Forces: Chapter 3 of Text

Definition of Dynamics

Dynamics is the study of why an object moves.

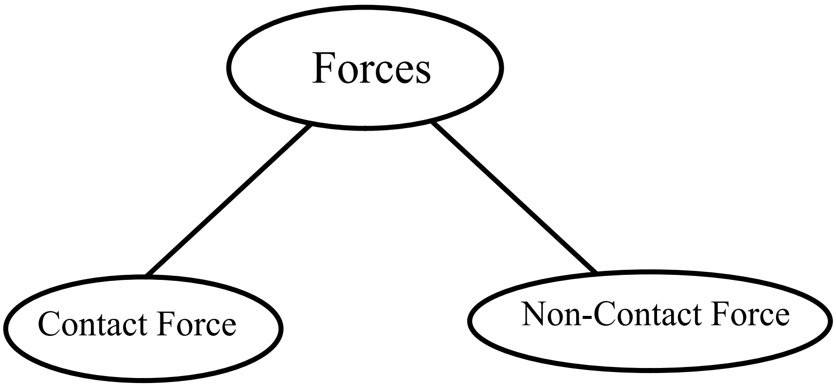
In order to understand why objects move, we must first study forces.

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. **N*et force***, $\mathbf{F}_{net}$, is another term used for the vector sum of forces.



Contact Force

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

Examples

friction
tension
normal force
applied force

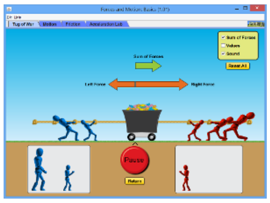
Non-Contact Force

- a force that acts over a distance

Examples

force of gravity
magnetic force
electric force

Types of Forces



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

$\vec{F}_g$: 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.

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

Unit is N, Newton

9.81 m/s² on avg. on Earth

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

Table 4.3 Free-Fall Accelerations Due to Gravity on Earth

Location	Acceleration due to gravity (m/s^2)	Altitude (m)	Distance from Earth's centre (km)
North Pole	9.8322	0 (sea level)	6357
equator	9.7805	0 (sea level)	6378
Mt. Everest (peak)	9.7647	8850	6387
Mariana Ocean Trench* (bottom)	9.8331	11 034 (below sea level)	6367
International Space Station*	9.0795	250 000	6628

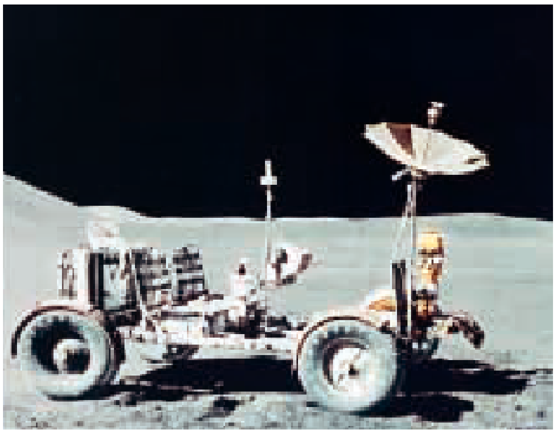
*These values are calculated.

Table 4.4 Free-Fall Accelerations Due to Gravity in the Solar System

Location	Acceleration due to gravity (m/s^2)
Earth	9.81
Moon	1.64
Mars	3.72
Jupiter	25.9

PRACTICE PROBLEMS

1. Find the weight of a 2.3 kg bowling ball on Earth.
2. You have a weight of 652.58 N[down] while standing on a spring scale on Earth near the equator.
   (a) Calculate your mass.
   (b) Determine your weight on Earth near the North Pole.
   (c) Determine your weight on the International Space Station. Why would this value be impossible to verify experimentally?
3. 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.
4. 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.



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1. Weight $\Rightarrow F_g$

$$F_g = mg$$

$m = 2.3\ kg$

$g = 9.81\ m/s^2$

$$F_g = (2.3)(9.81)$$

$$= 22.6\ N$$

2 a) $m = ?$

$F_g = 652.58\ N$

$g = 9.7805\ m/s^2$

$m = ?$

$F_g = mg$

$652.58 = m(9.7805)$

$66.7\ kg = m$

b) $F_g = ?$ @ North pole

$g = 9.8322\ m/s^2$

$m = 66.7\ kg$

$F_g = mg$

$= (66.7)(9.8322)$

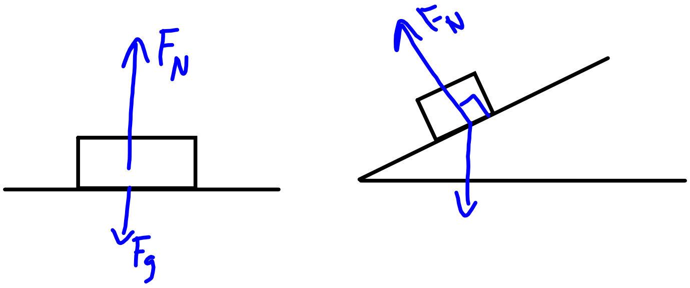
$F_g = 656\ N$

#2c, 3, 4
Pg 18 of
Prob. Set

$\vec{F}_a$: an ***applied*** force
- a push or pull you exert on an object

$\vec{F}_N$: the ***normal*** force
- a force that acts perpendicular to the surface on which an object rests

NOTE: "normal" means perpendicular



$\vec{F}_f$: 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)

$F_f = \mu mg$

Table 4.5 Coefficients of Friction

140 MHR • Unit 2 Dynamics

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
ice on ice	0.10	0.03
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.

Free-Body Diagrams

"***Physics is all about simplification***."

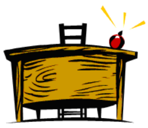
A ***free-body diagram*** (FBD) is a picture that shows ALL the forces acting on an object.

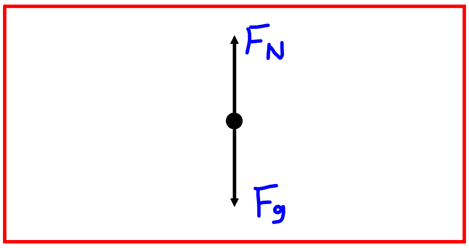
For the sake of simplicity, an object is usually represented by a dot and only the forces acting on the object are included on the diagram. The forces are represented by arrows.

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.

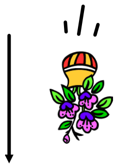
Examples:

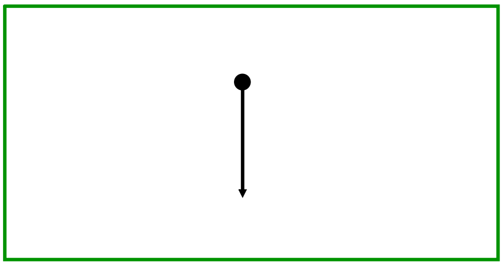
An ***apple*** rests on a desk.



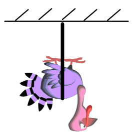


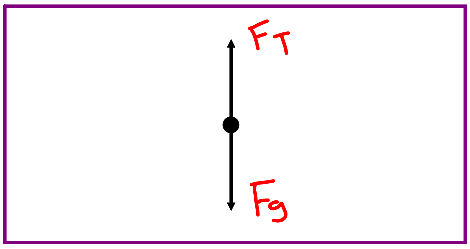
A ***flower pot*** falls in the absence of air resistance.





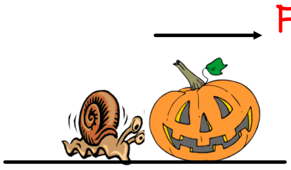
A ***turkey*** is hung from the ceiling of a classroom.

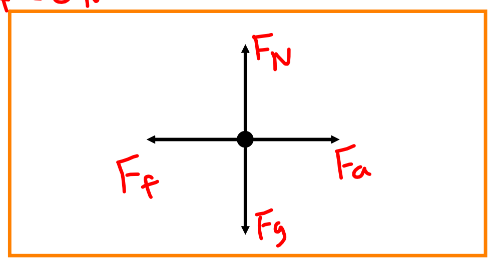




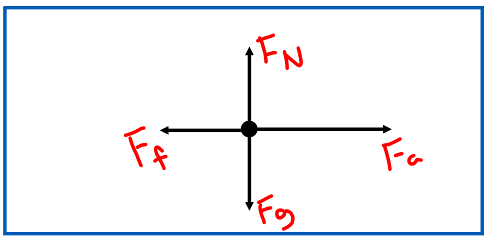
A snail pushes a ***pumpkin*** across the floor at constant speed.

$F_{net} = 0\ N$





A *car* speeds up while traveling on a dirt road.



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 : $\vec{F}_{net} = 0N$

* Very important

object at rest

object moving at constant velocity

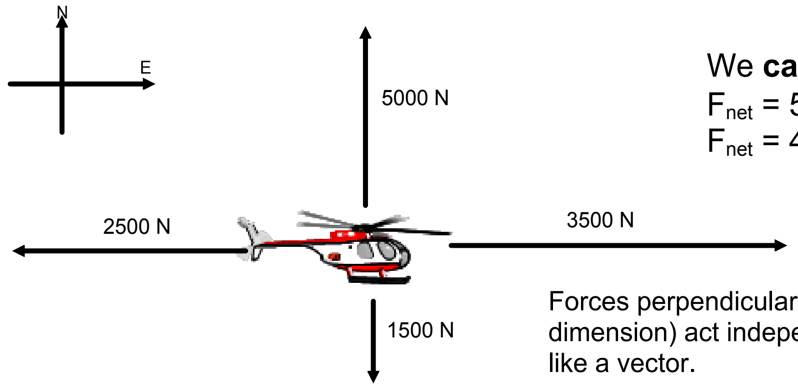
If the net force does not equal zero, the object will accelerate at a constant rate!

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

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} [E] = 1000 N

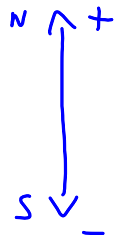
F_{net} [North] = 5000 N - 1500 N
F_{net} [N] = 3500 N

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.

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?

$F_{net} = F_g + F_{wind}$



$F_{net} = -10 N + 14 N$

$F_{net} = 4 N$ (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?

$F_{net} = F_a + F_{air}$

$= 1575 - 1230$

$F_{net} = 345 N$

•

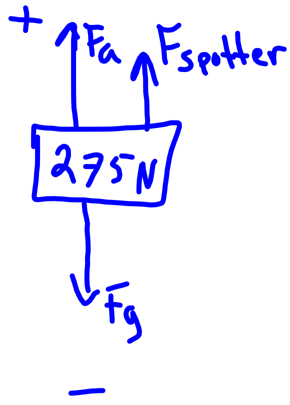
A person tries to bench press 275 N but can only lift 252 [N]. How much weight must a spotter support?

$F_{net} = F_a + F_{sp} + F_g$

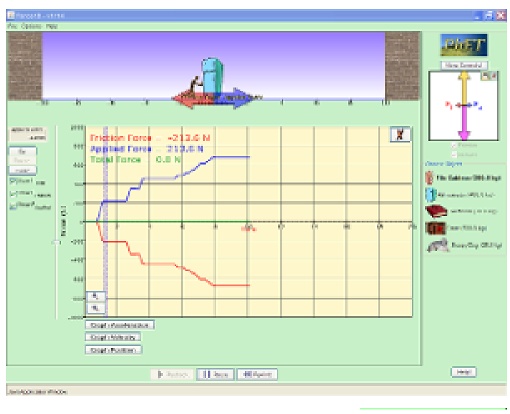
$F_{net} = 0\,N$ (just enough to overcome gravity)

$0 = 252 + F_{sp} - 275$

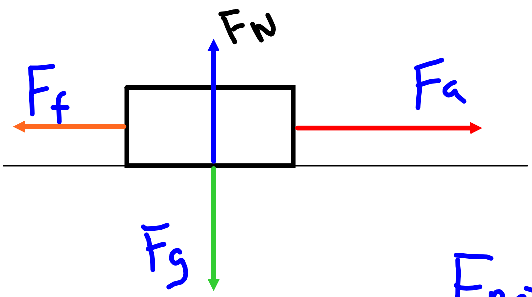
$23\,N = F_{sp}$



Forces in 1 Dimension



<u>NOTE</u>: 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:

$F_N = F_g = mg$

$F_N = (52)(9.81) = 510\ N$

<u>Find μ</u>

$F_f = \mu F_N$

$85 = \mu(510) \Rightarrow \mu = 0.17$

Always use magnitudes (positive) numbers with this formula.

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

a. Calculate the force of friction.

b. Calculate the normal force on the crate.

c. Calculate the coefficient of kinetic friction.

a) $F_{net} = 0\ N$ (constant velocity)

$F_{net} = F_a + F_f$ (only two forces acting in that direction)

$0 = 337 + F_f$

$-337\ N = F_f$

b) $F_N = F_g = mg$

$F_N = (62\ kg)(9.81\ m/s^2)$

$F_N = 608\ N$

c) $F_f = \mu F_N$ ← always use + numbers

$\mu = \frac{F_f}{F_N} = \frac{337}{608}$

$\mu = 0.55$

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.

a. What is the mass of the box?

b. What is the force of friction?

c. 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.

$156\text{ N} = F_a$

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.

a. What is the force of friction?

b. What is the force of gravity on the box?

c. What is the mass of the box?

a) $F_{net} = 0\,N$ $F_{net} = F_a + F_f$

$0 = 284 + F_f$

$-284\,N = F_f$

b) $F_g = ?$ remember $F_g = F_N$

So $F_f = \mu F_g$

$284 = (0.11) F_g$ → $F_g = 2580\,N$

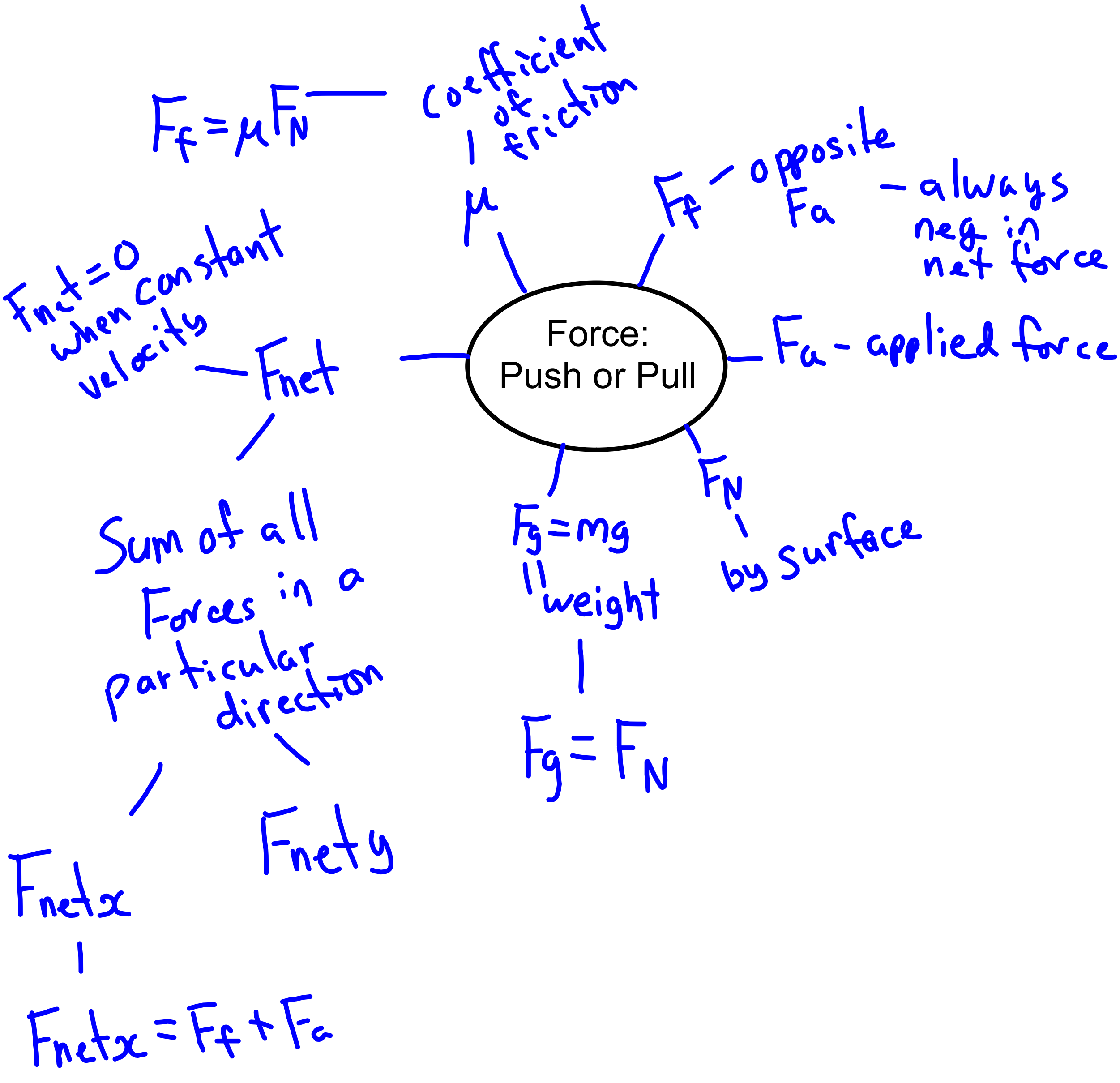
c) $m = ?$

$F_g = mg$

$2580\,N = m(9.81)$

$263\,Kg = m$

Force Practice:
Worksheets #1 & #2


Force: Push or Pull
$F_f = \mu F_N$ — coefficient of friction
μ
F_f - opposite F_a - always neg in net force
F_a - applied force
F_N
by surface
$F_g = mg$
weight
$F_g = F_N$
F_{net}
$F_{net} = 0$ when constant velocity
Sum of all Forces in a particular direction
$F_{net\,x}$
$F_{net\,y}$
$F_{net\,x} = F_f + F_a$