

Forces: Chapter 4 and 5

Definition of Dynamics

Dynamics is the study of why an object moves.

In order to understand why objects move, we must first study forces.

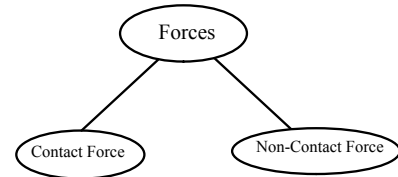
Forces

A **force** is defined as a push or a pull.

Forces are vector quantities - they have magnitude and direction.

In the last unit, the sum of all the forces acting on an object was referred to as the resultant force. **Net force**, F_{net} , is another term used for the vector sum of forces.

Oct 16-4:30 PM



- a force exerted by an object in direct contact with another object

- a force that acts over a distance

Examples

friction
tension
normal force
applied force

Examples

force of gravity
magnetic force
electric force

Feb 26-7:19 PM

Types of Forces

An object can experience many different forces simultaneously. Some of the more common forces are listed below.

F_g : gravitational force (force of **gravity**)
- this is an attractive force that acts over a distance between masses

NOTE: Weight is the force of gravity acting on an object.

$$\vec{F}_g = m\vec{g}$$

F_g -> Force of gravity or weight (N)
 m -> mass (kg)
 g -> acceleration due to gravity (m/s^2)

Oct 16-9:23 PM

PRACTICE PROBLEMS

Pg. 137 Date Pg 132/133

- Find the weight of a 2.3 kg bowling ball on Earth.
- You have a weight of 652.58 N[down] while standing on a spring scale on Earth near the equator.
 - Calculate your mass.
 - Determine your weight on Earth near the North Pole.
 - Determine your weight on the International Space Station. Why would this value be impossible to verify experimentally?
- The lunar roving vehicle (LRV) pictured here has a mass of 209 kg regardless of where it is, but its weight is much less on the surface of the Moon than on Earth. Calculate the LRV's weight on Earth and on the Moon.
- A 1.00 kg mass is used to determine the acceleration due to gravity of a distant, city-sized asteroid. Calculate the acceleration due to gravity if the mass has a weight of 3.25×10^{-2} N[down] on the surface of the asteroid.



Ans: Pg 958

Feb 27-8:20 PM

F_a : an **applied** force
- a push or pull you exert on an object

F_N : the **normal** force
- a force that acts perpendicular to the surface on which an object rests

NOTE: "normal" means perpendicular

F_f : the force of **friction**
- a force that opposes an object's motion

static frictional force (F_{fs}) - exists when you start to move an object from rest

kinetic frictional force (F_{fk}) - exists while an object is in motion

$F_f = \mu F_N$

F_f -> force of friction (N)
 μ -> coefficient of friction
 F_N -> normal force (N)

Table 4.8 Coefficients of Friction

Surfaces	Coefficient of Static Friction μ_s	Coefficient of Kinetic Friction μ_k
rubber on dry solid surfaces	1 - 4	1
rubber on dry concrete	1.00	0.80
rubber on wet concrete	0.70	0.50
glass on glass	0.94	0.40
steel on steel (unlubricated)	0.74	0.57
steel on steel (lubricated)	0.15	0.06
wood on wood	0.40	0.20
iron on iron	0.70	0.60
Teflon™ on steel in air	0.04	0.04
lubricated ball bearings	< 0.01	< 0.01
synovial joint in humans	0.01	0.003

F_T : **tension**
- the force that acts along a rope, wire, string, etc.

Feb 26-7:44 PM

Free-Body Diagrams

"Physics is all about simplification."

A **free-body diagram** (FBD) is a picture that shows ALL the forces acting on an object.


For the sake of simplicity, an object is usually represented by a dot and only the forces acting on the object are included on the diagram. The forces are represented by arrows.

When drawing FBDs, put the tail of the force vectors on the object, with the arrow pointing away from the object. NEVER draw a force vector pointing toward an object.


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Examples

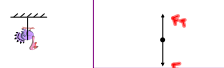
An apple rests on a desk.




A flower pot falls in the absence of air resistance.




A turkey is hung from the ceiling of a classroom.



A snail pushes a pumpkin across the floor at constant speed.



A car speeds up while traveling on a dirt road.



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Motion and Forces

When the net force on an object is zero, it is in a state of **equilibrium**. This means that the object is either at **rest** or moving at a **constant velocity**. It cannot be accelerating.

What determines an object's motion?
Why, the value of the net force of course!

Equilibrium: $F_{net} = 0N$ ** Very important*

object at rest object moving at constant velocity

If the net force does not equal zero, the object will accelerate at a constant rate!

NOTE

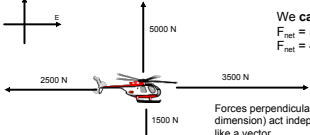
The object will accelerate in the direction of the net force.

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Net Force

The **net force** is the vector sum of all the forces acting on an object. Only forces acting in the same dimension (i.e. left and right or up and down) can be mathematically added (or subtracted).

Consider the four forces acting on the object below:



We cannot say the net force is:
 $F_{net} = 5000 - 1500 + 3500 - 2500$
 $F_{net} = 4500 N$

Forces perpendicular to each other (or in a different dimension) act independently on an object and must be added like a vector.

We can talk about the net force in each dimension:

$F_{net} [East] = 3500 N - 2500 N$ $F_{net} [North] = 5000 N - 1500 N$
 $F_{net} [E] = 1000 N$ $F_{net} [N] = 3500 N$


To find the actual net force on the object we would need to do a scale diagram with the vectors or a calculation (grade 12).

Often to identify which direction we are focusing on we use the subscripts x and y. Like in your math class, x - horizontal direction and y - vertical direction. Directions are all in the way your set up your problem for analysis - your frame of reference.

Oct 3-8:45 AM


the force of gravity on a ball is 10 N. An upward wind acts with 14 N. What is the net force on the ball?

$F_{net} = F_g + F_{wind}$
 $F_{net} = -10N + 14N$
 $F_{net} = 4N (up)$



The force applied to a car from the gas is 1575 N [E]. Air resistance acts with 1230 N [W]. What is the net force on the car?

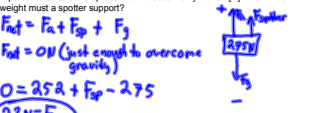
$F_{net} = F_a + F_{air}$
 $= 1575 - 1230$
 $F_{net} = 345 N$




Sep 12-1:48 PM

A person tries to bench press 275 N but can only lift 252 [N]. How much weight must a spotter support?

$F_{net} = F_a + F_{sp} + F_g$
 $F_{net} = 0N$ (just enough to overcome gravity)
 $0 = 252 + F_{sp} - 275$
 $23N = F_{sp}$



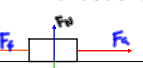
Two people are supplying forces on a 151 kg box sitting on the floor. One person pushes with 144 N [E] and the other pulls with 175 N [E]. What force would a third person need to apply to start the box moving if $\mu = 0.33$?



$F_{net} = 0N$ (not enough to overcome friction)
 $F_{net} = F_{a1} + F_{a2} + F_{a3} + F_f$
 $F_{a1} = 144 N, F_{a2} = 175 N, F_{a3} = ?; F_f = ?$
 $F_f = \mu F_N \rightarrow$ Normal Force = Force gravity, mg
 $F_f = \mu mg = (0.33)(151)(9.81)$
 $F_f = 489 N$
 So, use the F_{net} relation:
 $0 = 144 + 175 + F_{a3} - 489$
 $170 N = F_{a3}$ * Answer is positive so the direction is East.

Sep 12-1:54 PM

NOTE: The net force equation is applied to different dimensions independently.



A horizontal force of 85 N is required to pull a child in a sled at constant speed over dry snow to overcome the force of friction. The child and sled have a combined mass of 52 kg. Calculate the coefficient of kinetic friction between the sled and the snow. (0.17)

$F_{net} = F_a + F_f, F_{net} = 0$
 $F_f = \mu F_N$
 Find F_f :
 $0 = 85 + F_f \rightarrow -85 = F_f$
 Find F_N :
 $F_N = F_g = mg$
 $F_N = (52)(9.81) = 510 N$
 Find μ :
 $F_f = \mu F_N$
 $85 = \mu(510) \Rightarrow \mu = 0.17$

Always use magnitudes (positive)

Mar 14-10:52 PM

1. A 62 kg crate is pulled at a constant velocity with an applied force of 337 N.

- Calculate the force of friction.
- Calculate the normal force on the crate.
- Calculate the coefficient of kinetic friction.

a) $F_{net} = 0 \text{ N}$ (constant velocity)
 $F_{net} = F_a + F_f$ (only two forces acting in that direction)
 $0 = 337 + F_f$
 $-337 \text{ N} = F_f$

b) $F_N = F_g = mg$
 $F_N = (62 \text{ kg})(9.81 \text{ m/s}^2)$
 $F_N = 608 \text{ N}$

c) $F_f = \mu F_N$ ← always use + numbers
 $\mu = \frac{F_f}{F_N} = \frac{337}{608}$ $\mu = 0.55$

Oct 19-10:14 AM

2. A box has a weight of 625 N and is being pulled with a net force of 12 N. The coefficient of kinetic friction is 0.23.

- What is the mass of the box?
- What is the force of friction?
- What is the applied force?

a) $F_g = mg$
 $625 = m(9.81)$
 $63.7 \text{ kg} = m$

b) $F_f = \mu F_N$
 $F_N = F_g$
 So, $F_f = (0.23)(625)$
 $F_f = 144 \text{ N}$
 ↑ This is the magnitude of the force.

c) $F_{net} = F_a + F_f$
 $12 = F_a - 144$
 ↑ F_f always opposite motion of object.
 $156 \text{ N} = F_a$

Oct 19-10:16 AM

3. A box is being pulled across the floor at a constant velocity with an applied force of 284 N. The coefficient of kinetic friction is 0.11.

- What is the force of friction?
- What is the force of gravity on the box?
- What is the mass of the box?

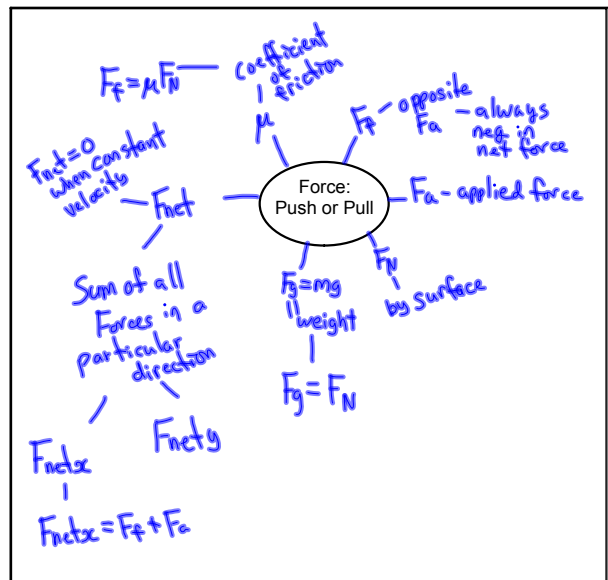
a) $F_{net} = 0 \text{ N}$ $F_{net} = F_a + F_f$
 $0 = 284 + F_f$
 $-284 \text{ N} = F_f$

b) $F_g = ?$ remember $F_g = F_N$
 So $F_f = \mu F_g$
 $284 = (0.11)F_g$ → $F_g = 2580 \text{ N}$

c) $m = ?$
 $F_g = mg$
 $2580 \text{ N} = m(9.81)$
 $263 \text{ kg} = m$

Force Practice: Worksheets #1 & #2

Oct 19-10:20 AM



Oct 19-10:12 AM

Forces Quiz

1.) A box has a weight of 150 N and is being pulled at a constant velocity. Calculate the applied force necessary if the coefficient of kinetic friction is 0.31.

2.) A 75 kg crate is being pulled an applied force of 205 N. The net horizontal force is 35 N. Calculate the coefficient of kinetic friction.

Oct 18-8:54 AM

Forces Quiz #2

1. A sled has a weight of 347 N and is being pulled with a net force of 29 N. The coefficient of kinetic friction is 0.36. What is the applied force?

2. A 50 kg box is moved with a net force of 46 N. The applied force necessary is 199 N. What is the coefficient of kinetic friction?

Oct 25-9:10 AM

Motion Equations

$$v_{avg} = \frac{d}{t}$$

$$d = v_0 t + \frac{1}{2} a t^2$$

$$v_{avg} = \frac{v_f + v_0}{2}$$

$$v_f^2 = v_0^2 + 2 a d$$

$$a = \frac{v_f - v_0}{t}$$

$$d = \text{displacement}$$

$$a = \text{acceleration}$$

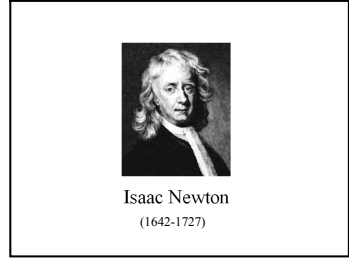
$$t = \text{time}$$

$$v_0 = \text{Initial velocity (speed)}$$

$$v_f = \text{Final velocity (speed)}$$

Aug 27-2:49 PM

Chapter 5 - Newton's Laws (Page 152)



Frames of Reference

1. inertial -> frame of reference in which Newton's laws are valid
-> frame of reference is at rest or has uniform motion
2. non-inertial -> frame of reference in which Newton's laws are not valid
-> frame of reference is accelerating uniformly

Oct 17-4:57 PM

Newton's First Law of Motion (The Law of Inertia)

An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

Objects keep on doing what they are doing.

The two parts of this law are summarized in the following diagram.

$F_{net} = 0 \text{ N}$

Forces are Balanced

Objects at Rest
($v = 0 \text{ m/s}$)

(vertically and horizontally)

Objects at Rest
($v = 0 \text{ m/s}$)

$a = 0 \text{ m/s}^2$

Stay at Rest

Objects in Motion
($v \neq 0 \text{ m/s}$)

Objects in Motion
($v \neq 0 \text{ m/s}$)

$a = 0 \text{ m/s}^2$

Stay in Motion
(same speed and dir'n)

Oct 17-8:52 PM

Newton's Second Law of Motion

Newton's second law can be formally stated as:

The acceleration of an object produced by a net force is:

- directly proportional to the magnitude of the net force
 $a \propto F_{net}$
- inversely proportional to the mass of the object
 $a \propto \frac{1}{m}$

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

F_{net} - net force (N)
 m - mass (kg)
 a - acceleration (m/s²)

Remember: The acceleration of an object has the same direction as the net force acting on the object.

Sample Problem

An object is accelerating at 2.0 m/s².

1. If the net force is tripled, what is the object's new acceleration?
 $a = \frac{F}{m}$, if $F \times 3$ then $a \times 3$
So $a = 6.0 \text{ m/s}^2$
2. If the net force is halved, what is the object's new acceleration?
 $F \times 2 \Rightarrow a \times 2$
 $a = 1.0 \text{ m/s}^2$
3. If the net force is halved and the mass is quadrupled, what is the object's new acceleration?
 $F \times \frac{1}{2}$ so $a \times \frac{1}{4}$
 $a = 0.5 \text{ m/s}^2$

Oct 18-11:01 PM

What is the acceleration of a 12 kg cart under a constant force of 88 N?

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

$$a = \frac{88 \text{ N}}{12 \text{ kg}}$$

$a = 7.3 \text{ m/s}^2$

A force of 1200 N accelerates an object at 21 m/s². What is the mass of the object?

$$F = ma$$

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

$$m = \frac{1200 \text{ N}}{21 \text{ m/s}^2} = 57 \text{ kg}$$

What average force is required to accelerate a 33 kg mass at 4.6 m/s²?

$$F = ma$$

$$F_{avg} = (33 \text{ kg})(4.6 \text{ m/s}^2)$$

$F_{avg} = 152 \text{ N}$

Sep 15-9:32 AM

An applied force of 50 N is used to accelerate an object to the right across a frictional surface. The object encounters 10 N of friction. The weight of the object is 80 N.

(a) Calculate the object's mass. (8.2 kg)
(b) Calculate the net force. (40 N to the right)
(c) Calculate the object's acceleration. (4.9 m/s² to the right)

(a) $F_g = 80 \text{ N} = mg$
 $80 = m(9.81)$
 $m = 8.2 \text{ kg}$

(b) $F_{net} = F_a + F_f$
 $F_{net} = 50 - 10$
 $F_{net} = 40 \text{ N}$

(c) $F = ma$
 $a = \frac{F}{m} = \frac{40}{8.2} = 4.9 \text{ m/s}^2$

Oct 18-11:00 PM

A 2.5 kg object falls on an air mattress. Just as it hit it was travelling 19 m/s. The air mattress depressed 0.75 m before coming to a stop. What was the average force stopping the object?

** Choose coordinate system: up +, down -*

Known variables:
 $m = 2.5 \text{ kg}$
 $v_i = -19 \text{ m/s}$ (downward)
 $v_f = 0 \text{ m/s}$ (stopped)
 $d = -0.75 \text{ m}$ (downward)
 $g = -9.8 \text{ m/s}^2$

Wanted:
 $F_{\text{avg}} = ?$

$F = ma$

* Check motion formulas: $v_f^2 = v_i^2 + 2ad$

Solving for acceleration:
 $(0)^2 = (-19)^2 + 2a(-0.75)$
 $0 = 361 - 1.5a$
 $-361 = -1.5a$
 $240.67 = a$ extreme acceleration, person probably died :c

↑ positive (directed upwards) on tension

$F_{\text{avg}} = ma$
 $F_{\text{avg}} = (2.5)(241)$
 $F_{\text{avg}} = 603 \text{ N}$ *Positive (upwards)*

Sep 15-9:38 AM

Newton's Third Law of Motion
 "For every action there is an equal and opposite reaction."
 "Forces come in equal and opposite reaction pairs."

If object A exerts a force on object B, then object B will exert an equal but opposite force on object A.

Examples

If I push down on the Earth, the Earth pushes up on me.

If a hockey stick applies a force to the puck, the puck applies the same amount of force back on the stick.

One of the most important conceptual questions of physics is:
 "If each action force causes an equal but opposite reaction force, then how can anything ever accelerate?"

Horse and Cart Scenario

force of cart on horse force of horse on cart

Each force acts on a different body. The forces don't cancel each other.

force of cart on horse force of horse on cart

force of ground on horse force of horse on ground

Oct 22-7:59 PM

Practice Questions:
 Pg 163 #s 1 - 3.
 Pg 168 #s 4 - 8.
 Pg 170 #s 9 - 10, 13.
 Pg 186 #s 21 - 23.

**Newton's Laws
 Handouts #1 & #2**

Mar 16-10:15 AM

Force Problems Involving Two Objects

Atwood's Machine

Chapter 10 - Page 478

Fletcher's Trolley

Chapter 10 - Page 485

Mar 11-3:27 PM

Atwood's Machine

Examples

1. Two masses are attached to a lightweight cord that passes over a frictionless pulley as shown in the diagram below. The mass of M_1 is 3.0 kg and the mass of M_2 is 4.0 kg.

- Draw an FBD for each mass.
- What is the magnitude and direction of the acceleration of the larger mass? 1.4 m/s^2 , up
- What is the magnitude of the tension in the cord? 34 N

Mar 20-8:13 PM

2. Two masses are attached to a lightweight cord that passes over a frictionless pulley as shown in the diagram below. The mass of M_1 is 7.0 kg and the mass of M_2 is 3.0 kg.

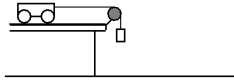
- Draw an FBD for each mass.
- What is the magnitude and direction of the acceleration of the larger mass? 2.3 m/s^2 , down
- What is the magnitude of the tension in the cord? 60 N

Textbook: Page 485, #19-21 (C10)

Mar 20-9:01 PM

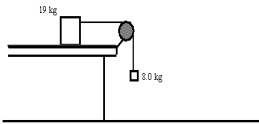
Fletcher's Trolley

A Fletcher's trolley apparatus consists of a cart on a level track attached to a light string passing over a pulley and holding a mass suspended in the air.



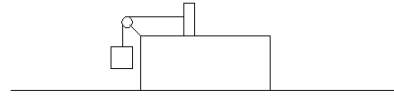
Examples

1. A 19 kg mass is accelerated along a frictionless table by an 8.0 kg mass hanging from the table as shown in the diagram below. What is the magnitude and direction of the acceleration of the mass along the frictionless table? The acceleration of the 19 kg mass is 2.9 m/s^2 , to the right.



Mar 20-8:17 PM

2. A 4.2 kg block is attached to a suspended mass of 6500 g by a string that passes over a pulley. If friction is not a factor, determine the magnitude and direction of the acceleration of the 4.2 kg block when the mass is released. Include an FBD for the 4.2 kg block and net force equations for each object. (-6.0 m/s^2)



Textbook: Page 488, #24, 25, 26

Mar 21-8:58 PM