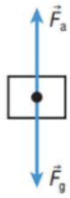
SPH3U: 3.1 Types of Forces

1. Measuring forces and force diagrams

Dynamics:	the study of the causes of motion
force	any push or pull.
newton (N)	unit for force. $1 N = 1 kg \cdot m/s^2$
measuring forces	spring scales or force sensors.
① system diagrams	a simple sketch of all objects in a situation.
② free-body diagrams (FBDs)	a simple drawing of one object showing all forces acting on it.

① System diagram

② FBD

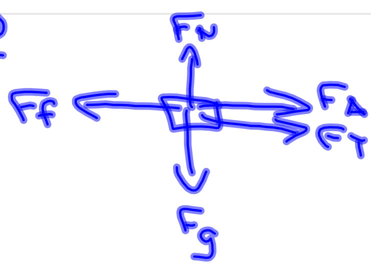


2. Everyday forces

$\vec{F}_a$	Applied force:	a force caused by an object pushing or pulling.
$\vec{F}_T$	Tension:	a rope or string pulling on an object.
$\vec{F}_N$	Normal force:	when a surface pushes back on an object. $\vec{F}_N$ is always perpendicular to the surface.
$\vec{F}_f$	Friction:	always tries to stop motion. acts in the opposite direction of motion.
$\vec{F}_g$	Gravity:	force of attraction between any 2 objects. $\vec{F}_g = mg$, where $g = 9.8 m/s^2$.

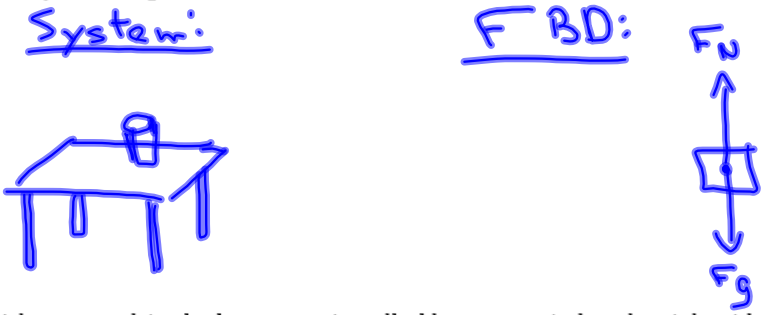
System

FBD

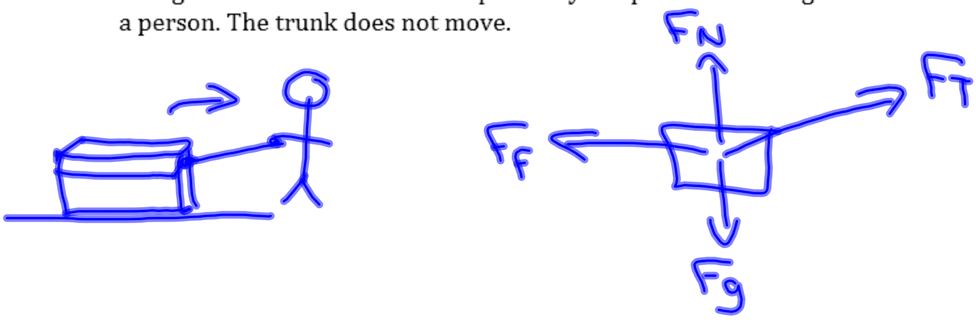


Draw both the system diagram and the FBD for each object in italics.

a. A *cup* is sitting at rest on a table.



b. A large *trunk* in the basement is pulled by a rope tied to the right side of the trunk by a person. The trunk does not move.



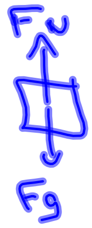
c. A *baseball player* is sliding to the left across the ground.

d. A *desk* is pushed to the left across the floor.

3. Calculating net forces

$\vec{F}_{Net}$ Net force:	the sum of all forces acting on an object. (total force).

The floor exerts a normal force of 36 N [up] on a stationary chair. The force of gravity on the chair is 36 N [down]. Draw the FBD of the chair and use the FBD to determine the net force on the chair.



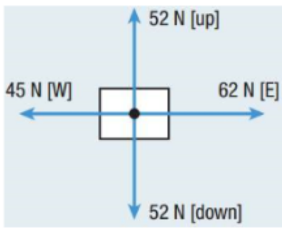
$\vec{F}_{Net} = \vec{F}_N + \vec{F}_g = 36\text{ N [up]} + 36\text{ N [down]}.$

$= 36\text{ N [up]} + (-36\text{ N [up]})$

$= 36\text{ N} - 36\text{ N}$

$= 0\text{ N}$

The figure to the right shows all the forces acting on an object. Use the FBD to calculate the net force.



$F_{Nety} = 52 - 52 = 0\text{ N}$

$F_{Netx} = 62 - 45 = 17\text{N [E]}$

$\therefore F_{Net} = 17\text{ N [E]}.$

4. Four fundamental forces

Gravitational:	acts between any 2 objects. only attractive (only pulls, doesn't push).
Electromagnetic:	caused by electric charges. can attract and repel (push or pull) holds atoms and molecules together } almost all forces are electromag.
Strong nuclear: ⊛strongest.	holds the nucleus together keeps the protons from repelling each other, and from getting too close to each other. holds a single proton or neutron together.
Weak nuclear:	

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

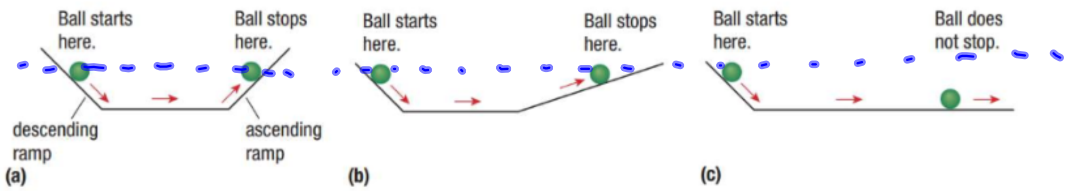
5. **Summary**

Homework: page 122: #1-3, 5, 7, 13, 15

SPH3U: 3.2 Newton's First Law of Motion

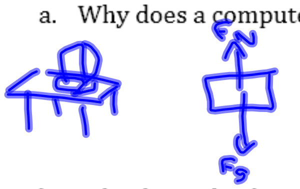
1. Inertia

Inertia:	the property of matter that causes it to resist changes in motion. More mass = more inertia
Newton's first law of motion	If the net force on an object is zero, the object will remain at rest or keep moving at a constant speed. F=0 → a=0.
Isaac Newton	Born in 1642 (year that Galileo died). Published Principia Mathematica (3 Laws).
Galileo Galilei's thought experiment	(below) Ball rolls back up to the same height that it started at.



Use Newton's first law to explain each situation below:

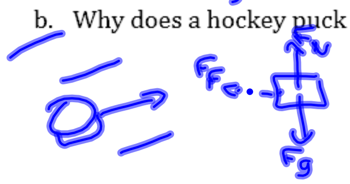
a. Why does a computer sitting on a desk remain at rest?



Normal force cancels out gravity.

Net force is zero.

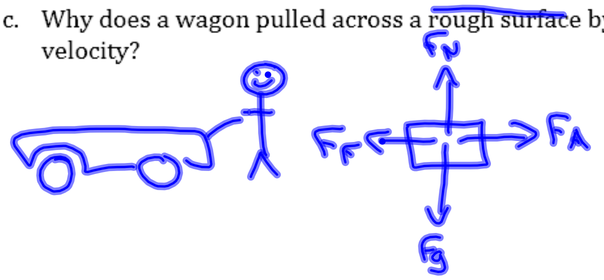
b. Why does a hockey puck moving across smooth ice move at a constant velocity?



Friction is (almost) zero.

Net force $F_{Net} = 0$.

c. Why does a wagon pulled across a rough surface by a child move at a constant velocity?



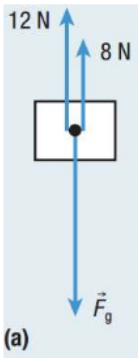
$F_{Net} = 0$

$\therefore F_A = F_F$

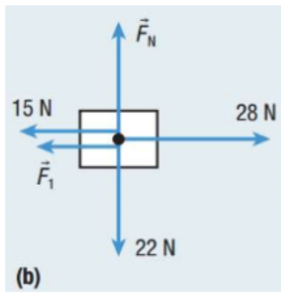
Older ~~cards~~ cars did not have headrests, but all new cars do. How do headrests help prevent injuries during a rear-end collision? Use Newton's first law to explain your answer.

Car moves forward, person does not.
Headrest prevents your head from moving backwords relative to your body.

What is the missing force on each FBD shown below? Figure a) is an object at rest and Figure b) is an object moving left at a constant velocity.



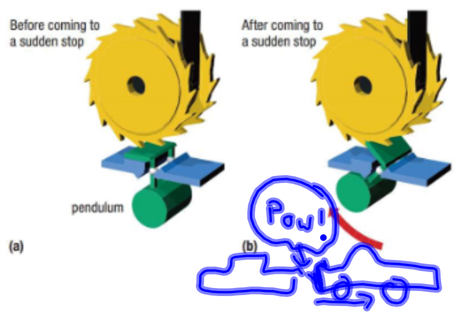
$F_{net} = 0.$
$F_{net} = 12 + 8 - F_g$
$0 = 12 + 8 - F_g$
$F_g = 12 + 8$
$= 20 N$



$F_{net} = 0$
$F_N = 22 N$
$28 N = 15 + F_1$
$F_1 = 28 - 15$
$= 13 N$

2. Applications of Newton's first law

Seat belt:	In a collision, the pendulum keeps moving forward, causing a metal piece to lock the gear in place.

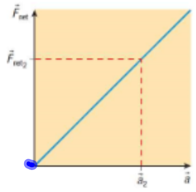


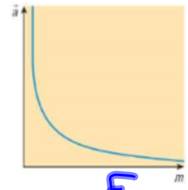
Homework: page 129: #1-4, 7, 10, 13

SPH3U: 3.3 Newton's Second Law of Motion

1. Newton's second law

Newton's second law:	F=ma. If there is an external force, it causes an acceleration inversely → proportional to the mass.
force vs. accel.	linear (straight line) increasing graph.
accel. vs. mass	inverse graph - as mass goes up, accel goes down.





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

A net force of 36 N [forward] is applied to a volleyball of mass 0.25 kg. Determine the acceleration of the volleyball.

$\vec{F} = m\vec{a}$ $\quad \vec{a} = \frac{\vec{F}}{m} = \frac{36\text{ N [F]}}{0.25\text{ kg}}$

$= 144\text{ m/s}^2$

$= 140\text{ m/s}^2$

$= 1.4\times10^2\text{ m/s}^2$

1 N = 1 kg·m/s²

A 64 kg runner starts walking at 3.0 m/s [E] and begins to speed up for 6.0 s, reaching a final velocity of 12.0 m/s [E]. Calculate the net force acting on the runner.

G: $\vec{v}_i = 3.0\text{ m/s [E]}$, $\Delta t = 6.0\text{ s}$, $\vec{v}_f = 12.0\text{ m/s [E]}$, $m = 64\text{ kg}$.

R: $\vec{F}_{Net}$

E: $\vec{F}_{Net} = m\vec{a}$, $\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$.

S: $\vec{a} = \frac{12-3}{6} = \frac{9}{6} = 1.5\text{ m/s}^2\text{ [E]}$

$\vec{F}_{Net} = m\vec{a} = (64)(1.5)$

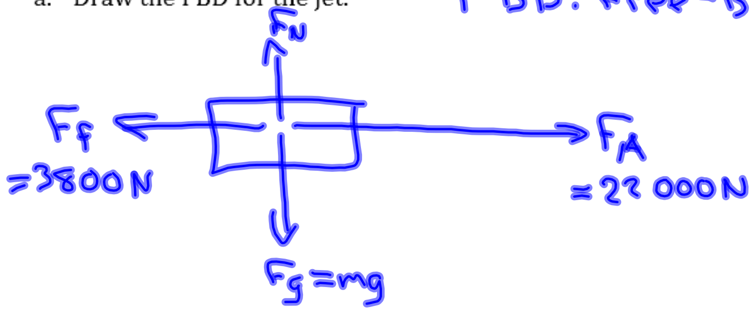
$= 96\text{ N [E]}$

S: ∴ the net force on the runner is 96 N [E].

A 9100 kg jet moving slowly on the ground fires its engines, resulting in a force of 22 000 N [E] on the jet. The force of friction on the jet is 3800 N [W].

a. Draw the FBD for the jet.

FBD: Free-Body Diagram.



b. Calculate the net force acting on the jet.

$$\vec{F}_{net} = F_A - F_f = 22\,000\text{ N} - 3800\text{ N}$$

$$= 18\,200\text{ N [E]}$$

c. Calculate the acceleration of the jet.

$$\vec{F}_{net} = m\vec{a}$$

$$\vec{a} = \frac{\vec{F}_{net}}{m} = \frac{18\,200\text{ N [E]}}{9100\text{ kg}}$$

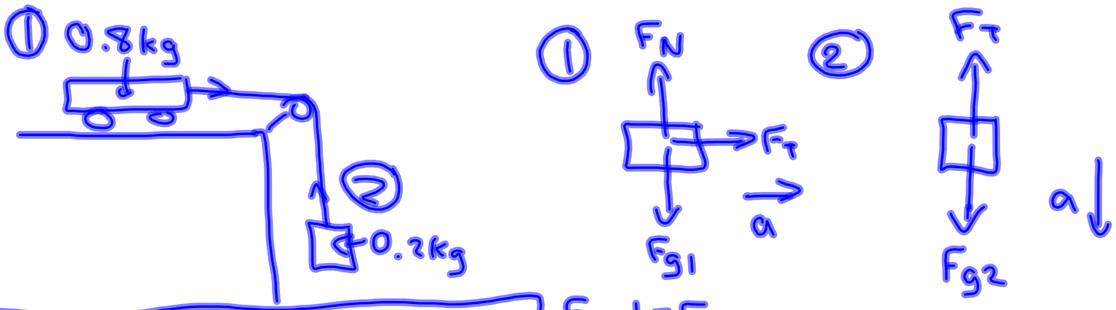
$$= 2.0\text{ m/s}^2$$

2. Newton's second law and gravity

Force due to gravity:	$\vec{F}_g = m\vec{g}$ ($\vec{F} = m\vec{a}$, where $\vec{g}$ is our accel.).

In an investigation, students place a 0.80 kg cart on a table. They tie one end of a light string to the front of the cart, run the string over a pulley, and then tie the other end to a 0.20 kg hanging object. Assume that no friction acts on either object.

a. Determine the magnitude of the acceleration of the cart and the hanging object.



$F_{Net} = F_T = m_1 a$

$F_{Net} = F_{g2} - F_T$

$F_{g2} - F_T = m_2 a$

① $F_T = m_1 a$ ② $F_T = F_{g2} - m_2 a$

$m_1 a = F_{g2} - m_2 a$

$m_1 a = m_2 g - m_2 a$

$m_1 a + m_2 a = m_2 g$ $a(m_1 + m_2) = m_2 g$

$a = \frac{m_2 g}{m_1 + m_2}$

$a = \frac{0.2(9.8)}{0.8 + 0.2} = 1.96\ m/s^2$

$= 2.0\ m/s^2$

b. Calculate the magnitude of the tension.

$F_T = m_1 a$

$= (0.8)(1.96\ m/s^2)$

$= 1.568\ N$

$= 1.6\ N$

~~3.~~ **Summary**

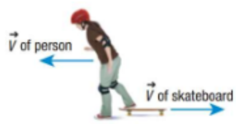
- $\vec{F}_{Net} = m\vec{a}$
- $\vec{F}_g = m\vec{g}$
- FBDs are important.

Homework: page 136: #1-4, 6, 10-11

SPH3U: 3.4 Newton's Third Law of Motion

1. Newton's third law

Newton's third law:	For every action force, there is an equal and opposite reaction force. $\vec{F}_R = -\vec{F}_A$
stepping off skateboard	As you step forward (F_A), the skateboard gets pushed back (F_R)
rocket launch	F_A pushes the fuel out the bottom. ∴ the fuel pushes the rocket up (F_R).

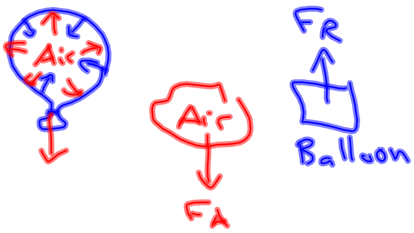


Explain each event in terms of Newton's third law:

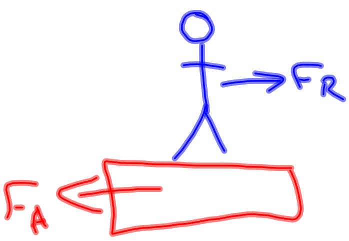
a. A swimmer moves through the water.

The swimmer pushes the water back (F_A). The water pushes the swimmer forward (F_R).

b. A small balloon releases air and flies around the classroom.



c. You start walking across the floor.



2. Separate objects

Action and reaction force:	Act on 2 different objects.
two FBDs	Draw 2 FBDs always for 3rd Law problems.

Two skaters are standing on ice facing each other. Skater 1 pushes on skater 2 with a force of 70 N [E]. Assume that no friction acts on either skater. The mass of skater 1 is 50 kg and the mass of skater 2 is 70 kg.

a. State the action and reaction forces.

F_A: Skater 1 pushes skater 2. $F_A = 70$ N [E].

F_R: Skater 2 pushes skater 1. $F_R = 70$ N [W].

b. Draw the FBD of each skater.

c. Describe what will happen to each skater.

Skater 1 will accelerate east.

Skater 2 will accelerate west.

d. Calculate the acceleration of each skater.

Skater 1: $F_{Net} = ma$

$F_{Net} = 70$ N [W]

$70 = 50a$

$a = \frac{70}{50} = \frac{7}{5} = 1.4\ m/s^2$ [W]

Skater 2: $F_{Net} = ma$

$F_{Net} = 70$ N [E].

$70 = 70a$

$\frac{70}{70} = a = 1.0\ m/s^2$ [E].

3. Summary

$F_R = -F_A$.

$F_A + F_R = 0$.

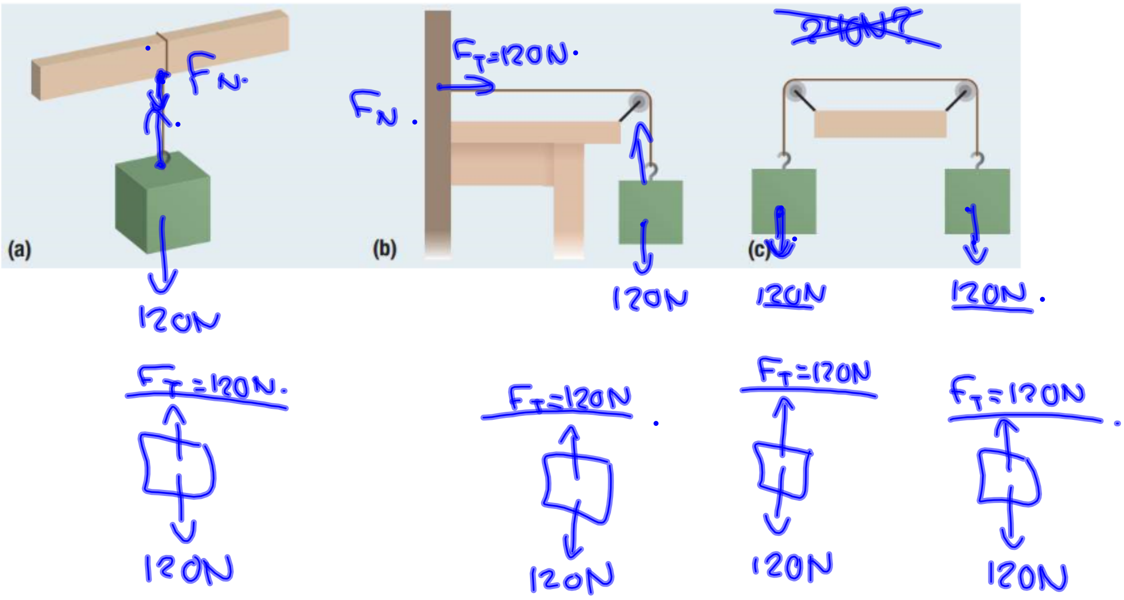
Homework: page 141: #2-3, 6-9

3.5 Using Newton's Laws

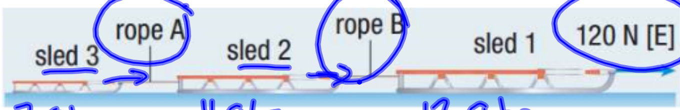
1. Tension and Newton's laws

Tension:	A pulling force exerted by ropes and strings. Always pulls toward the centre. $\vec{F}_{T1} = -\vec{F}_{T2}$
Newton's third law	$\vec{F}_A = -\vec{F}_R$
ignoring tension	Sometimes we can pretend that 2 or more objects are 1 combined object, and then ignore tension.

Each object below has a force of gravity of 120 N [down] acting on it. Determine the tension in each string.



Three sleds are tied together and pulled east across an icy surface with an applied force of ~~12~~ 120 N [E]. The mass of sled 1 is 12.0 kg, the mass of sled 2 is 11.0 kg, and the mass of sled 3 is 7.0 kg. Assume there is no friction.



7.0 kg. 11.0 kg 12.0 kg.

a. Determine the acceleration of the sleds.

Combined sleds: F_N, F_g, 120 N. $m = 12 + 11 + 7 = 30\ kg$.

$F_{net} = ma$.
$120\ N = 30a$.
$a = \frac{120}{30} = 4.0\ m/s^2$.

b. Calculate the magnitude of the tension in rope A.

Sled 3: $F_{net} = ma$.
$F_{TA} = 7a = 7(4)$
$F_{TA} = 28\ N$.

c. Calculate the magnitude of the tension in rope B.

Sleds 2 + 3: F_N, F_g, F_{TB}. $m = 7 + 11 = 18\ kg$

$F_{net} = ma$
$F_{TB} = 18(4)$
$= 72\ N$.

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(2). Sled 1:

F_{TB}, 120 N. $m = 12\ kg$, $a = 4$.

$F_{net} = 120\ N - F_{TB}$.
$= ma$.

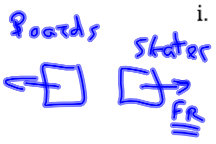
2. Kinematics and Newton's laws

Kinematics equations:	Assume constant acceleration. When a is changing, break the problem into steps.

Starting from rest, an ice skater (54.0 kg) pushes the boards with a force of 130.0 N [W] (1) and moves 0.704 m. He then moves at a constant velocity for 4.00 s (2) before he digs in his skates and starts to slow down. When he digs in his skates, he causes a net force of 38.0 N (3). [W] to slow him down until he stops.

a. Determine the acceleration of the skater

i. when he is pushing on the boards



(1)

$F_{net} = ma$.

$130N [E] = (54)a$

$a = \frac{130}{54} = 2.407 m/s^2$.

ii. just after he stops pushing on the boards

(2) No accel. $a = 0 m/s^2$.

iii. when he starts to slow down

(3). $F_{net} = ma$.

$38.0N [W] = 54a$

$a = \frac{54}{38} = 0.704 m/s^2 [W]$.

b. How far does he move?

(1) $\Delta d = 0.704m$, $v_f = ?$, $a = 2.407 m/s^2$, $v_i = 0 m/s$.

$v_f^2 = v_i^2 + 2a\Delta d$ $\quad v_f = \sqrt{v_i^2 + 2a\Delta d} = \sqrt{0 + 2(2.407)(0.704)}$

$= 1.841 m/s$.

(2) $\Delta t = 4.0s$, $v = 1.841 m/s$. $\quad \Delta d = v\Delta t = (1.841)(4) = 7.364 m$.

(3) $v_i = 1.841 m/s$, $v_f = 0 m/s$, $a = -0.704 m/s^2$, $\Delta d = ?$

$v_f^2 = v_i^2 + 2a\Delta d$ $\quad \Delta d = \frac{v_f^2 - v_i^2}{2a} = \frac{0 - 1.841^2}{2(-0.704)} = 1.981 m$.

Total: $\Delta d = 0.704m + 7.364 + 1.981 = 10.1 m$.

Homework: page 147: #1-2, 4-6