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

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

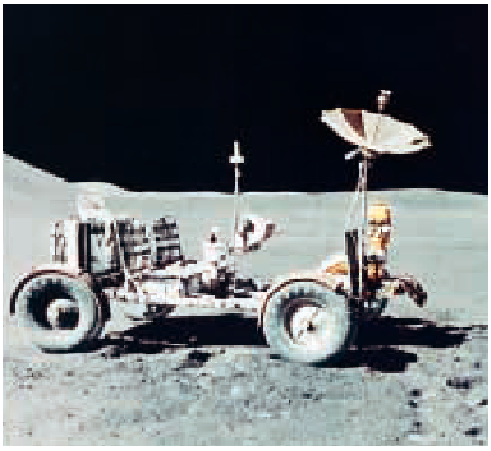
NOTE: Weight is the force of gravity acting on an object.

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

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

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.



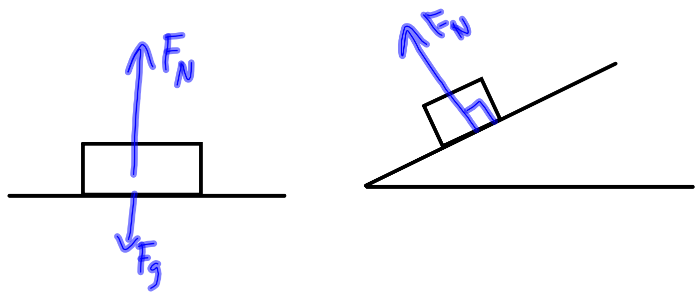
$\vec{F}_a$: an ***applied*** force

- 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)

140 MHR • Unit 2 Dynamics

Table 4.5 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
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

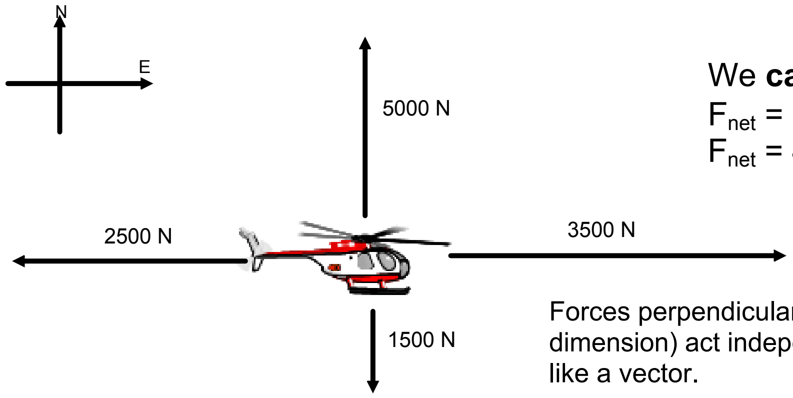
F_T : ***tension***

- the force that acts along a rope, wire, string, etc.

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).

Free-Body Diagrams

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

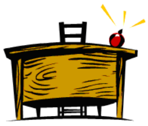
A ***free-body diagram*** (FBD) is a picture that shows ALL the forces acting on an object.

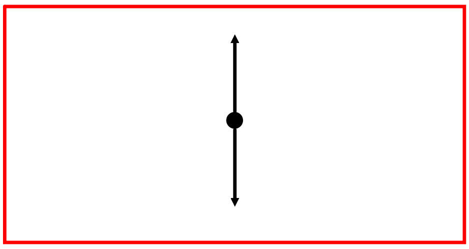
For the sake of simplicity, an object is usually represented by a dot and only the forces acting on the object are included on the diagram. The forces are represented by arrows.

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.

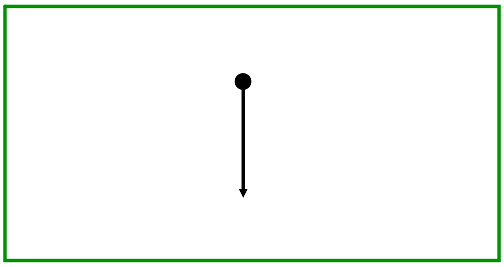
Examples:

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

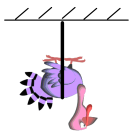


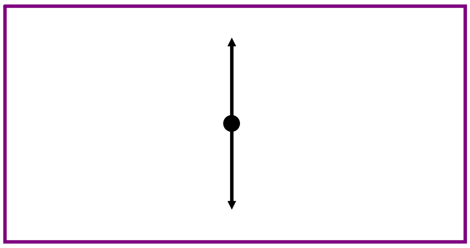


A ***flower pot*** falls in the absence of air resistance.

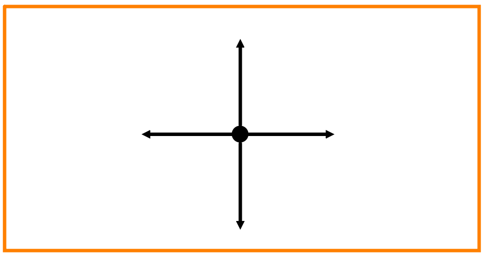


A ***turkey*** is hung from the ceiling of a classroom.

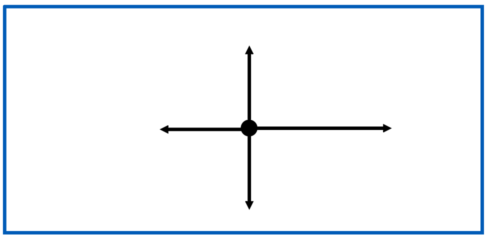




A snail pushes a ***pumpkin*** across the floor at constant speed.



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



Motion and Forces

In grade 10/11, an object was either:
- at rest
- moving at a constant velocity
- accelerating at a uniform rate

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

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

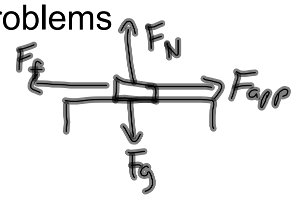
The object will accelerate in the direction of the net force.

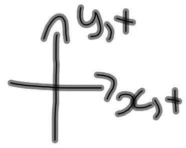
PRACTICE PROBLEMS

5. A friend pushes a 600 g (6.00×10^2 g) textbook along a lab bench at constant velocity with 3.50 N of force.
   (a) Determine the normal force supporting the textbook.
   (b) Calculate the force of friction and coefficient of friction between the book and the bench.
   (c) Which coefficient of friction have you found, μ_s or μ_k?
6. A 125 kg crate full of produce is to be slid across a barn floor.
   (a) Calculate the normal force supporting the crate.
   (b) Calculate the minimum force required to start the crate moving if the coefficient of static friction between the crate and the floor is 0.430.
   (c) Calculate the minimum force required to start the crate moving if half of the mass is removed from the crate before attempting to slide it.
7. Avalanches often result when the top layer of a snow pack behaves like a piece of glass, and begins sliding over the underneath layer. Calculate the force of static friction between two layers of horizontal ice on the top of Mount Everest, if the top layer has a mass of 2.00×10^2 kg. (Refer to Table 4.5 for the coefficient of friction.)

Friction Practice Problems

5) a) $F_N = ?$





$F_{net\,y} = ?$

$F_{net\,y} = 0$ (no motion up or down)

$F_{net\,y} = F_g + F_N$ (sum of all y-dir forces)

$0 = -(0.6\,kg)(9.81) + F_N$

↑ gravity acts down

$0 = -5.89\,N + F_N$

$\boxed{5.89\,N = F_N}$

b) $F_f = ?$
$\mu = ?$

$F_{net\,x}$ = Sum of all x-direction forces

$F_{net\,x} = F_f + F_{app}$

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

$F_{app} = 3.50\,N$

$0 = F_f + 3.50$

$\boxed{-3.50\,N = F_f}$

$\mu = ?$ $\quad F_f = \mu F_N$ (use all positive numbers)

← use magnitudes

$3.50 = \mu(5.89)$

$\frac{3.50\,N}{5.89\,N} = \mu$

$\boxed{0.594 = \mu}$

c) $\mu_{kinetic}$ friction

- book is moving