upon the object are balance

Object will stay at rest since there is no movement

Resultant of Force: In a Straight Line

The resultant force is 6N to the right.

The resultant force is 7N to the left.

The resultant force is zero.

Tutorial (Past year questions)

1. State the definition of moment and its SI unit. (Jun 2016)

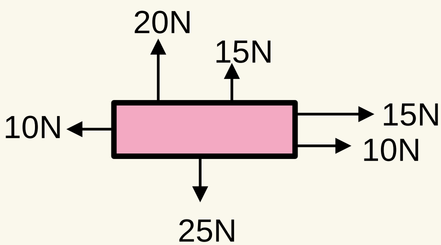
2. State the definition and SI unit of Force. (Dec 2018)

3. State Two (2) effects of force in everyday life. (Dec 2018)

4. State Two (2) differences between weight and mass. (Jun 2018)

5. A worker pushed a box with mass of 80kg an horizontal floor with constant acceleration of $2.0 m/s^2$. Calculate :
a) The force applied by the worker.
b) The acceleration if 70kg is released from the box. (Dec 2016)

6. Calculate the net force acting on the x-axis and y-axis of an object. (Dec 1028)



Check your answers

1. Moment is the product of force and the perpendicular distance of its line of an action from the point.
2. Force can be define as a push or pull action which will change the state of rest or uniform motion of an object.
3. A man pushing a big box. Kids playing archery.
4.

MASS	WEIGHT
Base Quantity	Derived Quantity
Scalar Quantity	Vector Quantity

5. F-160N , a = 16m/s^2
6. Fx = 15N , Fy = -20N

Resultant of Force: Directed at an Angle

Introduction

Application of Resultant Force

Case 1

Two forces acting at Quadrant 1 and Quadrant 2

Case 2

Two forces acting at Quadrant 1 and Quadrant 3

Case 3

Two forces acting at Quadrant 1 and Quadrant 4

Case 4

Two forces acting at Quadrant 1 and Quadrant 3 (towards the main point)

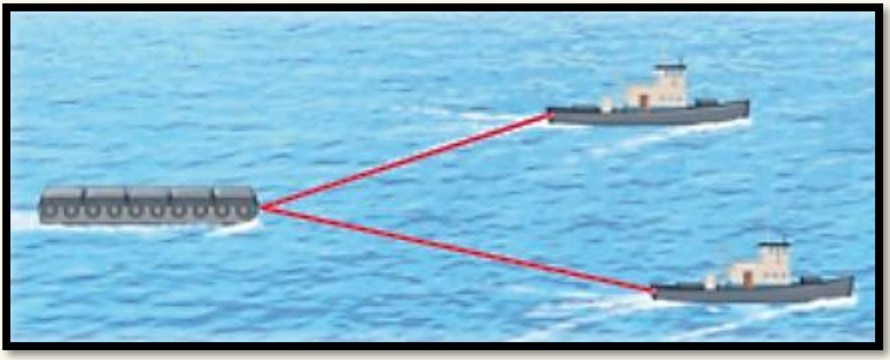
Case 5

Three forces acting at Quadrant 1, along x-axis and along y-axis

Tutorial

Past Year Questions & Answer

Introduction: Application of Resultant Force



Source: https://www.bartleby.com

SITUATION 1:

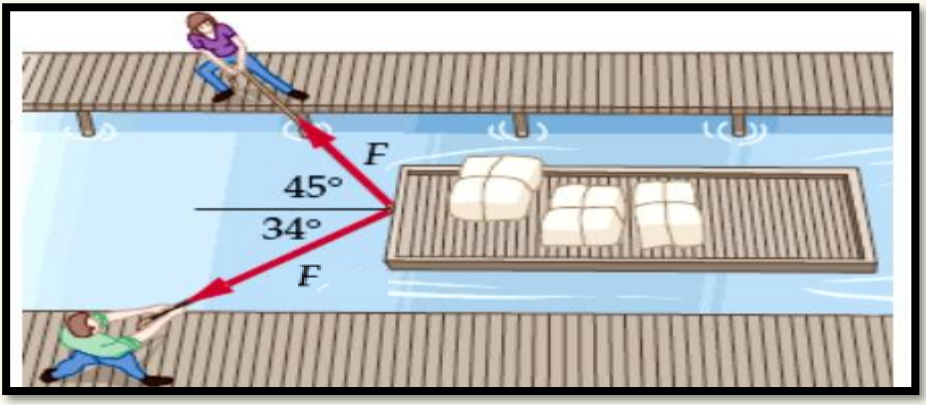
A barge loaded with heavy cargo is pulled horizontally by two tugboats.

! THINK

There are TWO forces acting on the barge.

- What is the total force (magnitude of resultant force) resulting from the tugboat?
- In which direction is the barge taken by the tugboat?

Introduction: Application of Resultant Force



Source: http://www.csun.edu

SITUATION 2:

Two crew members pull a raft containing loads with different directions (angles) and force strengths (magnitudes).

! THINK

There are TWO forces acting on the raft.

- Did they manage to pull the raft to move towards them?
- What is the total force (magnitude of the resultant force) produced?

Introduction: Application of Resultant Force

Based on Situation 1 and Situation 2 it can be concluded that **Resultant Force** refers to:

"… **The Net Force** acting on an object when it is subjected to several forces acting in various directions …"

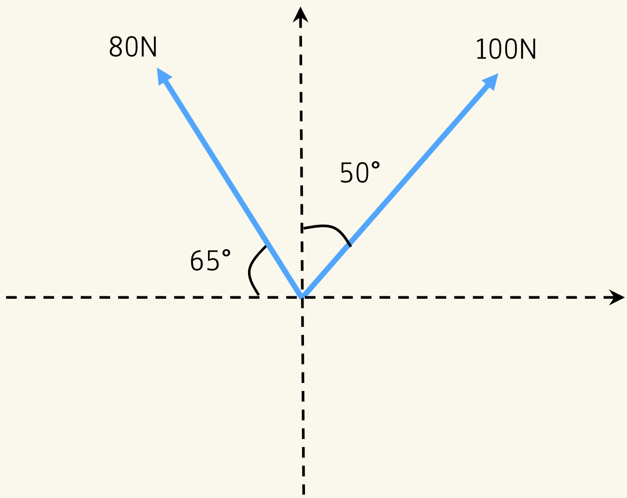
CHECK The process of obtaining Resultant Forces:

Step 1	Step 2	Step 3	Step 4
Resolve (break down) Force	Find FX & FY	Calculate Magnitude & Direction	Sketch the Resultant Force
Positive sign x-axis to → y-axis to ↑ Negative sign x-axis to ← y-axis to ↓	$F_x = F\cos\theta$ $F_y = F\sin\theta$ Arrange in a table and find the sum of F_x and F_y	Magnitude $\sqrt{\left(\sum F_x\right)^2 + \left(\sum F_y\right)^2}$ Direction (angle) $tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$	(i) Plot coordinate $(\sum F_x, \sum F_y)$; (ii) Label magnitude & direction value; (iii) Find the Real Angle

Case 1

QUESTION:

Calculate the magnitude and direction of the Resultant Force:

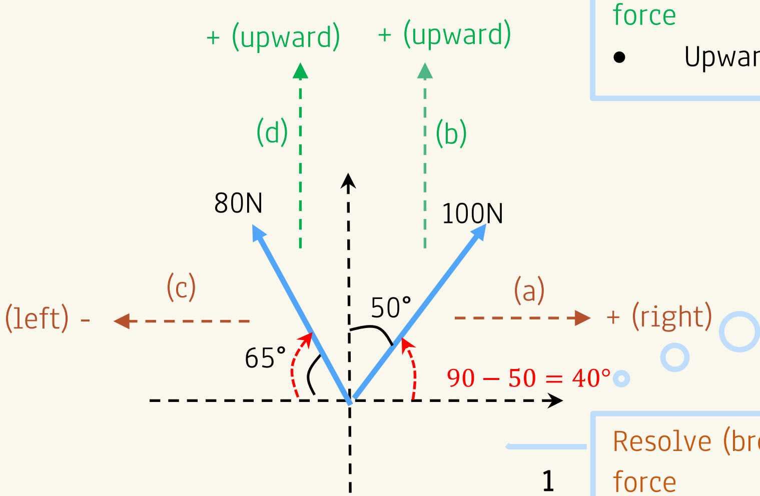


THINK

There are TWO forces acting:

- A force of 100N at Quadrant-1 with an angle of 50° from y-axis
- A force of 80N at Quadrant-2 with an angle of 65° from x-axis.

case 1



1 Resolve (break down) the y-axis force
- Upward: + sign

1 Resolve (break down) the x-axis force
- Right direction: + sign
- Left direction: - sign

$F_x = F\cos\theta$		$F_y = F\sin\theta$	
(a)	$+100\cos 40 = +76.60$	(b)	$+100\sin 40 = +64.28$
(c)	$-80\cos 65 = -33.81$	(d)	$+80\sin 65 = +72.50$
$\sum F_x = +42.79\,N\ (\rightarrow)$		$\sum F_y = +136.78\,N\ (\uparrow)$	

Coordinate:
$(42.79, 136.78)$

2 Collect and sum the x-axis forces.
- A positive (+) answer value indicates the Fx direction is to the **RIGHT**

2 Collect and sum the y-axis forces
- A Positive (+) answer value indicates the Fy direction is **UPWARD**

The combination of the **RIGHT** dan **UP** direction indicates the Resultant Force is:
- On the <u>right</u> side of the x-axis
- At the <u>top</u> of y-axis

Therefore, the Resultant Force will be in **Quadrant-1**, ok!

case 1

3

Calculate the magnitude and direction using formula

3

Magnitude
(Total of Resultant Force)

$$\sqrt{(\sum F_x)^2 + (\sum F_y)^2}$$

$= \sqrt{(+42.79)^2 + (+136.78)^2}$

$= \mathbf{143.32N}$

Direction
(Location of angle from x-axis)

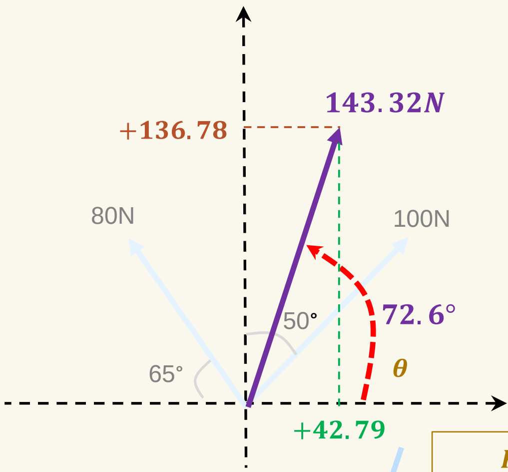
$$\tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$$

$= \tan^{-1}\left(\frac{136.78}{42.79}\right)$

$= \mathbf{72.6°}$

SUBMIT

FINAL ANSWER:



4

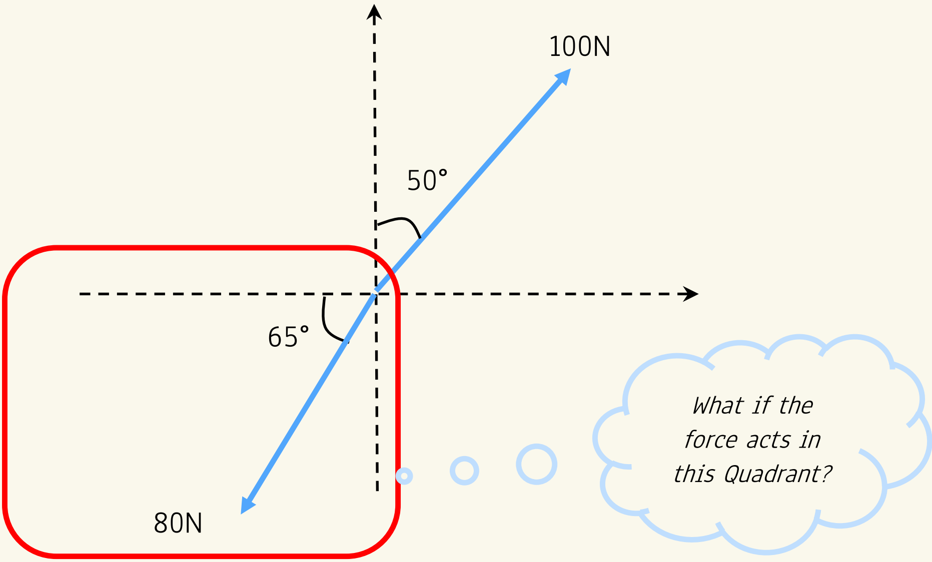
Sketch the location of Resultant Force based on the answer in step (2) and (3)

- The Resultant Force is located in Quadrant-1, good job!

Real angle
$\theta = 72.6°$ (anti-clockwise rotation)

Case 2

QUESTION:
Calculate the magnitude and direction of the Resultant Force:

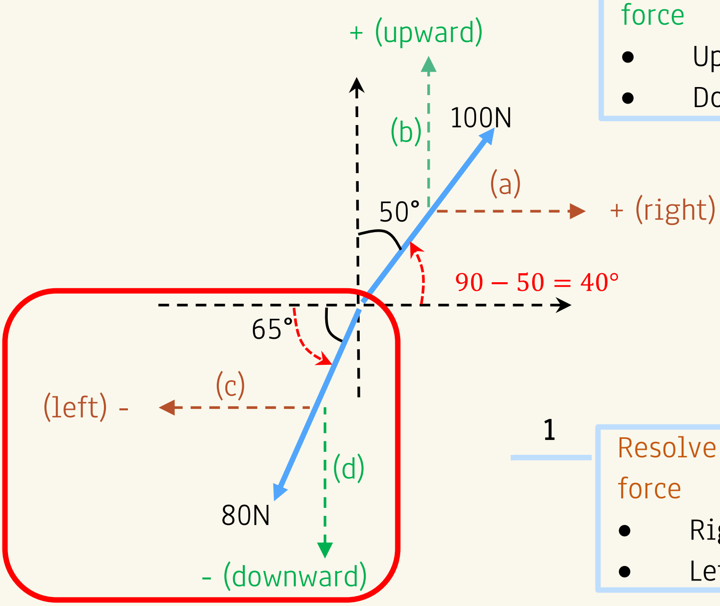


THINK

There are TWO forces acting:

- A force of 100N at Quadrant-1 with an angle of 50° from y-axis
- A force of 80N now at Quadrant-3 with an angle of 65° from x-axis.

case 2



1 Resolve (break down) the y-axis force

- Upward: + sign
- Downward: - sign

1 Resolve (break down) the x-axis force

- Right direction: + sign
- Left direction: - sign

$F_x = F\cos\theta$		$F_y = F\sin\theta$	
(a)	$+100\cos 40 = +76.60$	(b)	$+100\sin 40 = +64.28$
(c)	$-80\cos 65 = -33.81$	(d)	$-80\sin 65 = -72.50$
$\sum F_x = +42.79\,N\ (\rightarrow)$		$\sum F_y = -8.22\,N\ (\downarrow)$	

Coordinate: $(42.79, -8.22)$

2 Collect and sum the x-axis forces.

- A positive (+) answer value indicates the Fx direction is to the **RIGHT**

2 Collect and sum the y-axis forces

- A Negative (-) answer value indicates the Fy direction is **DOWNWARD**

CHECK

The combination of the **RIGHT** dan **DOWN** direction indicates the Resultant Force is:

- On the <u>right</u> side of the x-axis
- At the <u>below</u> of y-axis

Therefore, the Resultant Force will be in **Quadrant-4**, ok!

case 2

3

Calculate the magnitude and direction using formula

3

Magnitude
(Total of Resultant Force)

$$\sqrt{(\sum F_x)^2 + (\sum F_y)^2}$$

$$= \sqrt{(+42.79)^2 + (-8.22)^2}$$

$$= \mathbf{43.57N}$$

Direction
(Location of angle from x-axis)

$$\tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$$

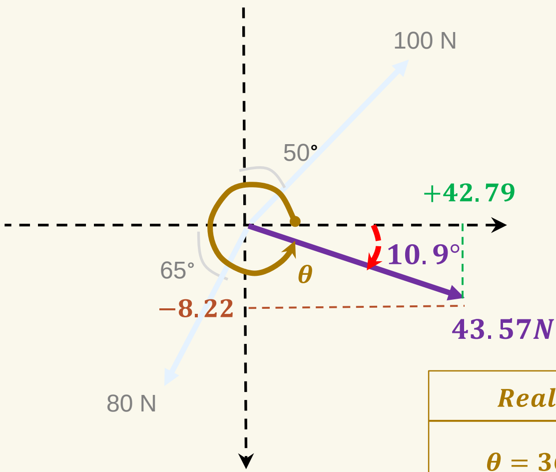
$$= \tan^{-1}\left(\frac{8.22}{42.79}\right)$$

$$= \mathbf{10.9°}$$

Ignore the negative sign (-) on Fy ok!

SUBMIT

FINAL ANSWER:



Real angle

$\theta = 360 - 10.9$
$= 349.1°$
(anti-clockwise rotation)

or

$\theta = -10.9°$
(clockwise rotation)

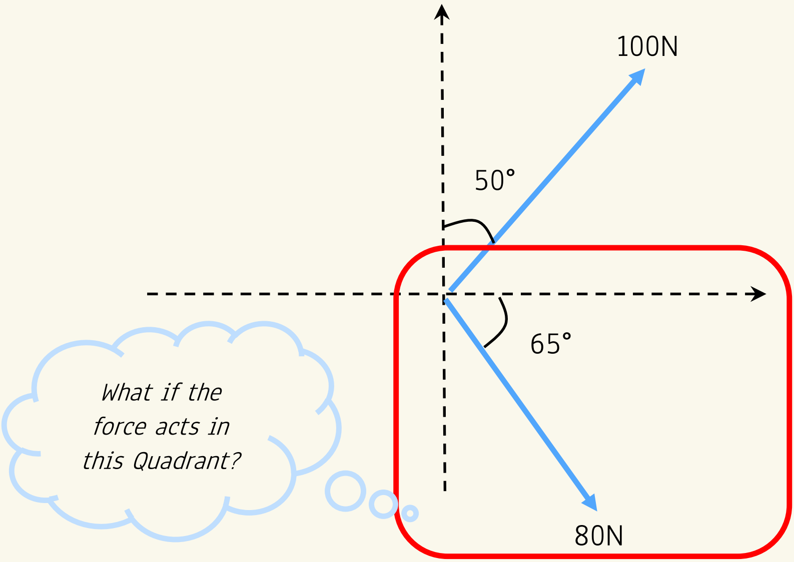
4

Sketch the location of Resultant Force based on the answer in step (2) and (3)

- The Resultant Force is located in Quadrant-4, good job!

Case 3

QUESTION:
Calculate the magnitude and direction of the Resultant Force:



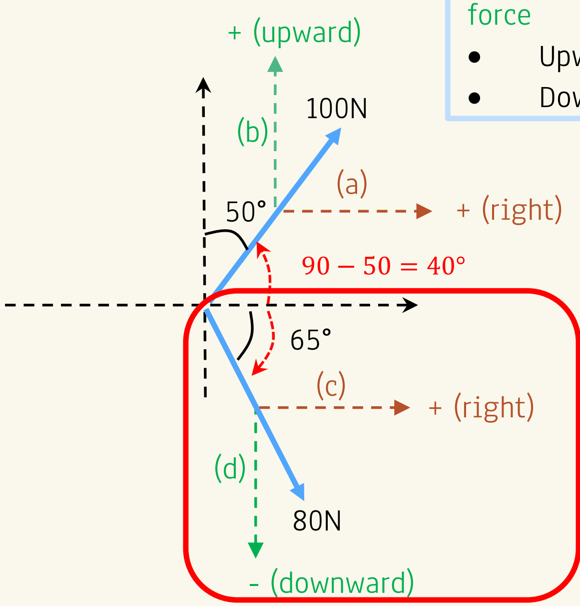
THINK

There are TWO forces acting:

- A force of 100N at Quadrant-1 with an angle of 50° from y-axis
- A force of 80N now at Quadrant-4 with an angle of 65° from x-axis.

case 3

1 Resolve (break down) the y-axis force
- Upward: + sign
- Downward: - sign



1 Resolve (break down) the x-axis force
- Right direction: + sign

$F_x = F\cos\theta$		$F_y = F\sin\theta$	
(a)	$+100\cos 40 = +76.60$	(b)	$+100\sin 40 = +64.28$
(c)	$+80\cos 65 = +33.81$	(d)	$-80\sin 65 = -72.50$
$\sum F_x = +110.41\,N\ (\rightarrow)$		$\sum F_y = -8.22\,N\ (\downarrow)$	

Coordinate: $(110.41, -8.22)$

2 Collect and sum the x-axis forces.
- A Positive (+) answer value indicates the Fx direction is to the **RIGHT**

2 Collect and sum the y-axis forces
- A Negative (-) answer value indicates the Fy direction is **DOWNWARD**

✓ CHECK

The combination of the **RIGHT** dan **DOWN** direction indicates the Resultant Force is:

- ➢ On the right side of the x-axis
- ➢ At the below of y-axis

Therefore, the Resultant Force will be in **Quadrant-4**, ok!

case 3

3 Calculate the magnitude and direction using formula 3

Magnitude
(Total of Resultant Force)

$$\sqrt{(\sum F_x)^2 + (\sum F_y)^2}$$

$$= \sqrt{(+110.41)^2 + (-8.22)^2}$$

$$= \mathbf{110.72N}$$

Direction
(Location of angle from x-axis)

$$\tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$$

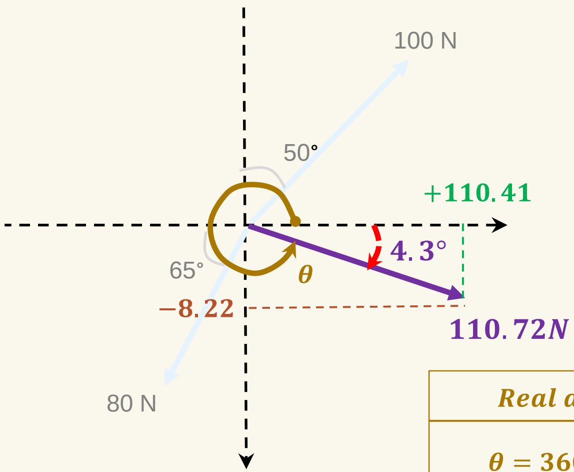
$$= \tan^{-1}\left(\frac{8.22}{110.41}\right)$$

$$= \mathbf{4.3°}$$

Ignore the negative sign (-) on Fy ok!

SUBMIT

FINAL ANSWER:



Real angle
$\theta = 360 - 4.3$ $= 355.7°$ (anti-clockwise rotation) **or** $\theta = -4.3°$ (clockwise rotation)

4

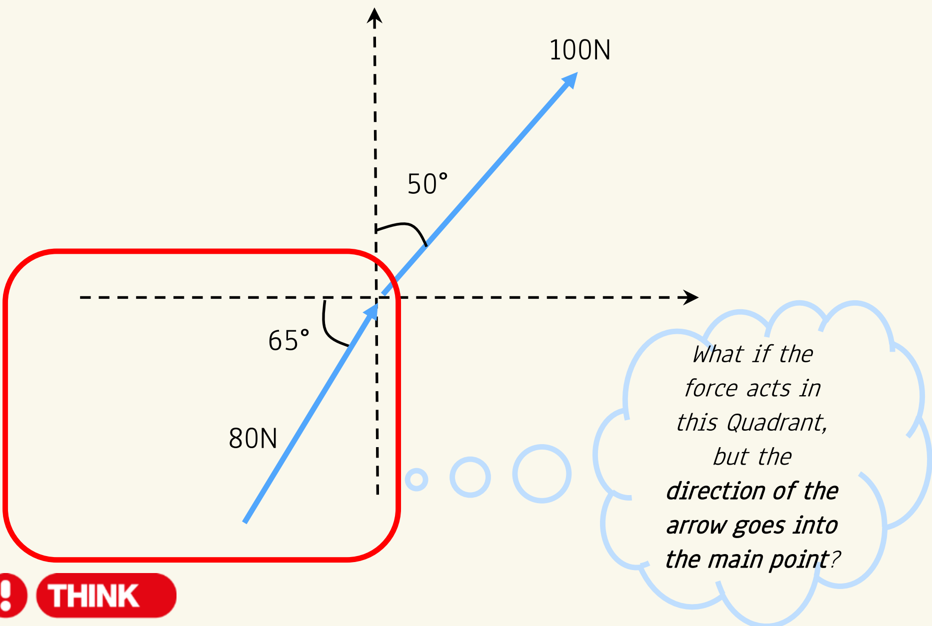
Sketch the location of Resultant Force based on the answer in step (2) and (3)

- The Resultant Force is located in Quadrant-4, good job!

Case 4

QUESTION:

Calculate the magnitude and direction of the Resultant Force:

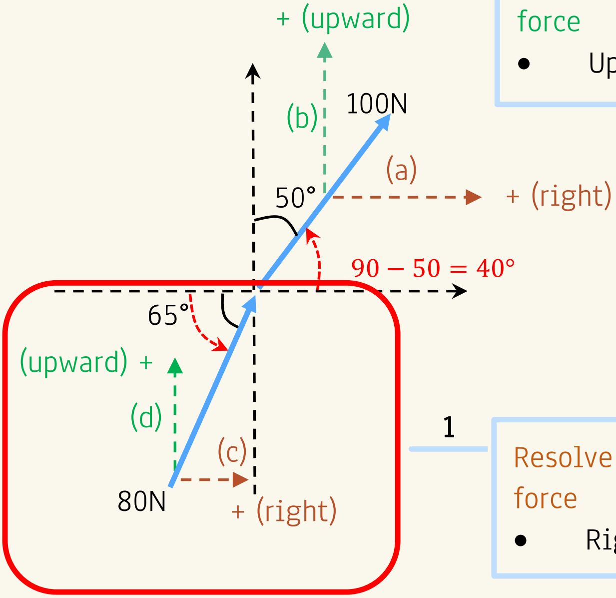


! THINK

There are TWO forces acting:

- A force of 100N at Quadrant-1 with an angle of 50° from y-axis
- A force of 80N at Quadrant-3 with an angle of 65° from x-axis is heading to the main point.

case 4



1 Resolve (break down) the y-axis force

- Upward: + sign

1 Resolve (break down) the x-axis force

- Right direction: + sign

$F_x = F\cos\theta$		$F_y = F\sin\theta$	
(a)	$+100\cos 40 = +76.60$	(b)	$+100\sin 40 = +64.28$
(c)	$+80\cos 65 = +33.81$	(d)	$+80\sin 65 = +72.50$
$\sum F_x = +\mathbf{110.41}\ \boldsymbol{N}\ (\rightarrow)$		$\sum F_y = +\mathbf{136.78}\ \boldsymbol{N}\ (\uparrow)$	

Coordinate:
$(\mathbf{110.41, 136.78})$

2 Collect and sum the x-axis forces.

- A positive (+) answer value indicates the Fx direction is to the **RIGHT**

2 Collect and sum the y-axis forces

- A Positive (+) answer value indicates the Fy direction is **UPWARD**

CHECK

The combination of the **RIGHT** dan **UP** direction indicates the Resultant Force is:

- On the <u>right</u> side of the x-axis
- At the <u>top</u> of y-axis

Therefore, the Resultant Force will be in **Quadrant-1**, ok!

case 4

3

Calculate the magnitude and direction using formula

3

Magnitude
(Total of Resultant Force)

$$\sqrt{(\sum F_x)^2 + (\sum F_y)^2}$$

$$= \sqrt{(+110.41)^2 + (+136.78)^2}$$

$$= \mathbf{175.78}N$$

Direction
(Location of angle from x-axis)

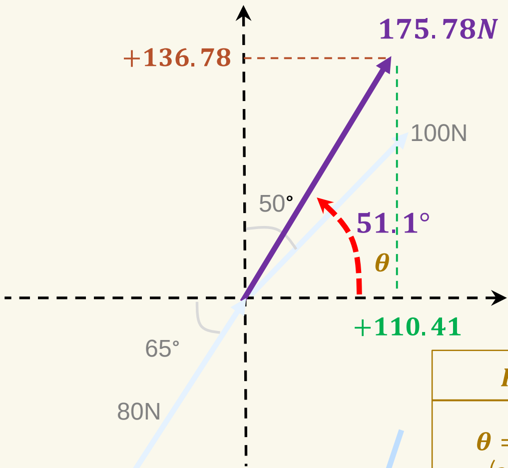
$$\tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$$

$$= \tan^{-1}\left(\frac{136.78}{110.41}\right)$$

$$= \mathbf{51.1}°$$

SUBMIT

FINAL ANSWER:



4

Sketch the location of Resultant Force based on the answer in step (2) and (3)

- The Resultant Force is located in Quadrant-1, good job!

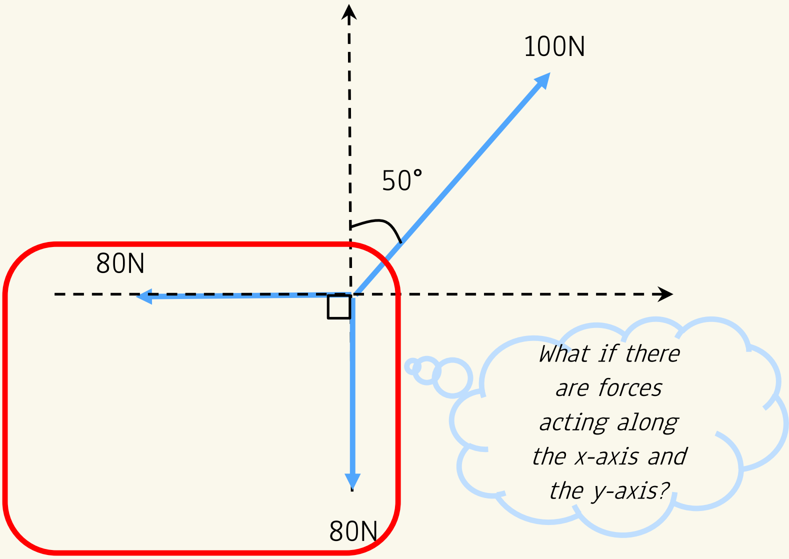
Real angle

$\theta = 51.1°$
(anti-clockwise rotation)

Case 5

QUESTION:

Calculate the magnitude and direction of the Resultant Force:



THINK

There are THREE forces acting:

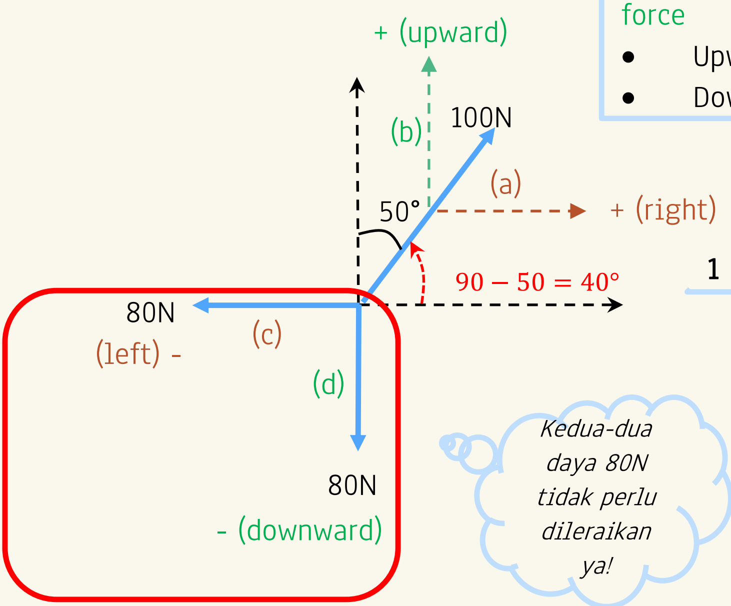
- A force of 100N at Quadrant-1 with an angle of 50° from y-axis
- Two forces of 80N now acting along the x-axis and y-axis

case 5

1

Resolve (break down) the y-axis force

- Upward: + sign
- Downward: - sign



1

Resolve (break down) the x-axis force

- Right direction: + sign

$F_x = F\cos\theta$		$F_y = F\sin\theta$	
(a)	$+100\cos 40 = +76.60$	(b)	$+100\sin 40 = +64.28$
(c)	$= -80$	(d)	$= -80$
$\sum F_x = -3.4\ N\ (\leftarrow)$		$\sum F_y = -15.72\ N\ (\downarrow)$	

Coordinate:

$(-3.4, 15.72\ )$

2

Collect and sum the x-axis forces.

- A negative (-) answer value indicates the Fx direction is to the **LEFT**

2

Collect and sum the y-axis forces

- A Negative (-) answer value indicates the Fy direction is **DOWNWARD**

✓ CHECK

The combination of the **LEFT** dan **DOWN** direction indicates the Resultant Force is:

- ➢ On the <u>left</u> side of the x-axis
- ➢ At the <u>below</u> of y-axis

Therefore, the Resultant Force will be in **Quadrant-3**, ok!

case 5

3

Calculate the magnitude and direction using formula

3

Magnitude
(Total of Resultant Force)

$$\sqrt{(\sum F_x)^2 + \left(\sum F_y\right)^2}$$

$$= \sqrt{(-3.4)^2 + (-15.72)^2}$$

$$= \mathbf{16.08N}$$

Direction
(Location of angle from x-axis)

$$\tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$$

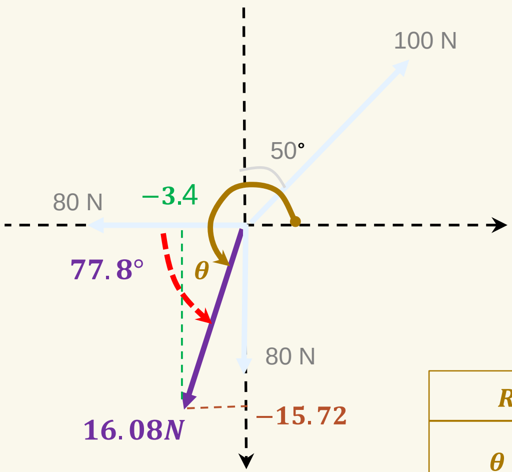
$$= \tan^{-1}\left(\frac{15.72}{3.4}\right)$$

$$= \mathbf{77.8^\circ}$$

Ignore the negative sign (-) on Fx and Fy ok!

SUBMIT

FINAL ANSWER:



Real angle
$\theta = 180 + 77.8$ $= 257.8^\circ$ (anti-clockwise rotation)

4

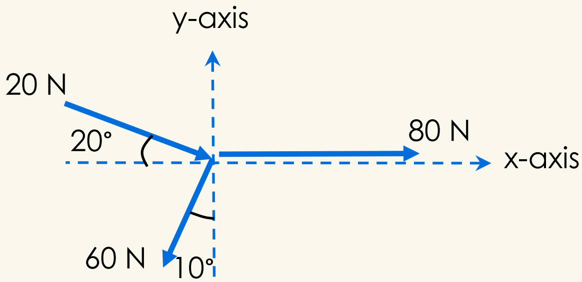
Sketch the location of Resultant Force based on the answer in step (2) and (3)

- The Resultant Force is located in Quadrant-3, good job!

Tutorial

Calculate the **magnitude** and **direction** of the resultant force:

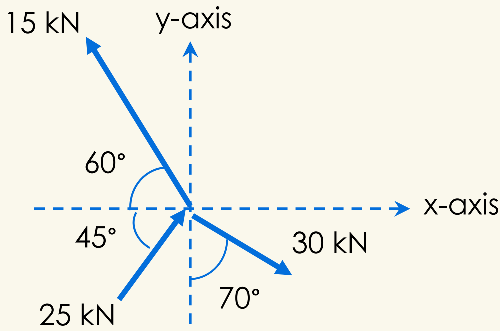
1



December 2014

[**ANSWER :** F_R = 110.25 N, θ = -36.73° or 323.27°]

2



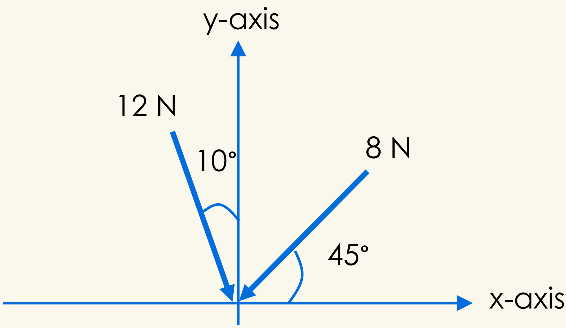
June 2014

[**ANSWER :** F_R = 43.46 kN, θ = 28.01°]

Tutorial

Calculate the **magnitude** and **direction** of the resultant force:

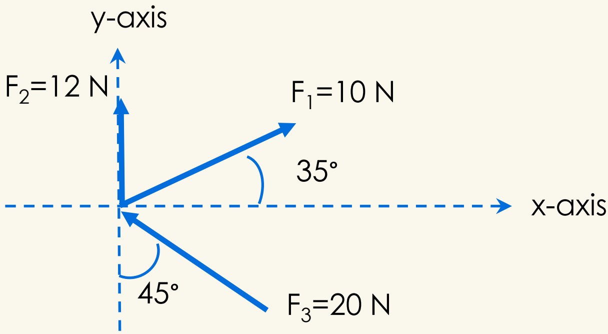
3



June 2015

[ANSWER : F_R = 17.837 N, θ = 258.44°**]**

4



June 2016

[ANSWER : F_R = 32.43 N, θ = 100.57°**]**

Moment of Force

Introduction

Application Moment of Force

Case 1

Finding Center of gravity with inclined force

Case 2

Finding Center of gravity with load

Case 3

Finding Center of gravity with inclined forced upwards

Case 4

Reaction Force

Case 5

Reaction Force with 2 unknown Force

Tutorial

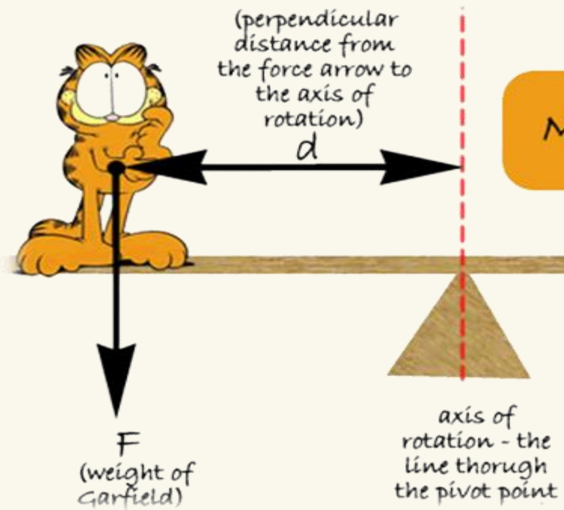
Past Year Questions & Answer

Moment Of Force

WHAT??

Product of force and the perpendicular distance of an action from point or the turning effect of force

Formula ???



Moment = Fd

M = Moment (Nm)
F = Force (N)
d = Perpendicular distance (m)

Unit??

Newton(meter) = Nm

Turning Effect

Total sum of the anti-clockwise moment is equal to the sum of the clockwise moment

STEP TO SOLVE???

Step 1	Step 2	Step 3
Choose Methods	Sketching FBD (free-body-diagram)	Solve using suitable methods

Methods???

Moment Force Method (MFM)

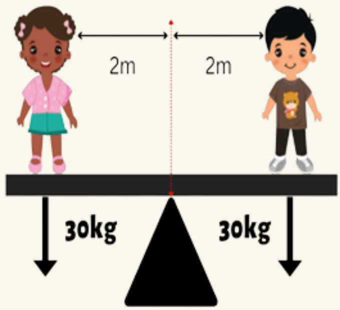
1. Total Force *(Fy)* is in equilibrium
2. $M_{clockwise} = M_{anti\text{-}clockwise}$

Moment Resultant Method (MRM)

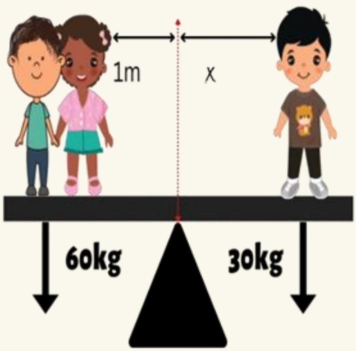
$$\bar{x} = \frac{\sum Moment}{\sum Force}$$

Problem Moment of FORCE????

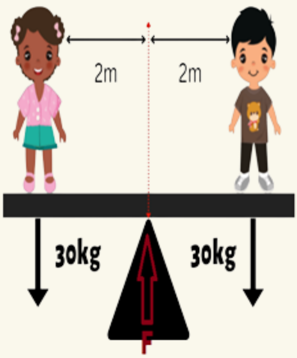
1. Gravititional Point



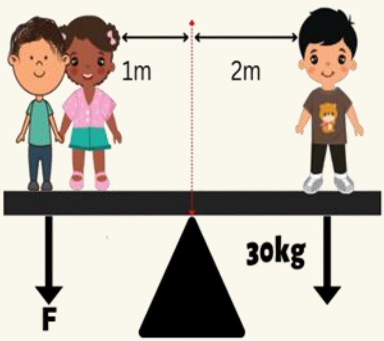
2. Distance of x

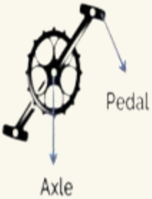


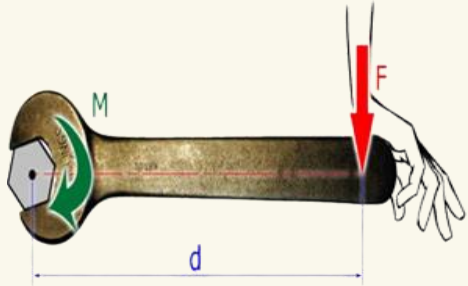
3. Reaction Force



4. Unknown Force

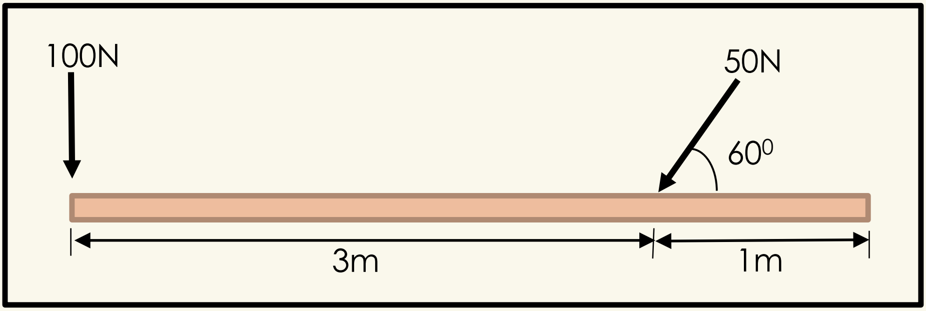






Application Moment Of Force Concept

CASE 1 : Center Of Gravity or Gravitional Point



Step 1 : Choose Methods

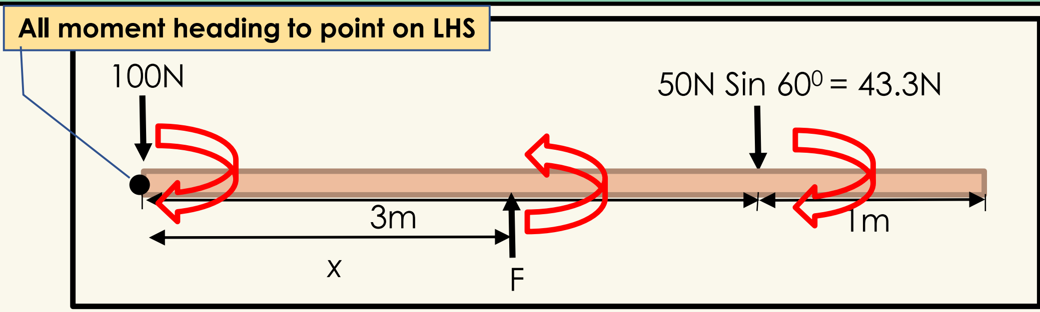
Both methods can be used

i) MFM

ii) MRM

Step 2 : Sketching FBD (free-body-diagram)

1. Make sure all the force is in the direction of y-axis (90°).
2. Place an additional force, F (MFM ONLY) that will support the system (at the appropriate location).
3. Show all the rotation of the moments.
4. The center of gravity, $\bar{x}$ is calculated from from point LSH to point F.



STEP 3 : Moment Force Method

STEP 3 : Moment Resultant Method

i) Divide F_1 in Horizontal Elemen ,

$F_1 = 50 \, Sin \, 60 = 43.3N$

ii) Finding **F**, $\sum\uparrow F_y = \sum\downarrow F_y$

"Total Force *(Fy)* is in equilibrium"

$$F = 100 + 43.3$$
$$\therefore F = 143.3N$$

ii) Finding **F**

No Need to Find F

iii) Finding **center of gravity**, $\bar{x}$

$$M_{clockwise} = M_{anti\text{-}clockwise}$$

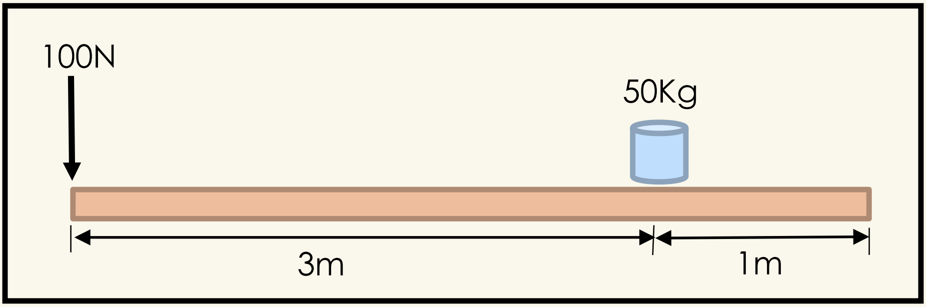
$$F(\bar{x}) = 43.3(3) + 100(0)$$
$$143.3(\bar{x}) = 129.9 + 0$$
$$\therefore \bar{x} = \frac{129.9}{143.3}$$
$$= 0.91 \, m \, (from \, LHS)$$

iii) Finding **center of gravity**, $\bar{x}$

$$\bar{x} = \frac{\sum Moment}{\sum Force}$$

$$(\bar{x}) = \frac{43.3(3) + 100(0)}{100 + 43.3}$$
$$\therefore \bar{x} = \frac{129.9}{143.3}$$
$$= 0.91 \, m \, (from \, LHS)$$

CASE 2 : Center Of Gravity or Gravitational Point



Step 1 : Choose Methods

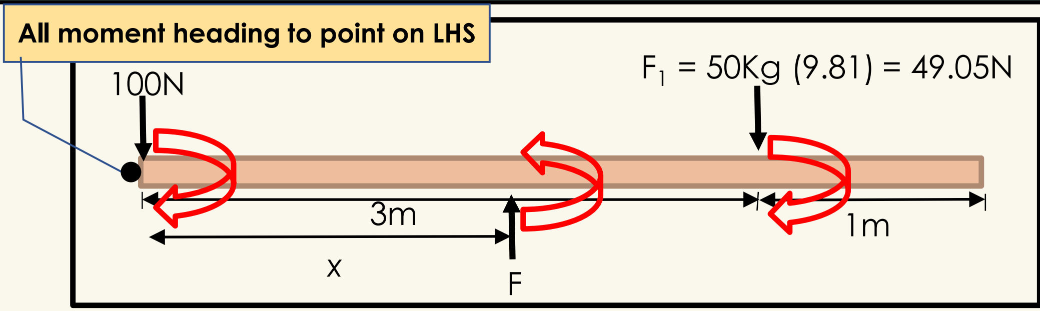
Both methods can be used

i) MFM

ii) MRM

Step 2 : Sketching FBD (free-body-diagram)

1. Make sure all the force is in the direction of y-axis (90°).
2. Place an additional force, F M ONLY) that will support the system (at the appropriate location).
3. Show all the rotation of the moments.
4. The center of gravity, $\bar{x}$ is calculated from from point LSH to point F.



STEP 3 : Moment Force Method

STEP 3 : Moment Resultant Method

i) Finding Weight of the load , $F_1 = mg = 50(9.81) = 49.05N$

ii) Finding **F**, $\sum \uparrow F_y = \sum \downarrow F_y$

"Total Force *(Fy)* is in equilibrium"

$$F = 100 + 49.05$$
$$\therefore F = 149.05N$$

ii) Finding **F**,

No Need to Find F

iii) Finding **center of gravity**, $\bar{x}$

$M_{clockwise} = M_{anti\text{-}clockwise}$

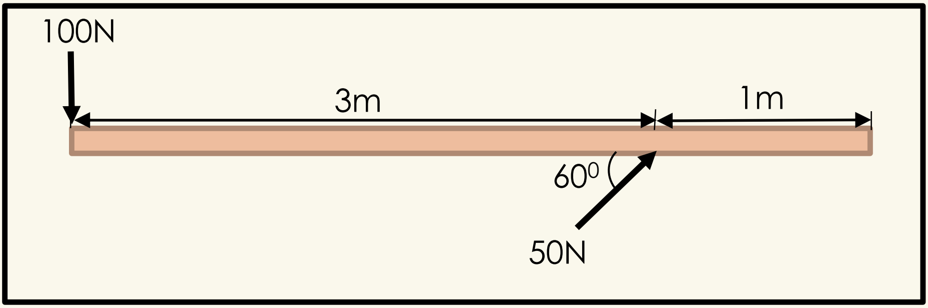
$$F(\bar{x}) = 49.05(3) + 100(0)$$
$$143.3(\bar{x}) = 147.15 + 0$$
$$\therefore \bar{x} = \frac{147.15}{143.3}$$
$$= 0.99\ m\ (from\ LHS)$$

iii) Finding **center of gravity**, $\bar{x}$

$$\bar{x} = \frac{\sum Moment}{\sum Force}$$

$$(\bar{x}) = \frac{49.05(3) + 100(0)}{100 + 43.3}$$
$$\therefore \bar{x} = \frac{147.15}{143.3}$$
$$= 0.99\ m\ (from\ LHS)$$

CASE 3 : Center Of Gravity or Gravitational Point



Step 1 : Choose Methods

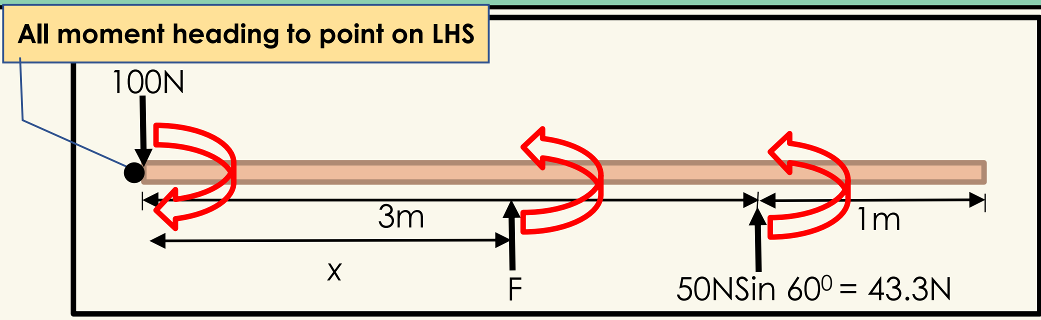
Both methods can be used

i) MFM

ii) MRM

Step 2 : Sketching FBD (free-body-diagram)

1. Make sure all the force is in the direction of y-axis (90°).
2. Place an additional force, F (MFM ONLY) that will support the system (at the appropriate location for).
3. Show all the rotation of the moments.
4. The center of gravity, $\bar{x}$ is calculated from from point LSH to point F.



STEP 3 : Moment Force Method

STEP 3 : Moment Resultant Method

i) Divide F_1 in Horizontal Elemen, $F_1 = 50sin60^0 = 43.3N$

STEP 3 : Moment Force Method

ii) Finding **F**, $\sum\uparrow F_y = \sum\downarrow F_y$

"Total Force *(Fy)* is in equilibrium"

$$F + 43.3 = 100$$
$$\therefore F = 100 - 43.3N$$
$$= 56.7\text{N}$$

iii) Finding **center of gravity**, $\bar{x}$

$M_{clockwise} = M_{anti\text{-}clockwise}$

$$F(\bar{x}) + 43.3(3) = 100(0)$$
$$56.7(\bar{x}) = -129.9$$
$$\therefore \bar{x} = \frac{-129.9}{56.7}$$
$$= -2.29m\ (from\ LHS)$$

STEP 3 : Moment Resultant Method

ii) Finding **F**,

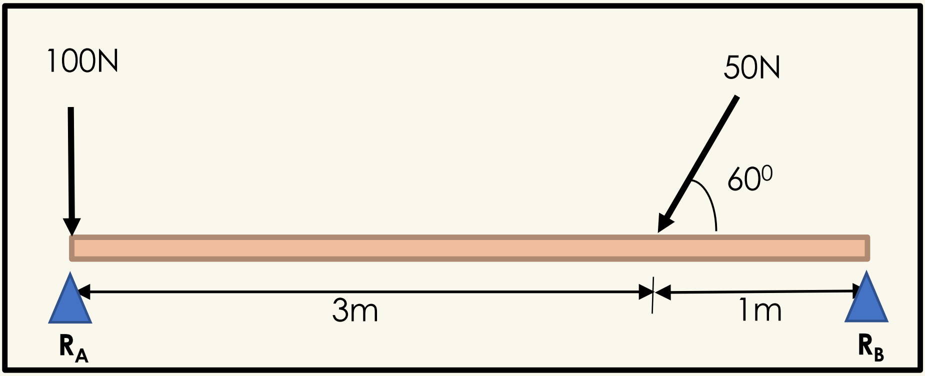
No Need to Find F

iii) Finding **center of gravity**, $\bar{x}$

$$\bar{x} = \frac{\sum Moment}{\sum Force}$$

$$(\bar{x}) = \frac{-43.3(3) + 100(0)}{-43.3 + 0}$$
$$\therefore \bar{x} = \frac{-129.9}{56.7}$$
$$= -2.29\text{m}\ (from\ LHS)$$

Case 4 :Reaction Force



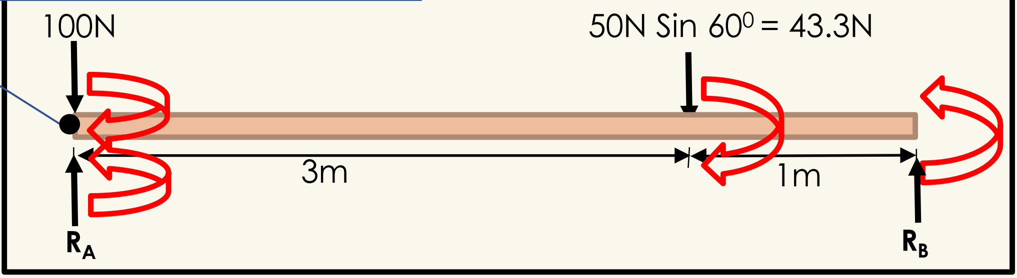
Step 1 : Choose Methods

Find Reaction can use MFM **ONLY**

Step 2 : Sketching FBD (free-body-diagram)

1. Make sure all the force is in the direction of y-axis (90°).
2. Place an Reaction forced, RA and RB at the support point of the system.
3. All moment calculated from from point LSH to point F.

All moment heading to point on LHS



STEP 3 : Moment Force Method

i) Divide F_1 in Horizontal Elemen , $F_1 = 50\,sin\,60 = 43.3N$

ii) Using $\sum\uparrow F_y = \sum\downarrow F_y$

"Total Force *(Fy)* is in equilibrium"

$$R_A + R_B = 100 + 43.3$$
$$R_A + R_B = 143.3N$$

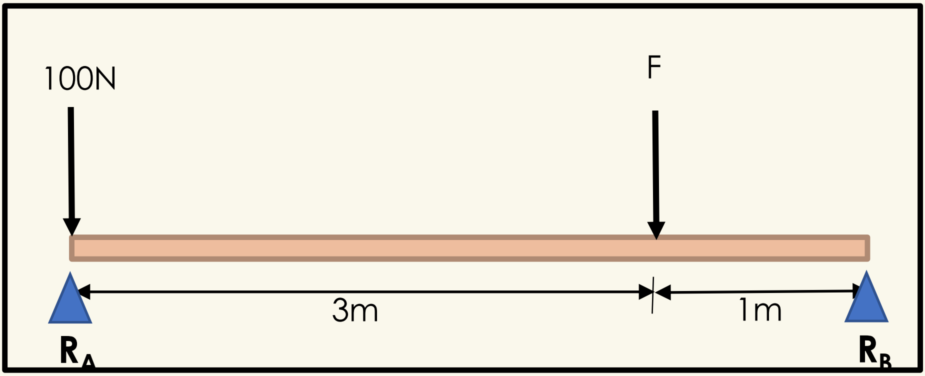
iii) Using Total Moment = 0

$M_{clockwise} = M_{anti\text{-}clockwise}$

$$R_A(0) + R_B(4) = 100(0) + 43.3(3)$$
$$\therefore R_B = \frac{129.9}{4} = 32.48N$$
$$\therefore R_A = 143.3 - 32.48$$
$$= 110.82\,N$$

$$R_A + R_B = 100 + 43.3$$

CASE 5 :Reaction Force

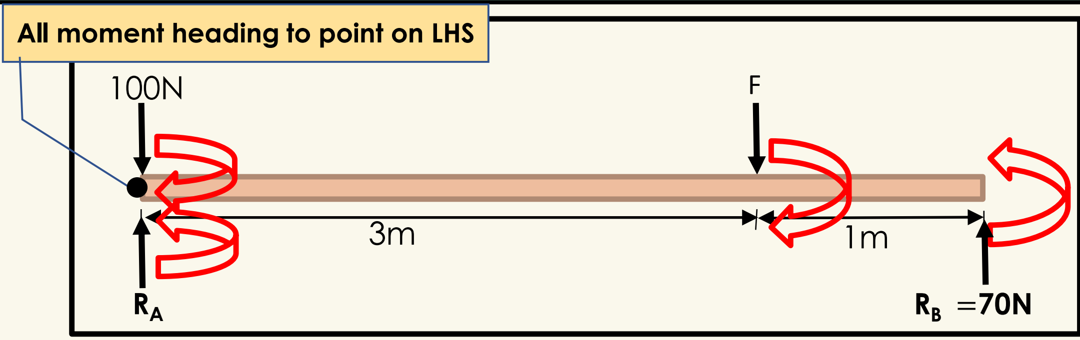


Step 1 : Choose Methods

Find Reaction can use MFM **ONLY**

Step 2 : Sketching FBD (free-body-diagram)

1. Make sure all the force is in the direction of y-axis (90°).
2. Place an Reaction forced, RA and RB at the support point of the system.
3. All moment calculated from from point LSH to point F.



STEP 3 : Moment Force Method

i) Divide F_1 in Horizontal Elemen ; none Inclined force

ii) Using $\sum\uparrow F_y = \sum\downarrow F_y$

"Total Force *(Fy)* is in equilibrium"

$$R_A + R_B = 100 + \mathrm{F}$$
$$R_A + 70 = 100 + \mathrm{F}$$

iii) Using Total Moment = 0

$M_{clockwise} = M_{anti\text{-}clockwise}$

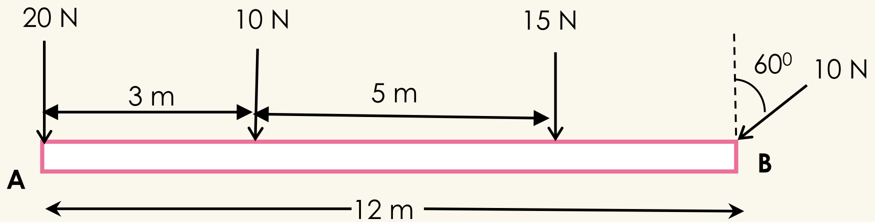
$$R_A(0) + 70(4) = 100(0) + \mathrm{F}(3)$$
$$\therefore \mathrm{F} = \frac{280}{3}$$
$$= \mathbf{93.3N}$$

$$R_A + 70 = 100 + 93.3$$
$$= 193.3 - 70$$
$$= \mathbf{123.3N}$$

Tutorial

Calculate the **center of gravity, x from point A** to be system in equilibrium

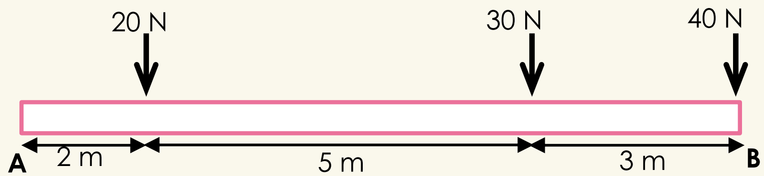
1



December 2013

[**ANSWER :** $\overline{x}$ = 4.2m from A

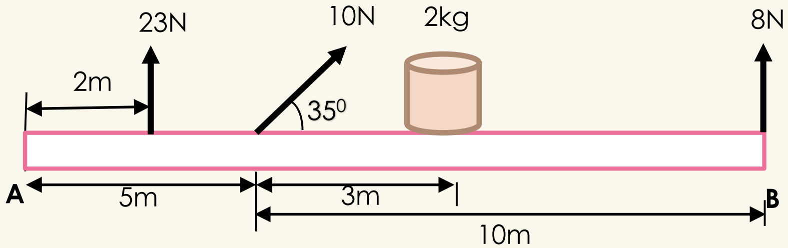
2



June 2015

[**ANSWER :** $\overline{x}$ = 4.83m from A]

3

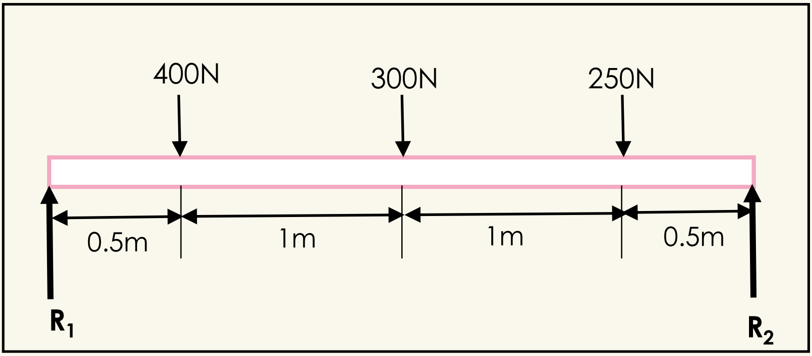


June 2016

[**ANSWER :** $\overline{x}$ = 2.20m from A]

Tutorial

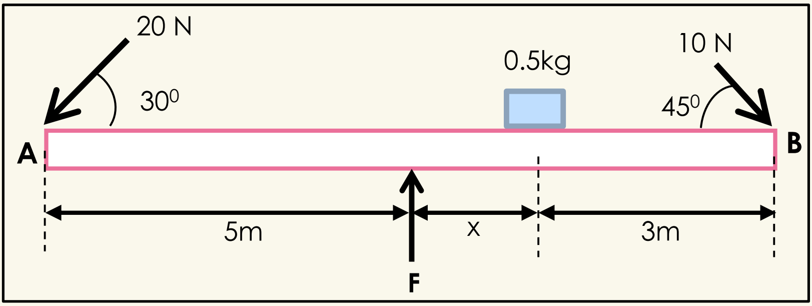
4 The solar panels are fitted to a frame supported by a beam, as shown in Figure(a) and the forces acted on the beam as shown in the Figure(b). **Calculate the size of reaction force, R_2** by considering the moment at R_1



June 2017

[ANSWER : R_2 = 425**]**

5 Figure shows a loaded beam. Find the **reaction force**, F and the **value of x** if the beam is in equilibrium. Given $g=10m/s^2$.



June 2013

[ANSWER : $\overline{x}$ = 2.385m , F = 67.07N**]**

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