2021 Sec 3 Physics Chapter 6 Dynamics

Answers to Examples and Exercises

6.1 Types of Forces

Example 6.1.1
Weight on Moon = mg = 20 kg x 1.6 m s^{-2} = 32 N;
Weight on Mars = mg = 20 kg x 3.7 m s^{-2} = 74 N

Exercise 6.1.1

6.1.1 Gravitational Force

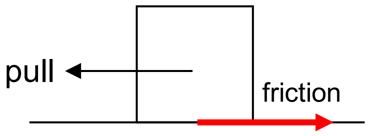
1. (a) Mass on Moon = 45 N/10 m s^{-2} = 4.5 kg
   (b) Weight on Moon = 4.5 kg x 1.6 m s^{-2} = 7.2 N

2. Friction prevents them from moving towards each other.

3. 20 kg ≠ 200 N, because 20 kg is a mass while 200 N is weight (or a force). These are different types of physical quantities and hence cannot be equated with an equal sign. She should write the step as: weight = 20 kg x 10 m s^{-2} = 200 N.

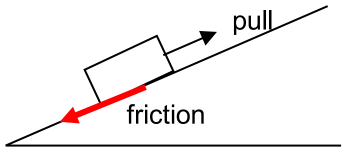
Example 6.1.2

(a)



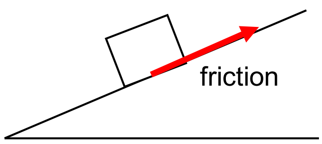
block being pulled to the left

(b)



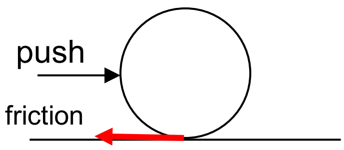
block being pulled up a ramp

(c)



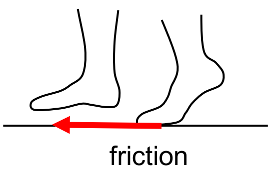
block at rest on a ramp
(f prevents block from sliding down)

(d)

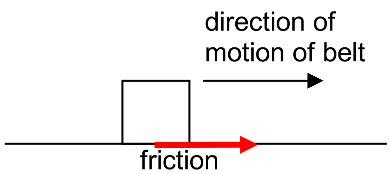


ball sliding to the right at constant speed

(e)



girl walking to the left
(f prevents foot from sliding to the right)



block accelerating to the right on a conveyer belt (f prevents block from sliding to the left)

Exercise 6.1.2

6.1.2 Friction

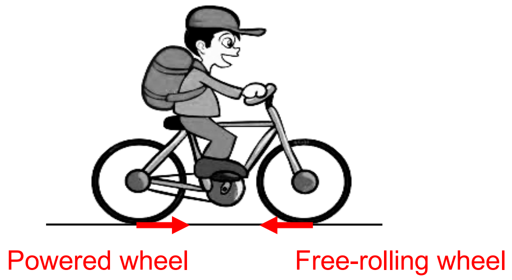
4. (a) No. Horizontal force acts on ball by vertical wall (assume ball bounces off horizontally)
   (b) Yes. There is friction in the forward direction on each foot in contact with ground (see Example 3(b))
   (c) No. Drum skin vibrates perpendicular to itself (as it interacts with air)
   (d) No. Although there is significant friction (air resistance) opposing motion of rocket.

5. Draw arrow to represent friction **exactly** on the surface of contact.

(a)1 N to left, not moving	(b) 2 N to left, not moving	(c) 3 N to right, not moving
(d) 5 N to left, not moving	(e) 5 N to left, accelerates to right	(f) No friction acting

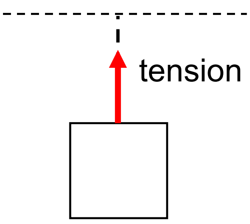
6. Not necessary. There may be other forces that balanced the friction.

7.

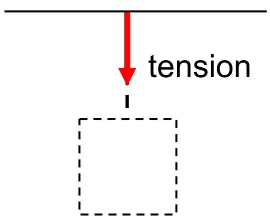


Example 6.1.4

(a)



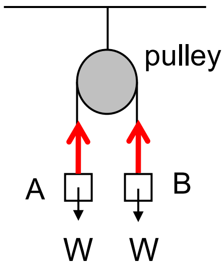
(b)



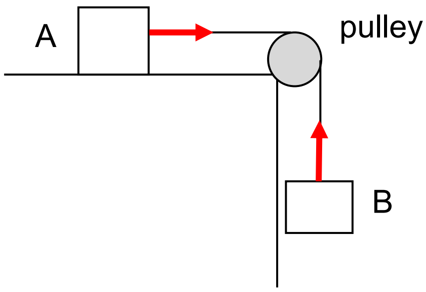
Exercise 6.1.4

6.1.4 Tension

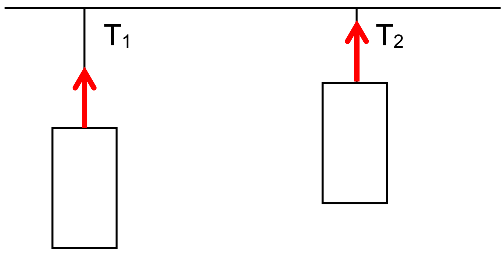
8. (a)



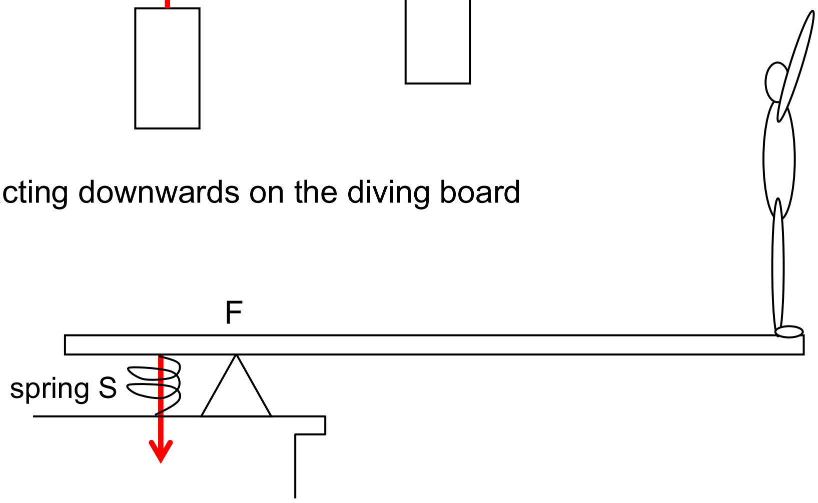
(b)



9. (a) upwards
   (b) same

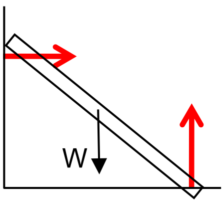


10. tension acting downwards on the diving board



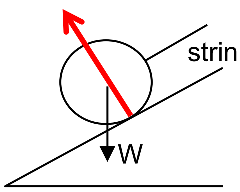
Example 6.1.5

(a)



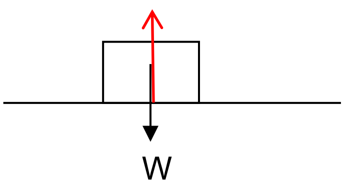
A ladder leaning against a wall

(b)



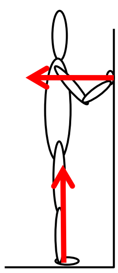
A cylinder resting on a slope

(c)



A box resting on a surface

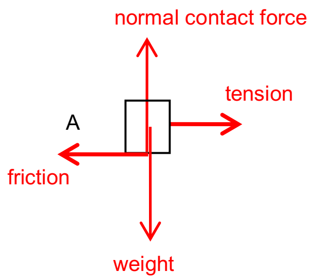
(d)

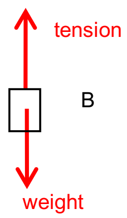


A man pushing against a wall

6.2 Free-body diagram*

Example 3.2.1

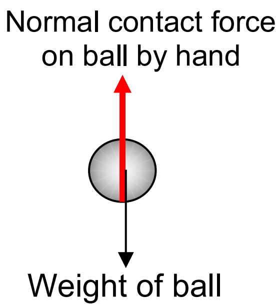




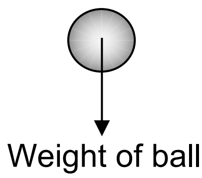
Exercise 6.2

6.2 Free-body Diagram

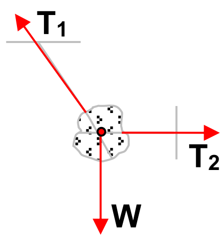
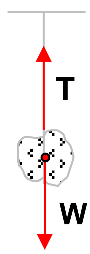
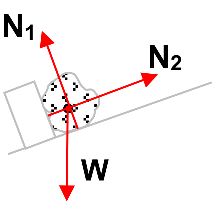
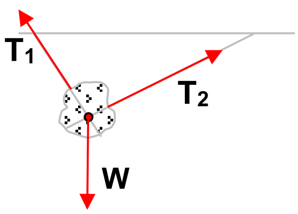
1. (a)

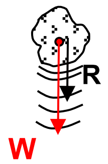
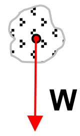
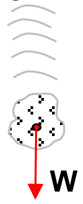
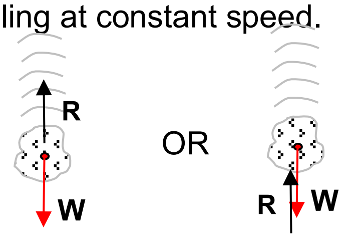
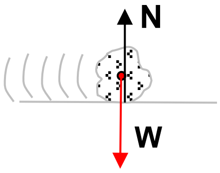
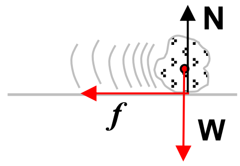


(b)

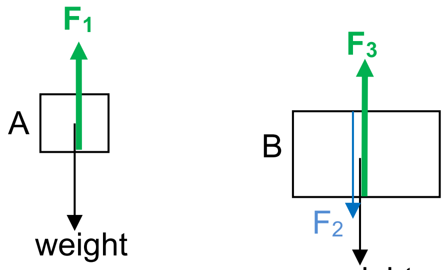


2.

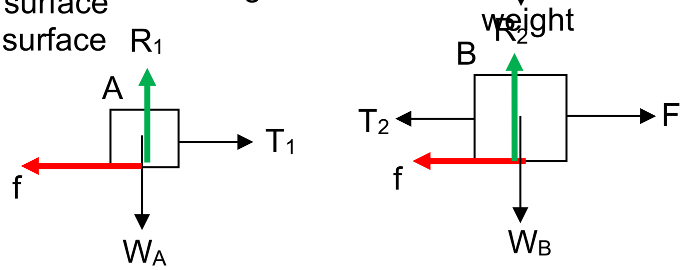
(a) Static. 	(b) Static. 
(c) Static. 	(d) Static. 

(e) Rising vertically upwards	(f) At the top of a vertical path.
	
(g) Falling rock. Ignore air resistance. 	(h) Falling at constant speed. 
(i) Sliding to the right at constant speed without friction. 	(j) Moving to the right and decelerating due to friction. 

3. (a) F_1 = normal contact force on A by B
 F_2 = normal contact force on B by A
 F_3 = normal contact force on B by surface



(b) R_1 = normal contact force on A by surface
 R_2 = normal contact force on B by surface
 T_1 = tension acting on A
 T_2 = tension acting on B
 W_A = weight of A
 W_B = weight of B
 f = friction



6.3 Balanced and Unbalanced forces

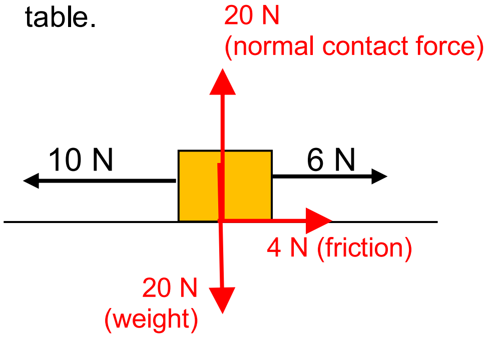
Example 6.3.1
The forces acting on it are <u>unbalanced</u> and the resultant force is <u>4 N to the left</u>.

Exercise 6.3

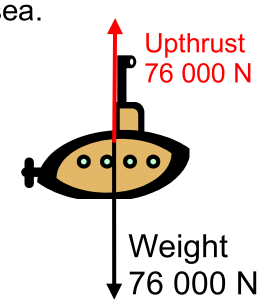
6.3 Balanced and Unbalanced forces

1.

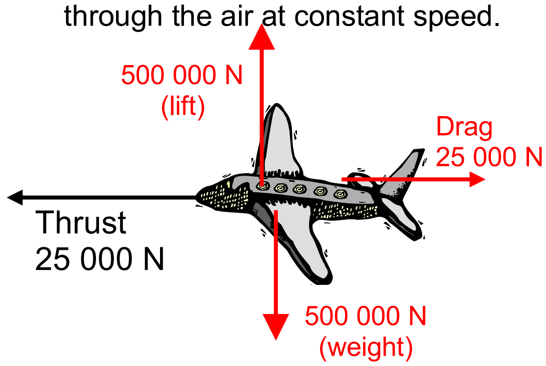
(a) Three horizontal forces being applied on a box of mass 2 kg at rest on a table.



(b) A submarine remains stationary below the sea.



(c) A plane of mass 50 000 kg moves through the air at constant speed.

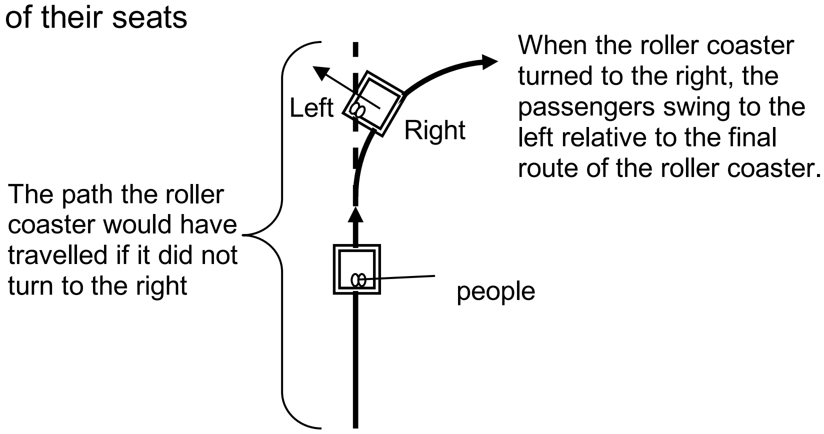


6.4 Newton's First Law of Motion

Example 6.4.1

(a) By Newton's first law, the passenger will continue to move forward with constant speed in a straight line when the bus comes to a stop.

(b) When the roller-coaster suddenly turns right, the people will continue to move in a straight line (as shown below) according to Newton's first law. Hence they appear to swing to the left of their seats



Exercise 6.4

6.4 Newton's First Law of Motion

1. Assumptions made: the train is moving in a straight line, the train is closed and there is an absence of air resistance acting on the girl.
   (a) train at constant velocity:
   She will land on the <u>same spot</u> from which she jumped. Before jumping upward, she had a forward velocity, which is same as that of the train. When she jumped, she continue to move with the same forward velocity as the train, according to Newton's first law of motion.

   (b) train with positive acceleration in a straight line:
   She will land <u>behind the spot</u> from which she jumped. When she jumped, she - continue to move with the same forward velocity but the train is speeding up.

   (c) train with negative acceleration (slowing down) in a straight line:
   She will land <u>in front of the spot</u> from which she jumped. When she jumped, she continue to move with the same forward velocity but the train is slowing down.

2. (a) A car is accelerating from rest: <u>Accelerating means velocity is not constant. Hence, resultant force is not zero</u>

   (b) The moon circling around the Earth: <u>Change in direction of velocity means velocity if not constant, hence, there is resultant force.</u>

   (c) An apple falling to the ground: <u>Velocity is not constant means resultant force is not zero.</u>

   (d) A car moving at constant speed around a corner: <u>Change in direction of velocity means velocity if not constant, hence, there is resultant force.</u>

6.5 Newton's Second Law of Motion

Example 6.5.1

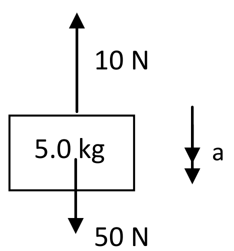
(a) F_{net} = ma = (0.120 kg)(0.60 m s^{-2}) = 0.072 N

(b) $a = \frac{F_{net}}{m} = \frac{4.0\,N}{2.5\,kg} = 1.6\ m\ s^{-2}$

(c) $m = \frac{F_{net}}{a} = \frac{0.32\,N}{9.8\,m\,s^{-2}}$ = 0.03265 kg (4 s.f.) ≈ 0.033 kg (rounded off to 2 s.f.)

Example 6.5.2

(a) Resultant force F_{net} = 50 N – 10 N = 40 N



(b) F_{net} = ma

$a = \frac{F_{net}}{m} = \frac{40\,N}{5.0\,kg} = 8.0\ m\ s^{-2}$

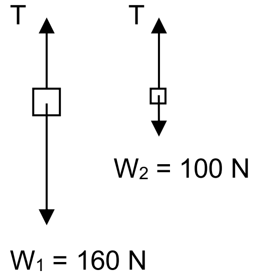
Exercises 6.5

6.5 Newton's Second Law of Motion

1. (a) 120 N (b) 80 N (c) 243 N (or 240 N: 2 sf)
   (d) 30 N, 50 N (e) 10 N, 50 N (f) 25 N, 50 N

2. (a) 150 N (b) 50 N (c) 100 N

3. Tension on both masses are equal (same string, frictionless pulley)
   16 kg mass will move down and 10 kg mass will move up.
   (same *acceleration* because they are connected by a string)



   On 16 kg mass: $160 - T = 16\,a$
   On 10 kg mass: $T - 100 = 10\,a$
   Solving for T, $1600 - 10T = 16\,(T - 100)$
   T = **<u>123 N</u>**
   Therefore, a = **<u>2.3 m s^{-2}</u>**

Terminal Velocity
Example 6.5.3

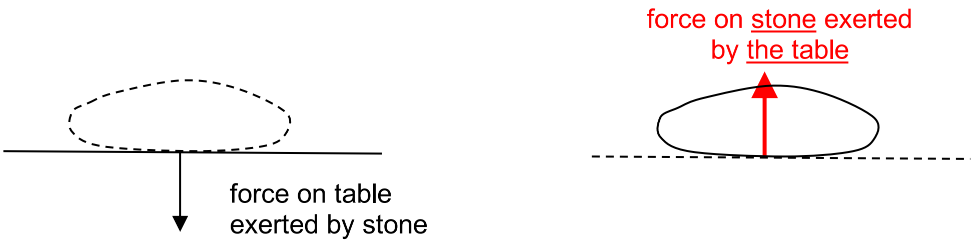
(a) (i) Net force = mg = 50 kg x 10 m s^{-2} = 500 N (air resistance is negligible)
Net acceleration = 10 m s^{-2}
(ii) Net force = mg – R = 500 N – 60 N = 440 N
Net acceleration = net force ÷ m = 440 N ÷ 50 kg = 8.8 m s^{-2}
(iii) Net force = mg – R = 500 N – 475 N = 25 N
Net acceleration = net force ÷ m = 25 N ÷ 50 kg = 0.5 m s^{-2}

(b) When acceleration is zero, net force = zero. Hence, air resistance = weight = 500 N

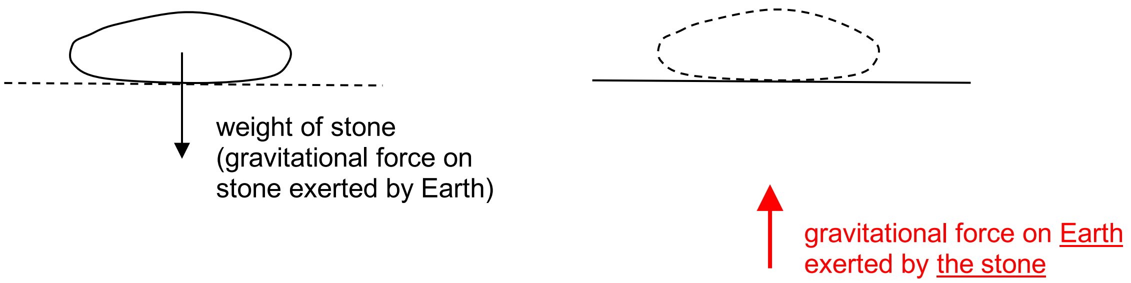
6.6 Newton's Third Law of Motion (Action & Reaction)

Example 6.6.1

(a)



(b)

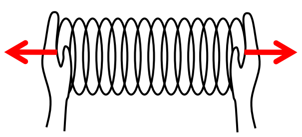


Therefore, two pairs of action-reaction forces are related to a stone that is at rest on the ground.

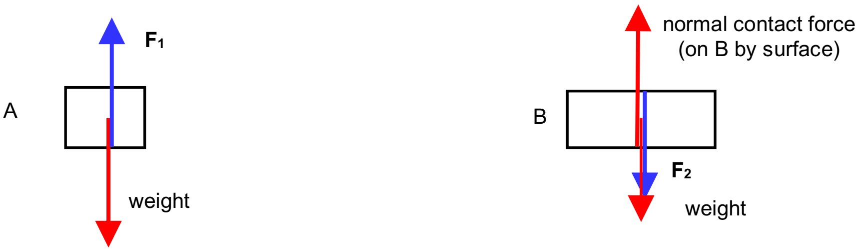
Exercise 6.6

6.6 Newton's Third Law of Motion

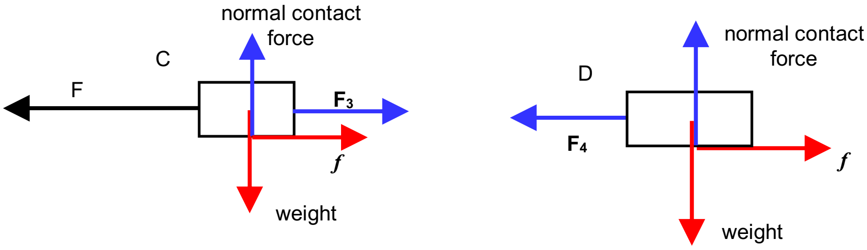
1.



2.



3.



4. (a) $F_{net} = ma$

$a = F \div m = 20\text{ N} \div (2.0\text{ kg} + 3.0\text{ kg}) = \underline{4.0\text{ m s}^{-2}}$

(b) For the 3.0 kg mass, $T = m\,a = 3.0\text{ kg} \times 4.0\text{ m s}^{-2} = \underline{12\text{ N}}$

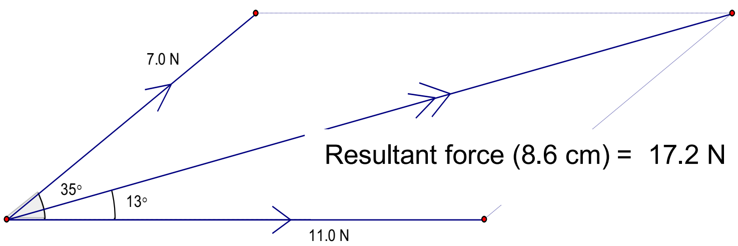
OR for the 2.0 kg mass, net force $= 20 - T = ma$; $T = 20\text{ N} - 2.0\text{ kg} \times 4.0\text{ m s}^{-2} = \underline{12\text{ N}}$

6.7 Vector Addition

6.7.1 Unbalanced forces (Resultant force)

Example 6.7.1

(a) Resultant force = 45 N + 20 N -15 N
= 50 N to the right.

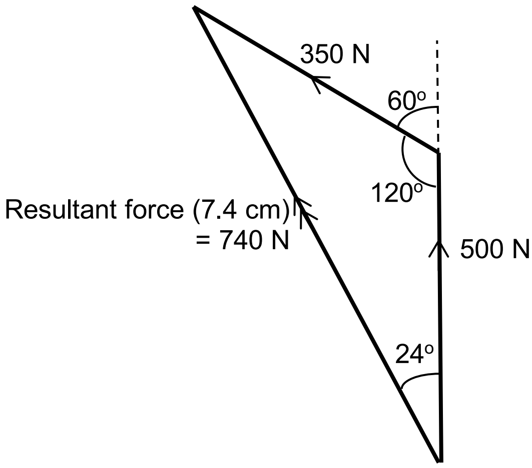


(b) Scale 1.0 cm represents <u>2.0 N</u>

Magnitude of the resultant force = <u>17.2 N</u>
direction of resultant force: <u>13°</u> anticlockwise from 11.0 N force

(c) Scale 1.0 cm represents <u>100 N</u>

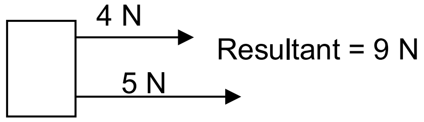
Magnitude of the resultant force = <u>740 N</u>
Its direction is <u>24° west of north</u>

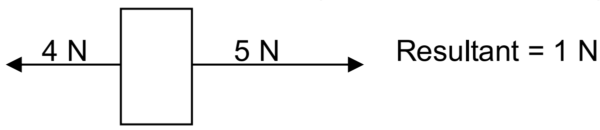


Exercise 6.7.1

6.7.1 Unbalance forces (Resultant force)

1. Maximum resultant (sum of forces)   Minimum resultant (difference of forces)

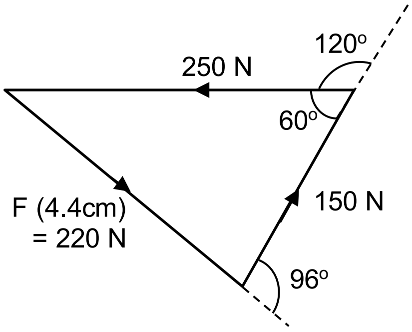




2. Resultant force = 8700 N (±100); Direction is 30° (±1°) anticlockwise from force Q.

6.7.2 Balanced forces (Object at equilibrium)

Example 6.7.2



Scale 1.0 cm represents 50 N

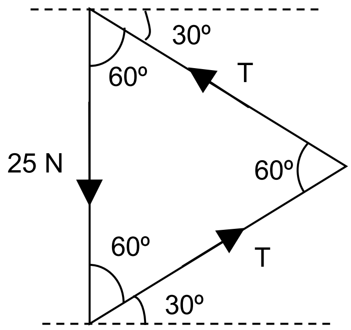
The magnitude of the third force F is 220 N and it acts 96° clockwise from the 150 N force.

6.7.3 Comparison of vector triangles

Question: *The resultant force R and the 3rd force F_3 are in opposite directions.*

Exercise 6.7.2

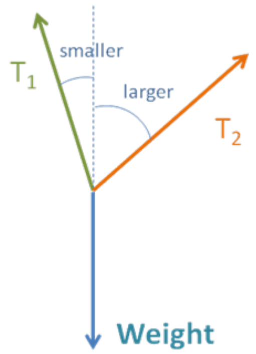
6.7.2 Balanced forces (Object at equilibrium)



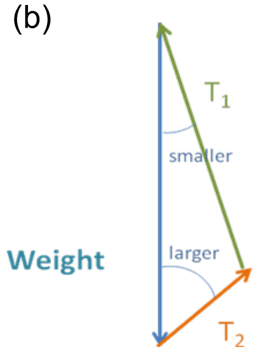
3. (a) (i) Scale: 1.0 cm represents 5.0 N
T (5.0 cm) = 25 N
(ii) Since vector triangle is an equilateral triangle,
T = 25 N.

(b) The tensions listed in order from highest to the lowest is T_3, T_1, T_2

4.
(a)



(b)



(c) T_1 is greater than T_2 as T_1 although T_1 has a shorter string than T_2. Therefore, a longer string does not imply a greater amount of tension.

(d) Since the angles are equal, the vector diagram for blocks A and B are the same! The tensions, T_1=T_3 and T_2=T_4. The tensions are dependent on the angles of inclination of the strings and not the length of the strings.

(e) No. The triangle has a horizontal side but the weight is vertical!

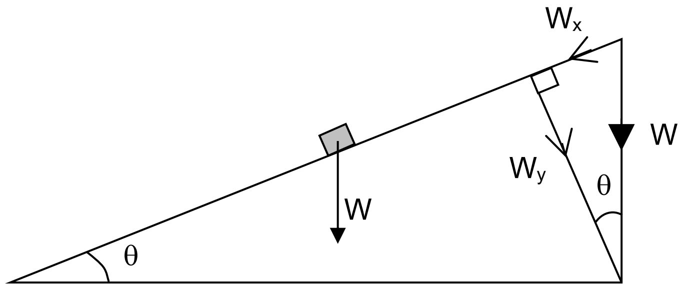
6.8 Vector Resolution of Forces

Example 6.8.1

(a) F_x = 320 cos 40° = 245 N

(b) F_y = 320 sin 40° = 206 N

Example 6.8.2
(a) W_x = W sin θ
(a) W_y = W cos θ



Question*: The original triangle has a horizontal side, but the weight is vertical!*

Example 6.8.3

QR_x = PQ = QR cos 30°
QR_y = 10 N = QR sin 30°

---> PQ/10 = cos 30°/ sin 30°
PQ = 10/ tan 30°
= 17.3
= 17 N (2 sf)

Exercise 6.8

6.8 Vector Resolution of Forces

1. (a) Horizontal component = 25 cos 40° = 19 N
   (b) Net force = horizontal component = 19 N = ma; ∴ a = 19 N ÷ 2.0 kg = $9.5\ m\ s^{-2}$

2. (a) Vertical component = 200 sin 40° = 129 N
   (b) This force is equal to the normal contact force N on the roller by the ground
   Vertical forces on the roller: upward force = downward force
   N + 129 = Weight
   Vertical force acting on the ground = N = Weight – 129 = 500 N – 129 N = 371N

   (c)(i) Consider the sum of the vertical forces (weight & normal contact force) as a side when drawing the vector triangle. The normal contact force would be larger.
   (ii) With a larger normal contact force, the roller would be more effective in flattening the ground.

3. Sum of horizontal components
   = 50 cos 40° + 30 sin 35° − 40 cos 25°
   = 19.25 N

   Sum of vertical components
   = 50 sin 40° + 40 sin 25° − 30 cos 35°
   = 24.46 N

   $R^2 = 19.25^2 + 24.46^2$
   R = 31.12
   = 31 N (2 sf)