Unit Two - Chapter Three - Forces

Learning Goal: By the end of this section, I will be able to recognize the forces acting on an object and draw a free body diagram of the forces.

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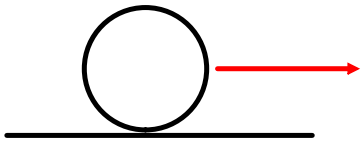
Section 3.1 - Types of Forces

Dynamics is the study of the causes of motion.

In its most basic sense, a **FORCE** can be considered a PUSH or PULL that acts on an object.

Sometimes we can see how the forces is applied, ie a rope tied to wagon, but most times we cannot actually SEE the force, yet we can feel it.

We use vector diagrams to represent forces that act on objects.



Force on a ball

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Units of Measure

The unit of measure for force in the Metric systems is called a NEWTON (N), after the scientist who did a great of work in this field of study. It is a derived unit, which means it is a mathematically created and calculated unit of measure.

$1\ N = 1\ \frac{kg \cdot m}{s^2}$

It is equal to the force that would give a mass of one kilogram an acceleration of one meter per second per second.

The force required to hold (resist gravity) a small apple (100g) is about 1 N.

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The unit of measure for force in the Imperial System is called the pound (lb). It has its roots dating back to the Roman libra, hence the symbol.

Avoirdupois pound

The **avoirdupois pound** was invented by London merchants in 1303. Originally it was based on independent standards. During the reign of Henry VIII of England, the avoirdupois pound was redefined as 7,000 troy grains. Since then, the grain has often been considered as a part of the avoirdupois system. By 1758, two standard weights for the avoirdupois pound existed, and when measured in troy grains they were found to be of 7,002 grains and 6,999 grains.

A **grain** is a unit of measurement of mass that is based upon the mass of a single seed of a cereal. In medieval times the average masses of wheat and barley grain were used to define units of mass, with the troy grain based on barley. The grain is the only unit of mass measure common to the three traditional English mass and weight systems (avoirdupois, Apothecaries', troy); the obsolete Tower grain was lighter than the troy grain.

There are precisely 7,000 grains per avoirdupois pound in the Imperial and U.S. customary units, and 5,760 grains in the Troy pound.

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To measure the force acting on an object, one tool we can use is a Newton spring scale. For the next example we will measure the force of gravity acting on a hanging mass.

One side measures grams (g) or kilograms (kg), and the other measures Newtons (N).

A scale you use to measure the weight of a fish is the exact same thing.

Hanging mass

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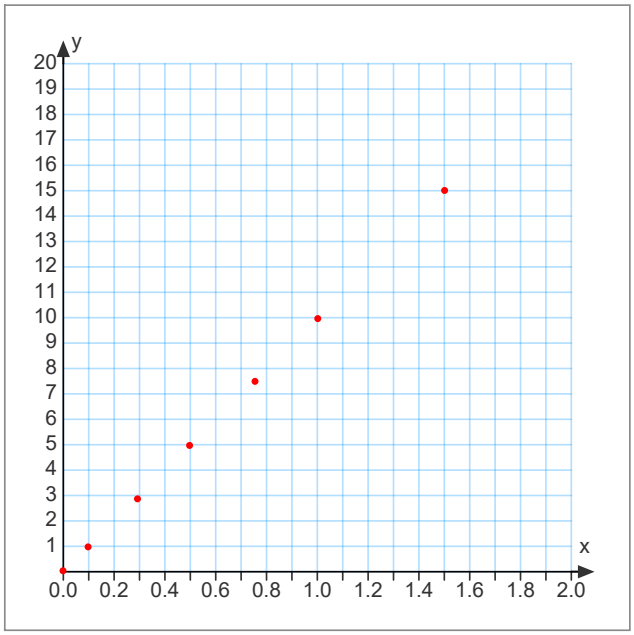
Masses measured with spring scale

Mass (kg)	Force (N)
1.5	15
1.0	10
0.75	7.5
0.5	5
0.3	3
0.1	1
0	0



Find the equation of the line.

Find the slope of the line; what units would the slope have?

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The FORCE of Gravity

The force of gravity is given by the expression: $F_G = m \cdot g$

where "m" is the mass of the object in kilograms, and "g" is the acceleration due to gravity (9.8 m/s^2)

Example

A 70kg wrestler has a gravitational weight of _____ (N)

Example

A truck pulls up onto a weight station scale and has a weight of 20,000N.

What is the mass of the truck?

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Newton and Pounds - Connecting the Two

It is sometimes necessary to move between the two systems of measurement.

1 pound force = 4.45 newtons

Example

What is the weight in Newtons of a 200lb human?

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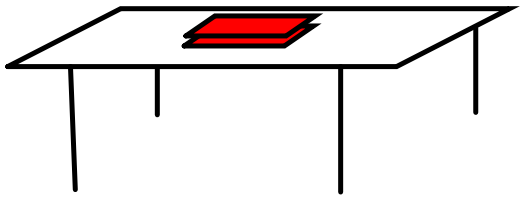
What forces are acting on this book resting on the table?

What forces are acting on this book as I push it across the table?



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Applied Force (F_a)
- a force that results when one object makes contact with another and pushes or pulls on it

Tension Force (F_T)
- a pulling force from a rope or string on an object that always points toward the rope or string

Normal Force (F_N)
- a perpendicular force exerted by a surface on an object in contact with the surface; the normal force always points away from the surface

Friction Force (F_f)
- opposes the sliding of two surfaces across one another; friction acts opposite to the motion or attempted motion

Free-Body Diagram (FBD)
-a simple drawing of an object showing all the forces that are acting on it

Watch the subscripts - they are important for communication

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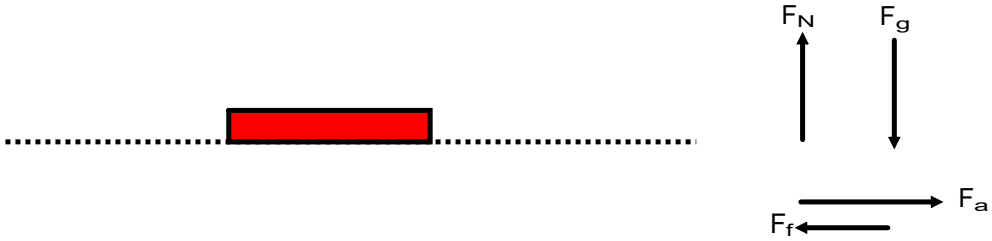
Draw the Free Body Diagram for the forces acting on this book at rest on the table?

Draw the Free Body Diagram for the forces acting on the book as I push it across the table?



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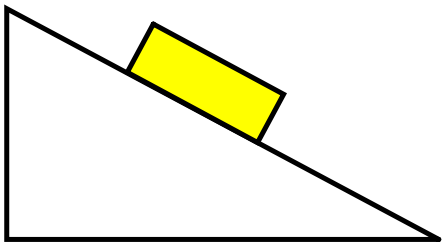
What would the free body diagram look like for a book resting (not moving) on a ramp?



If the book is sliding (moving) down the ramp, there must be an unbalanced force in the system. Where might that unbalanced force come from?

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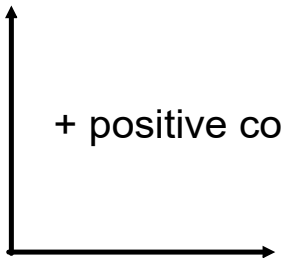
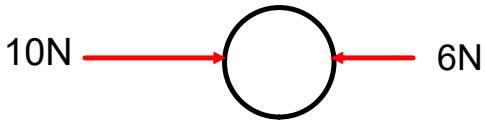
The NET Force (F_{Net}) is the sum of all the forces acting on an object.

To sum the net forces on an object, we will continue to use the same positive direction convention previously discussed, also, we will continue to break up vectors into their respective x and y components.





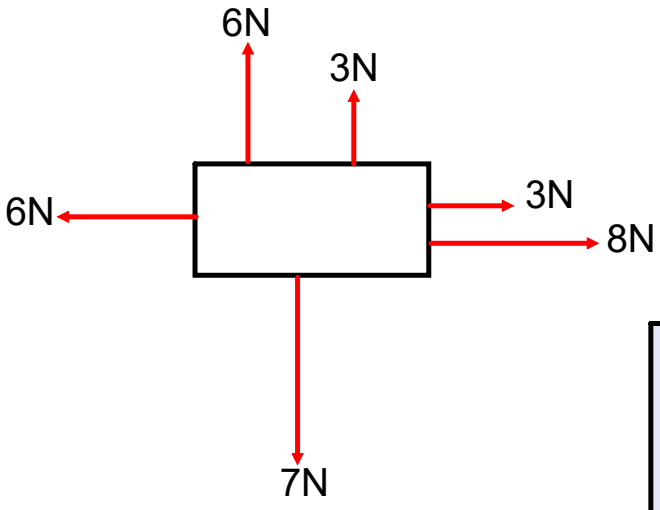
$F_{Net} = 10 - 6$

$= 4\ N$

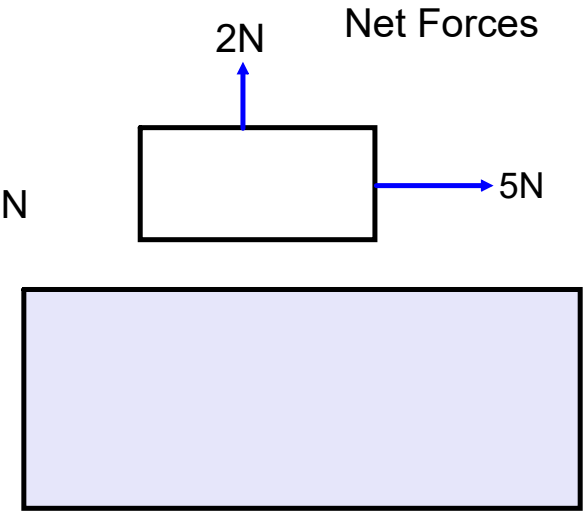
Note: F_N (normal) and F_{Net} (Net) are VERY DIFFERENT

The Net Force on an object is what the object "feels". The object doesn't know how many forces are acting on it, it just knows what the Net (total) force is.

What is the Net Force on the object below?



Net Forces

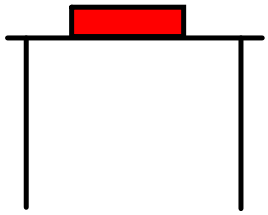


Grade 11 - forces will be one restricted to one dimension

Grade 12 - forces will expand to two dimensions

Find the NET Force acting on the 5 kg book*resting* on the table?

1. Draw FBD



2. Determine the force of gravity.

3. Determine the Normal Force.

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(Pause and try)

Practice

1. Calculate the net force when each set of forces acts on the same object.
Draw an FBD for each object.
(a) 5.5 N [W], 3.4 N [W], 4.2 N [E]
(b) 92 N [up], 35 N [down], 24 N [down]
(c) 15 N [up], 15 N [down], 35 N [E], 12 N [W]

2. A chain exerts a force of 1200 N [up] on a beam which experiences a force of gravity of 1100 N [down]. Draw the FBD of the beam and determine the net force on the beam.

3. You push a book across a table to your friend with a force of 6.5 N [E]. The force of friction on the book is 4.5 N [W]. The normal force and the force of gravity have a magnitude of 7.5 N. Draw the FBD of the book and calculate the net force on the book.

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The Four Fundamental Forces

Table 1 Comparing the Fundamental Forces

Type of force	Approximate relative strength	Range	Effect
gravitational	1	infinite	attract only
electromagnetic	10^{20}	infinite	attract and repel
strong nuclear	10^{38}	less than 10^{-15} m	attract and repel
weak nuclear	10^{25}	less than 10^{-18} m	attract and repel

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3.1 Questions

1. Assume that you are sitting at your desk facing north with a book on the desk directly in front of you. K/U
   (a) If you push on the side of the book that is closest to you, in which direction is the applied force?
   (b) If you pull on the side of the book that is closest to you, in which direction is the applied force?
2. Name the force or forces that cause these objects to experience changes in motion. Neglect air resistance. K/U
   (a) A ball falls toward the ground.
   (b) A person accelerates up in an elevator.
   (c) A car gradually slows down while approaching a red light.
3. A student forgets to zero the force sensor before performing an investigation. What effect, if any, will this have on the data collected during the investigation? T/I
4. Some everyday forces are gravity, tension, friction, an applied force, and the normal force. It is important that you be able to determine the direction of each of these forces when drawing an FBD. Create a table or a graphic organizer to help you remember the direction of these forces. K/U
5. Draw both the system diagram and the FBD for each object in italics. K/U C
   (a) A *car* is parked on the road.
   (b) A small *fish* is hanging from a fishing line.
   (c) A *football* is falling toward a player.
   (d) A *puck* is being pushed forward across the ice by a hockey stick.
6. Create a poster to teach students about common everyday forces. Include at least two system diagrams in your poster and the corresponding FBDs. You may include several everyday forces in your poster or concentrate on just one. K/U C
7. Determine the force of gravity acting on each object. T/I C
   (a) A 2.0 kg object falls straight down.
   (b) A 62 kg person stands on the floor.
8. Your teacher says, "Any applied force can also be called a normal force." Discuss the validity of this statement. K/U C
9. You tie a long string to a cart on the ground. Explain why you can only pull the cart forward but cannot push the cart away with the string. Draw diagrams to help explain your answer. K/U C
10. Describe the main difference between contact forces and action-at-a-distance forces. What implication does this difference have when drawing an FBD? K/U C
11. Explain the difference between system diagrams and FBDs. Describe why both are used to solve force problems. K/U C
12. For a physics project, you are given a small block of wood, a paper clip, some masking tape, a balloon, a magnet, and an elastic band. The objective is to move the block from one end of a long hallway to the other in the least amount of time using only the materials listed, without touching the wood directly. Draw a system diagram showing how you would complete the task. Draw an FBD of the block of wood. Include a brief description of what you would do. T/I C
13. Examine **Figure 8**, showing a spider in a web. The web is currently under construction and consists of only a few fine strands. Draw the FBD of the spider. T/I C

Figure 8

14. A doctor states, "The bones in the human arm can exert forces that can either push or pull other objects. The muscles are made of small fibres and can only cause tension forces." C A
   (a) What does the doctor mean when he says muscles can only cause tension forces?
   (b) Why can bones both push and pull whereas muscles cannot?
15. Calculate the net force when each set of forces acts on a single object. T/I
   (a) 56 N [up], 35 N [down]
   (b) 12.3 N [right], 14.4 N [right], 32.7 N [left]
   (c) 45 N [up], 45 N [down], 21 N [W], 21 N [E]
16. (a) List the four fundamental forces from weakest to strongest.
   (b) Describe two ways that gravity is different from the other three fundamental forces.
   (c) Explain why friction and tension are not fundamental forces. K/U C

Section 3.1

#2, 5, 7, 15

(try more if you like)

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