Physics 122
Course Outline 2009 - 2010

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Unit 1 (25 hours)
Dynamic Extension
Vectors to Analyze: Force and Motion
Conservation of Momentum
Collisions in Two Dimensions

Unit 2 (25 hours)
Projectiles
Circular Motion
Simple Harmonic Motion
Universal Gravitation

Unit 3 (30 hours)
Magnetic, Electrical, and Gravitation Fields
Coulomb's Law
Electric Circuits
Electromagnetism and Electromagnetic Induction

Evaluation:
Tests, Quizzes, Labs: 70%
Final Exam 30%

Materials:
Binder & paper
Scientific Calculator
Ruler/Protractor
Pen/Pencil
Lab Book

Textbook: Physics (McGraw-Hill Ryerson): Text and CD
ROM Price >$150

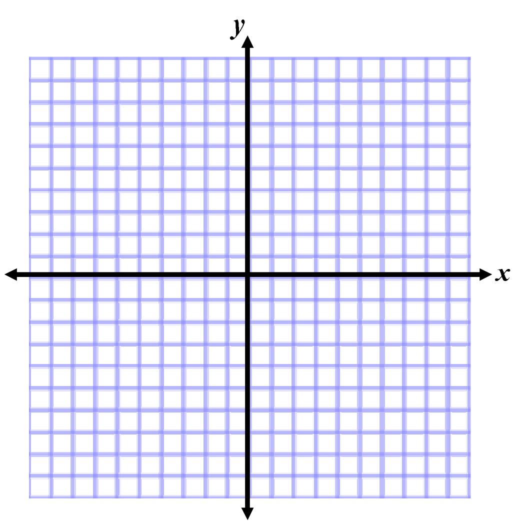
1D Motion: Mathematical Analysis

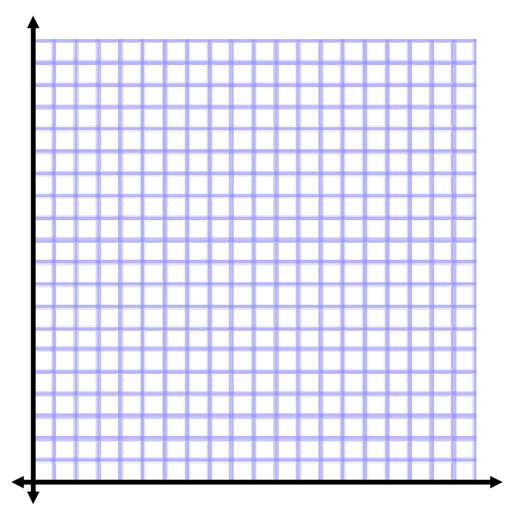
FRAME OF REFERENCE (Ch. 2.1 - pg 30):
a subset of the physical world defined by an observer in which positions or motions can be discussed or compared. This can be stationary or moving.

Ex. If you are in a stopped school bus and you walk towards the front of the bus you are moving with respect to others sitting in the bus, the floor of the bus and the ground.
If you are sitting in a moving school bus, you are NOT moving with respect to the floor of the bus, or others around you sitting down. You ARE moving with respect to the ground and landscape outside the bus.

Coordinate System

Used to describe an object's position and motion mathematically.





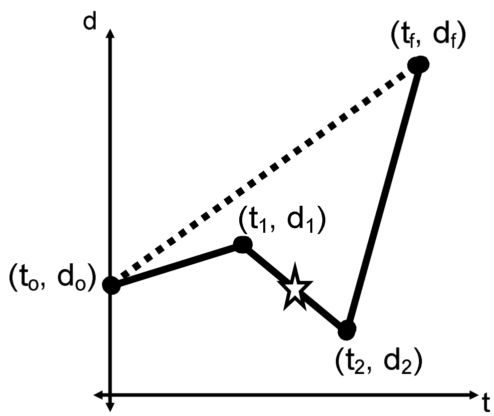
1D Motion: Mathematical Analysis

We want to be able to solve problems involving the following *vectors*:

- displacement, *d*
- time, *t*
- velocity, *v*
- acceleration, *a*

You may remember some of the equations of motion from grade 10. We will derive the equations to use based on our graphical study of motion in grade 11.

Instantaneous Velocity = Change in position (displacement) per unit time. It is the slope of the d-t graph at a point (t,d).



$$v_{\star} = slope = \frac{d_2 - d_1}{t_2 - t_1} = \frac{\Delta d}{\Delta t}$$

Remember that if the displacement works out to be negative that means the object has traveled in the direction that our frame of reference has labeled to be negative.

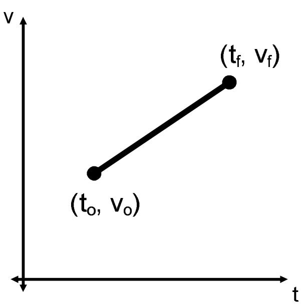
If you are ant average velocity the concept is the same but you have to use the initial and final points:

$$v_{avg} = \frac{d_f - d_o}{t_f - t_o}$$

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

For many of our problems we are only concerned with average velocity.

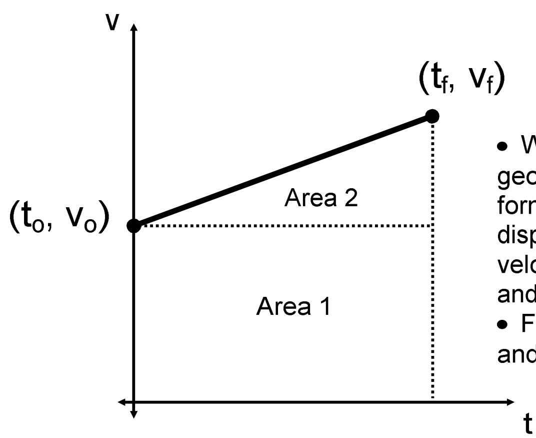
Acceleration works very similarly to velocity. The instantaneous velocity is the slope of the v-t graph at a point (t, v) and the average acceleration is found using the initial and final information. We will limit ourselves to objects undergoing a constant acceleration.



$$a = \frac{v_f - v_o}{t_f - t_o} = \frac{\Delta v}{\Delta t}$$

Read problems carefully as quite often the initial velocity and time is zero, but not always.

Displacement for an object undergoing constant acceleration equals the area between the v-t graph and the time axis



- We can use the geometry to derive a formula that relates displacement to initial velocity, acceleration, and time.
- For simplicity $t_o = 0$ and t_f is written as t.

Displacement = Area 1 + Area 2

$$d = v_o t + \frac{1}{2}(v_f - v_o)t$$

This is a perfectly valid formula but many times we are given information about acceleration. We can incorporate acceleration by using a little math trick:

$$d = v_o t + \frac{1}{2}(v_f - v_o)t \times \frac{t}{t}$$

$$d = v_o t + \frac{1}{2}\left(\frac{v_f - v_o}{t}\right)t^2$$

remember that: $a = \frac{v_f - v_o}{t_f - t_o} = \frac{\Delta v}{\Delta t}$

$$d = v_o t + \frac{1}{2}at^2$$

Motion Equations

$$v_{avg} = \frac{d_f - d_o}{t_f - t_o}$$

$$a = \frac{v_f - v_o}{t_f - t_o} = \frac{\Delta v}{\Delta t}$$

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

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

Remember that everything is a vector (sign of the variable depends on its direction) except time and that the change in time can never be negative!

Motion Examples

A car accelerates from zero to 35 m/s in 7.3 seconds.
a) What is the average acceleration?
b) What distance was covered during the acceleration?

a) What is the stopping distance required for a car initially traveling 100 km/h that skids to a stop in 4.3 s? (59 m)
b) Assuming the same acceleration as in (a) what distance is needed if the car is traveling 120 km/h? (86 m)

Standing near the edge of a cliff a baseball is launched straight up with a velocity of 15 m/s. The ball is in the air for a total of 4.5 s before it hits the ground at the bottom of the cliff. Find the height of the cliff (magnitude of the acceleration of gravity, g = 9.8 m/s^2).

Forces Review: 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. **N*et force***, $\vec{\mathbf{F}}_{net}$, 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.

$$\vec{F}_g = \vec{W}$$

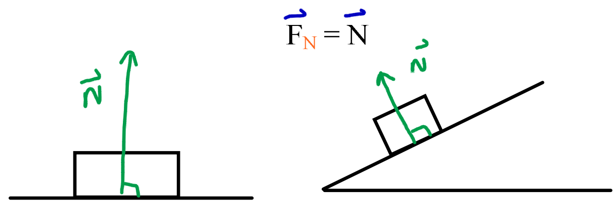
$$\boxed{\vec{W} = m\vec{g}}$$

$\vec{W}$ -> weight (N)
m -> mass (kg)
$\vec{g}$ -> acceleration due to gravity (m/s^2)

$\vec{F}_a$: 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

$$F_f = \mu N$$

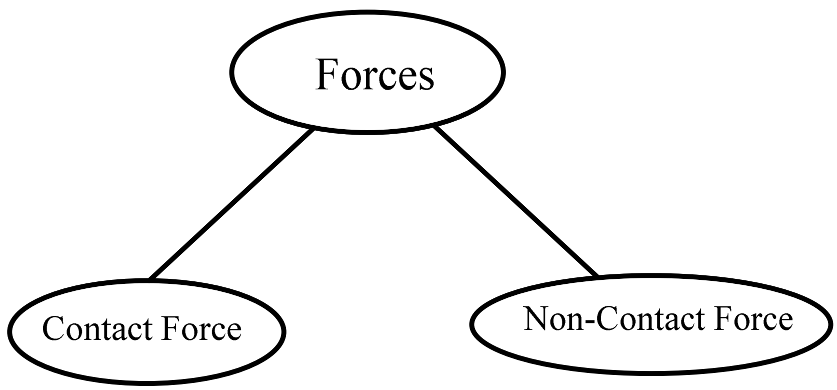
F_f -> force of friction (N)
μ -> coefficient of friction
N -> normal force (N)

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

$\vec{F}_T$: ***tension***
- the force that acts along a rope, wire, string, etc.



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

Free-Body Diagrams

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

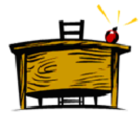
A ***free-body diagram*** (FBD) is a picture that shows ALL the forces acting on an object.

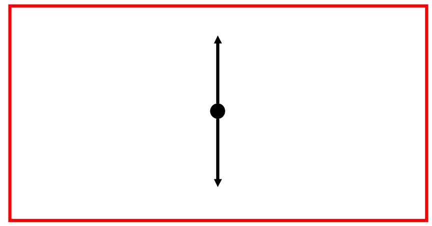
For the sake of simplicity, an object is usually represented by a dot and only the forces acting on the object are included on the diagram. The forces are represented by arrows.

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.

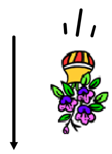
Examples:

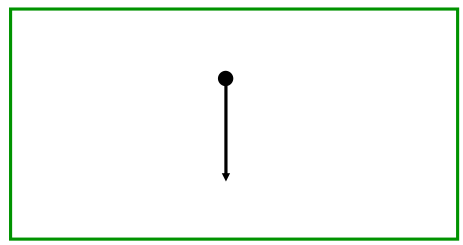
An ***apple*** rests on a desk.



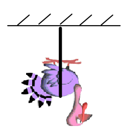


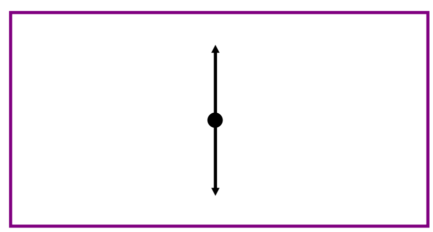
A ***flower pot*** falls in the absence of air resistance.



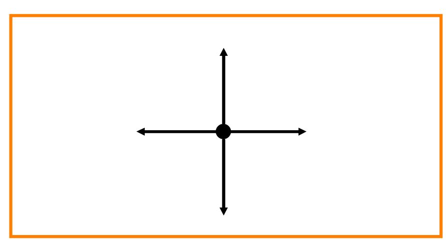


A ***turkey*** is hung from the ceiling of a classroom.

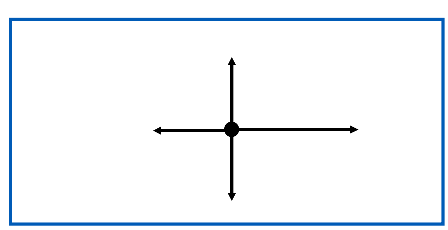




A snail pushes a ***pumpkin*** across the floor at constant speed.



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 (PP) - Page 137: 1, 2, 3, 4.
Page 144 # 5 - 7.

Answers P. 958

Page 132–133 ⇒ $\vec{g}$ Values

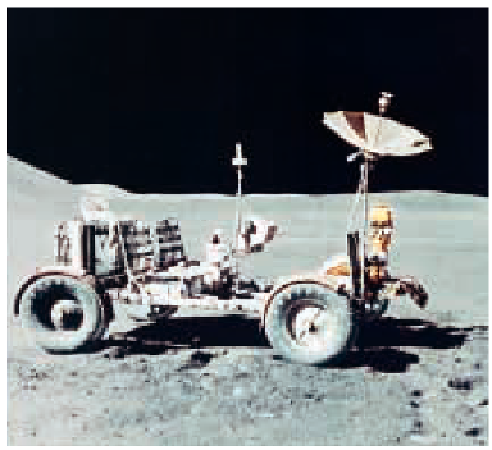
PRACTICE PROBLEMS

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.

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.



$W = F_g = mg \leftarrow 9.81\ m/s^2$

PRACTICE PROBLEMS

p. 144

5. A friend pushes a 600 g (6.00×10^2 g) text-book 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.)

Galileo

Galileo Galilei (1564 - 1642) brought the scientific method to physics, creating the modern version of the science.

He invented the pendulum clock, investigated the motion of falling bodies and discovered the moons of Jupiter.

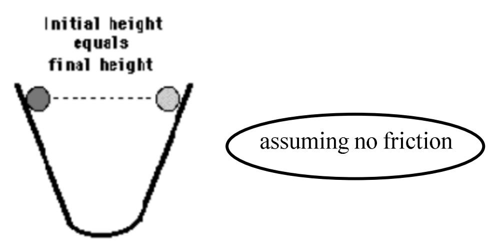
He paved the way for Newton's discovery of the relationhsip between force and motion.

Thought Experiment

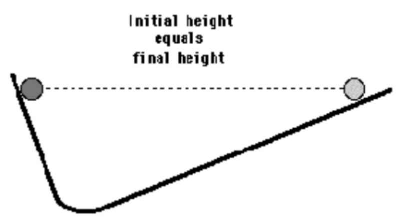
In experiments using a pair of inclined planes, Galileo observed that a ball will roll down one plane and up the opposite plane approximately to the same height.

He thought that if friction could be eliminated entirely, the ball would stop at exactly the same height on the opposite plane.

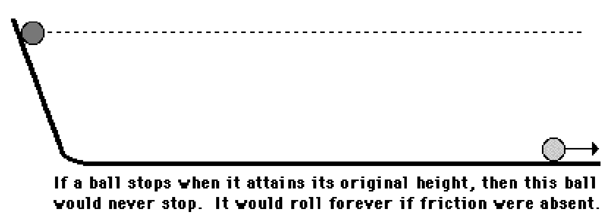
With a steep angle a ball will roll a small distance to attain the original height.



As the angle of the opposing incline is reduced, the ball must roll farther in order to attain the original height.



What happens if the opposing incline is not inclined?



The results of these experiments led Galileo to develop the concept of ***inertia***.

Inertia

Inertia is the tendency of an object to resist changes in its state of motion.

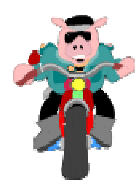
Mass is a measure of an object's inertia.

More Matter → More Mass → More Inertia

Simulations (The Physics Classroom)

1. The Car and the Wall
   - a good argument for wearing seatbelts

2. The Motorcyclist
   - why don't seatbelts have safety harnesses?



Section Review: Page 147, #5-8, 10-12(a), 14-15(b, c)

PFU: Page 151, #26-28, 30-32, 34

Chapter 5 - Newton's Laws (Page 152)

Isaac Newton

(1642-1727)

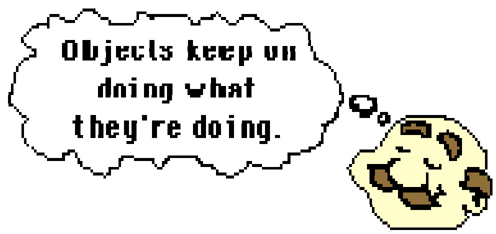
Frames of Reference

1. inertial -> frame of reference in which Newton's laws are valid
   -> frame of reference is at rest or has uniform motion

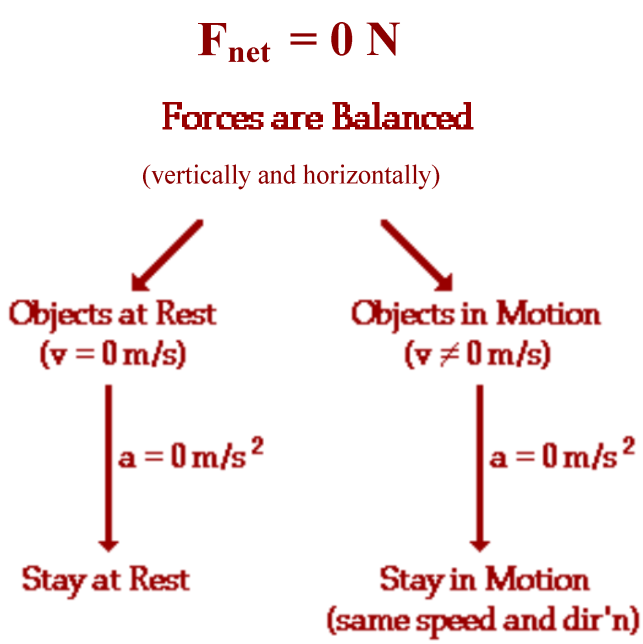
2. non-inertial -> frame of reference in which Newton's laws are not valid
   -> frame of reference is accelerating uniformly

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.



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



Newton's Second Law of Motion Pg 160

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

$$a \propto F_{net}$$

$\propto$ → proportional to

- inversely proportional to the mass of the object

$$a \propto \frac{1}{m}$$

$$\vec{a} = \frac{\vec{F}_{net}}{m} \qquad \vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

$$\boxed{\vec{F}_{net} = m\vec{a}}$$ ← Starting point for force problems involving acceleration.

$\vec{F}_{net}$ -> net force (N)
m -> mass (kg)
$\vec{a}$ -> acceleration (m/s^2)

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

Sample Problems

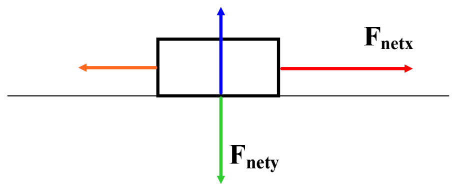
An object is accelerating at 2.0 m/s^2 east.

1. If the net force is tripled, what is the object's new acceleration?

2. If the net force is halved, what is the object's new acceleration?

3. If the net force is tripled and the mass is quadrupled, what is the object's new acceleration?

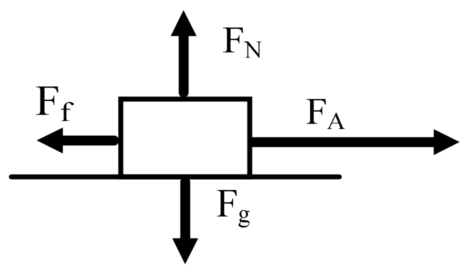
NOTE: The net force equation is applied to different dimensions independently.



Example: 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)

Example:

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. Use the diagram to determine the normal force, the net force, the mass, and the acceleration of the object. (Neglect air resistance.) The weight of the object is 80 N.



Mass = 8.2 kg
Fnormal = 80 N (up)
Fnet = 40 N (right)
a = 4.9 m/s^2 (right)

Pg 163 #s 1 - 3.
Handout #s 1, 2.

Newton's Third Law of Motion

"***For every action there is an equal and opposite reaction***."

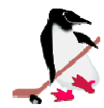
"***Forces come in equal and opposite reaction pairs***."

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.

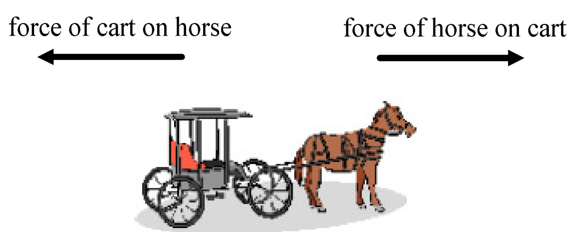
If a hockey stick applies a force to the puck, the puck applies the same amount of force back on the stick.



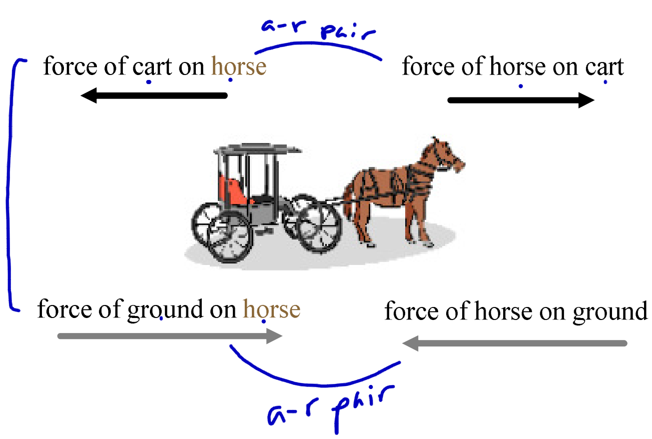
One of the most important conceptual questions of physics is:

"***If each action force causes an equal but opposite reaction force, then how can anything ever accelerate***?

Horse and Cart Scenario



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



Text: Page 163, PP #1-3

Handout: Problems - Newton's Second law
#1, 2, 5-11

Text - Page 168 #4-7

Newton's Laws #1

1) $\vec{F} = 2360\ N$

2) $M = 750\ N$

5) $\vec{a} = 3.33\ m/s^2$

6a) $\vec{a} = 3.6\ m/s^2$

b) $\vec{F}_E = 490\ N$

7) $\vec{F}_{proton} = 1.64 \times 10^{-26}\ N$

8a) $\vec{F}_f = 2.0\ N$

b) $\mu = 0.023$

9) $\vec{F}_{app} = 7.46\ N$

10) $\vec{a} = 0.59\ m/s^2$

11) $\vec{F}_{app} = 3306\ N$

Physics 122/121

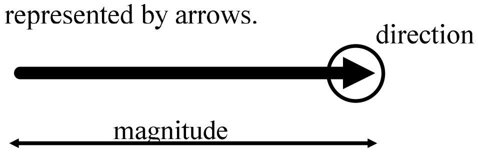
Unit 1

Dynamics Extension

VECTOR REVIEW

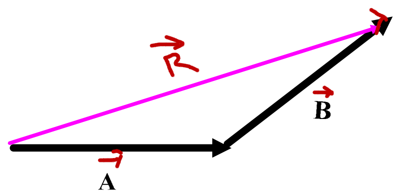
Vector quantities have both magnitude and direction. Some vector quantities are velocity, force, acceleration and momentum.

Vectors are represented by arrows.



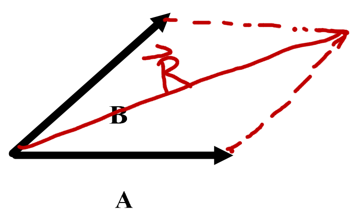
Graphical Methods of Adding Vectors

1. Tip-to-tail Method

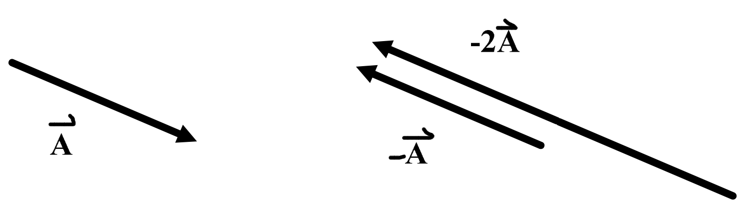


R - resultant (sum of vectors)

2. Parallelogram Method

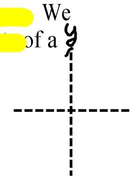


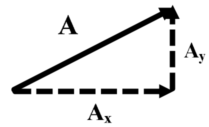
Negative Vectors



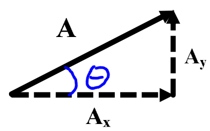
Components of a Vector

A vector can be expressed as the sum of two other vectors, called the [illegible] of the vector. The process of finding the components of a vector is called [illegible]. We will always be finding the [illegible] of a vector.

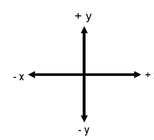




Use trigonometric ratios to determine the magnitudes of the components. The arrows of the components show their directions.



Ex: Find the components of the following:
a) 95 km [E39°N]



b) 112 m/s [E77°S]

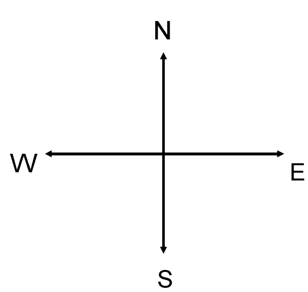
c) 1575 m [W22°S]

Adding Vectors Using Perpendicular Components

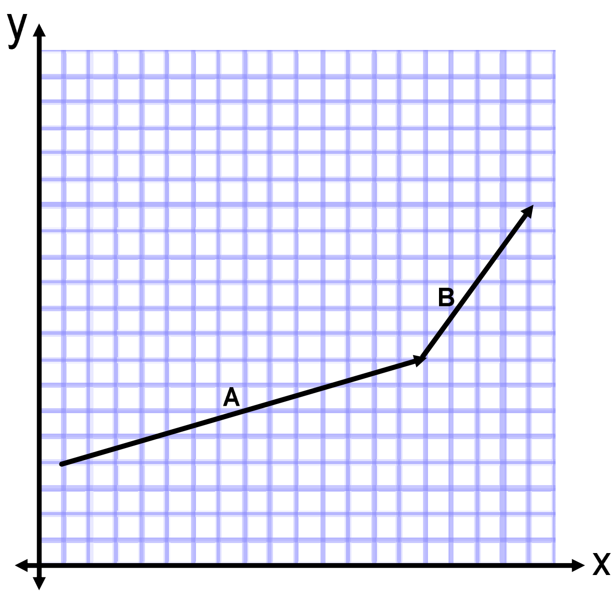
1. Resolve each vector into its perpendicular components.
2. Add corresponding vector components.

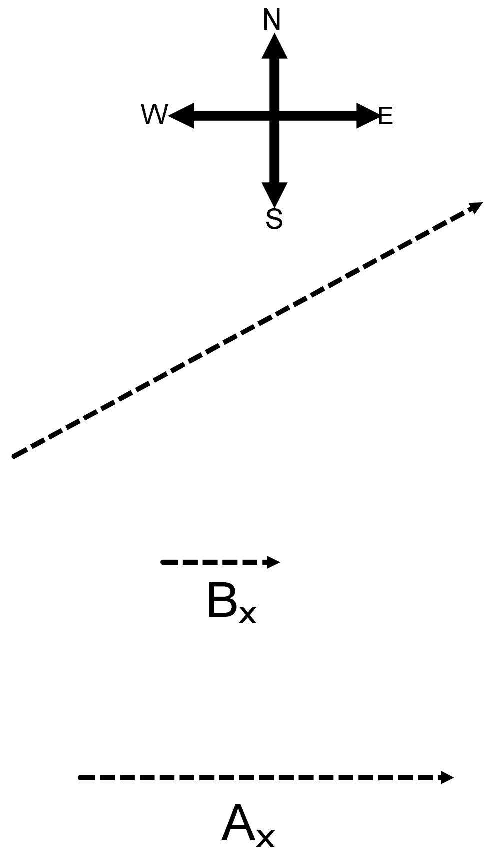
$$\mathbf{R_x} = \mathbf{A_x} + \mathbf{B_X}$$
$$\mathbf{R_y} = \mathbf{A_y} + \mathbf{B_y}$$

3. Sketch $\mathbf{R_x}$ and $\mathbf{R_y}$ tip-to-tail.
4. Use the Law of Pythagoras and a trig ratio to determine the magnitude and direction of the resultant.

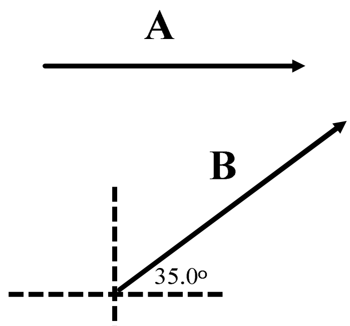


Consider the two vectors A and B.





Example - Find the resultant of 1.60 km, east and 3.40 km, E35.0° N

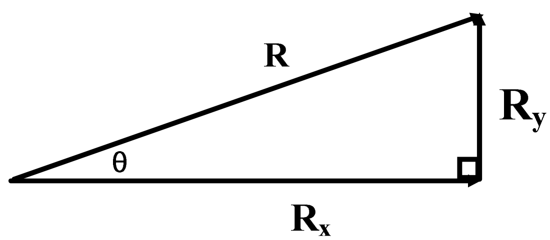


$\mathbf{A_x}$ = + 1.60 km
$\mathbf{A_y}$ = 0 km

$\mathbf{B_x}$ = (3.40 km)(cos 35.0°)
$\mathbf{B_x}$ = + 2.785 km

$\mathbf{B_y}$ = (3.40 km)(sin 35.0°)
$\mathbf{B_y}$ = + 1.95 km

$\mathbf{R_x}$ = 1.60 km + 2.785 km = 4.385 km
$\mathbf{R_y}$ = 0 km + 1.950 km = 1.950 km



$R = \sqrt{(4.385)^2 + (1.950)^2}$

R = 4.80 km

$\tan\theta = \frac{R_y}{R_x}$

$\theta = 24.0^\circ$

R = 4.80 km, E24.0°N

Warm Up

Try - Determine the resultant of 243 km, E50.0^o N and 57.0 km, E20.0^{o}S. (268 km, E38.5^{o}N)

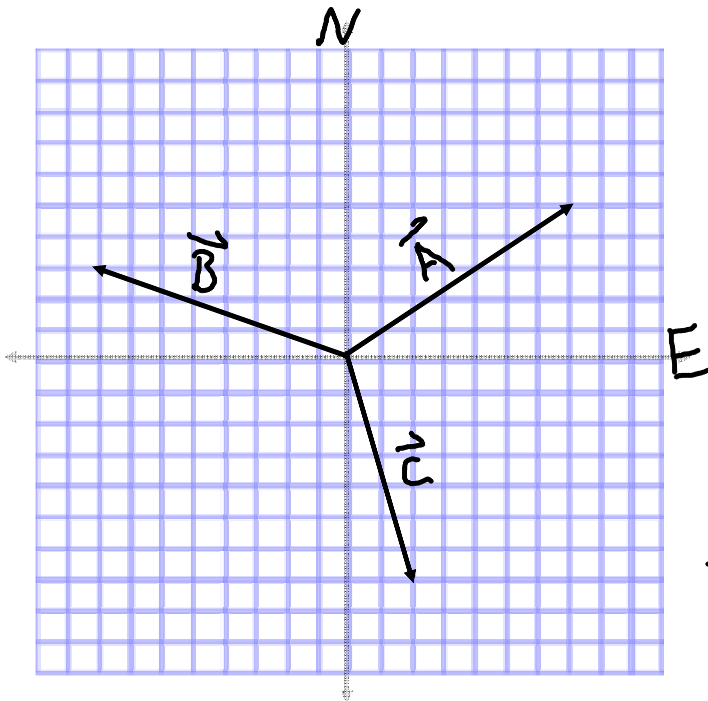
Part II

a) $\vec{R} = 19.8$ [E 59° N]

b) $\vec{R} = 19$ [E 44° S]

c) $\vec{R} = 16$ [W 82° N]

d) $\vec{R} = 20.8$ [W 87° S]



$\vec{A}$ = 55 N, E42°N

$\vec{B}$ = 47 N, W 25° N

$\vec{C}$ = 53 N, S 22° E

definition of equlibrium: *the state of an object when the vector sum of all the forces acting on it is zero.*

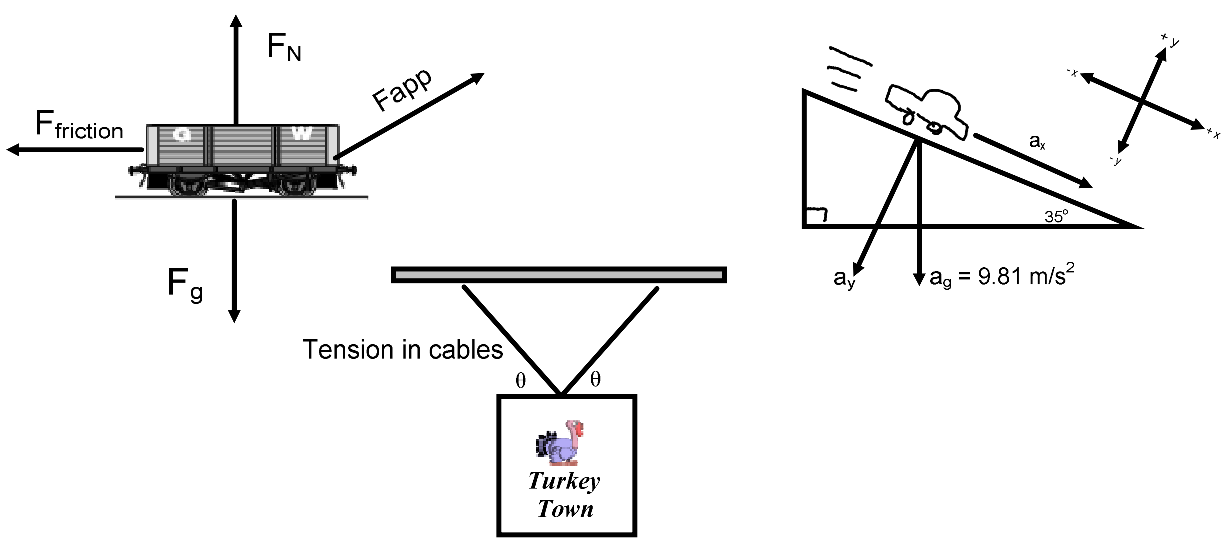
If an object is at ***rest*** and is in ***equilibrium***, then we say that it is in a state of "***static equilibrium***."

<u>Equilibrant:</u> is the one vector, when added to 2 or more other vectors produces a state of equilibrium. It is equal to the resultant but opposite in direction.

<u>Try</u> - Three forces act simultaneously on point P. The first force is 10 N east. The second force is 15 N south. The third force is 28 N, E46^{o}S . Find the resultant force. (46 N, E50^{o}S). Find the equilibrant.(46N, W50^{0}N)

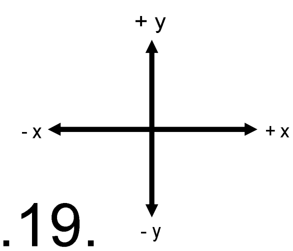
Three Types of Force Problems

1 - Pushing or pulling an object along a horizontal surface.
2 - Tension and hanging signs.
3 - Objects on an incline.



Force Problems - Type I

A 55 kg snow blower is pushed along the ground at an angle of 35° to the horizontal with an applied force of 175 N.



a) Find the F_{ax} and F_{ay}.

b) Calculate F_N. ⟵

c) Find the force of friction if $\mu = 0.19$.

d) Find the F_{netx}.

e) Find a_x.

A 35 kg wagon is pulled along the ground at an angle of 25° to the horizontal with an applied force of 97 N.

a) Find the F_{ax} and F_{ay}.

b) Calculate F_N.

c) Find the force of friction if $\mu = 0.22$.

d) Find the F_{netx}.

e) Find a_x.

Physics 122/121

Force Problems - Type I

MHR - Chapter 5 - Page 174

17. A student pushes a 25 kg lawn mower with a force of 150 N. The handle makes an angle of 35° to the horizontal.

(a) Find the vertical and horizontal components of the applied force.

(b) Calculate the normal force supporting the lawn mower while it is being pushed.

(c) Calculate the net force propelling the mower if a frictional force of 85 N exists.

(d) Calculate the horizontal acceleration of the lawn mower. (Remember: Only part of the $F_{applied}$ is parallel to the direction of horizontal acceleration.)

a) 86 N, down
1.2 x 10^2 N, right
b) 3.3 x 10^2 N, up
c) 38 N, right
d) 1.5 m/s^2, right

MHR - Chapter 5 - Page 208

24. A toboggan with a mass of 15 kg is being pulled with an applied force of 45 N at an angle of 40° to the horizontal. What is the acceleration if the force of friction opposing the motion is 28 N?

0.43 m/s^2, right

25. A grocery cart is being pushed with a force of 450 N at an angle of 30.0° to the horizontal. If the mass of the cart and the groceries is 42 kg,

(a) Calculate the force of friction if the coefficient of friction is 0.60.

(b) Determine the acceleration of the cart.

a) 3.8 x 10^2 N, left
b) 0.23 m/s^2, right

MHR - Chapter 5 - Page 209

36. A 45.0 kg box is pulled with a force of 205 N by a rope held at an angle of 46.5° to the horizontal. The velocity of the box increases from 1.00 m/s to 1.50 m/s in 2.50 s. Calculate

(a) the net force acting horizontally on the box.

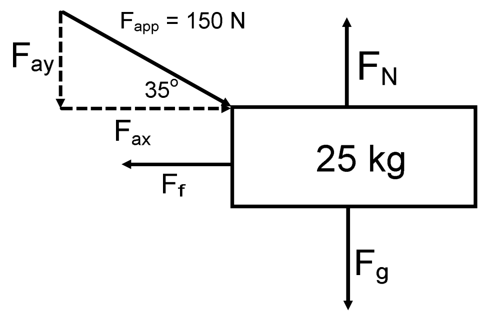
(b) the frictional force acting on the box.

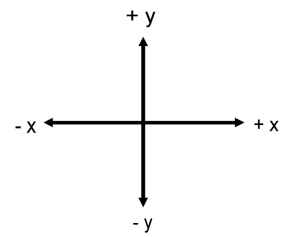
(c) the horizontal component of the applied force.

(d) the coefficient of kinetic friction between the box and the floor.

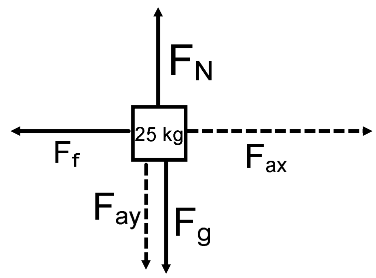
a) 9.0 N, right
b) 132 N, left
c) 141 N, right
d) 0.451

#17





Free Body Diagram



(a) $F_{ax} = +150\cos(35)$
$= 123$ N

$F_{ay} = -150\sin(35)$
$= -86$ N

(b) $F_{nety} = F_{ay} + F_g + F_N$
$0 = -86 \text{ N} - mg + F_N$
$0 = -86 - 25(9.81) + F_N$
$0 = -86 - 245.25 + F_N$
$0 = -331.25 + F_N$
$+330 \text{ N} = F_N$

(c) F_{netx} = Sum of horizontal forces
$= F_{ax} + F_f$
$= 123 + -85$
$= +38$ N

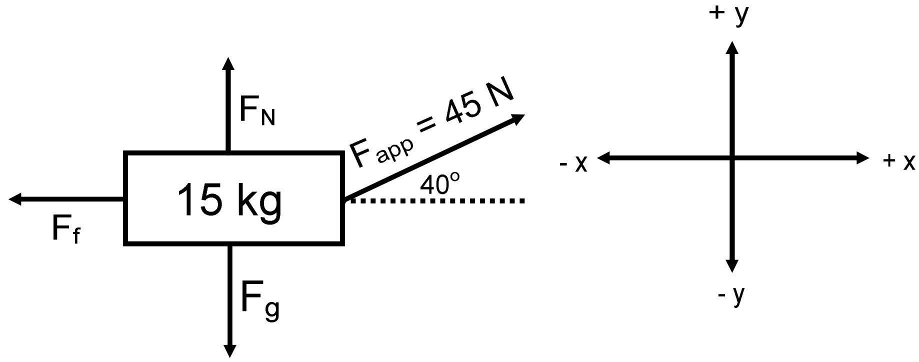
(d) $F_{net} = ma$

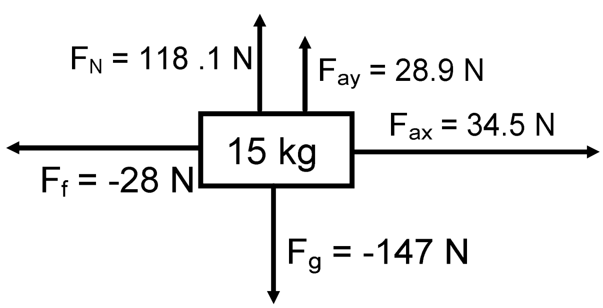
$$a = \frac{F_{net}}{m}$$

$$a = \frac{+38\ N}{25\ kg}$$

$a = +1.5 \text{ m/s}^2$

24





$$F_{net} = F_{ax} + F_f$$
$$= 34.5 + (-28)$$
$$= +6.5\ \text{N}$$

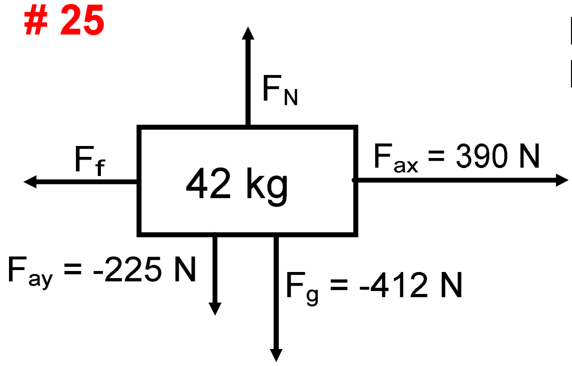
$$F_{net} = ma$$

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

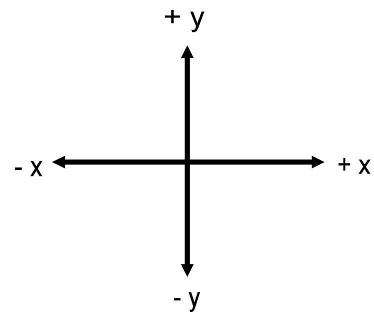
a = +6.5 N/15 kg

a = +0.43 m/s^2

25



F_{ax} = 450cos(30) N
F_{ay} = 450sin(30) N



(a) $F_f = \mu F_N$, μ = -0.60

$F_{nety} = F_{ay} + F_g + F_N$
$0 = -412\text{ N} + -225\text{ N} + F_N$
$F_N = +637\text{ N}$

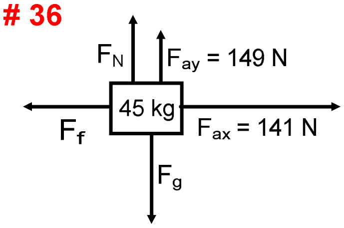
$F_f = 0.60(637\text{ N})$
F_f = 380 N [left]

(b) $$a = \frac{F_{net}}{m} = F_{ax} + F_f$$

$a = (389.7\text{ N} + -382\text{ N}) \div 42\text{ kg}$

$a = +0.19\text{ m/s}^2$

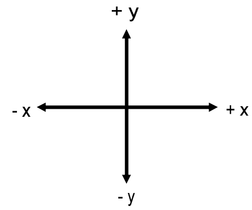
36



F_{app} = 205 N @ 46.5°

F_{ax} = 205cos(46.5)

F_{ay} = 205sin(46.5)



(a) $F_{net} = ma$ ← find acceleration

$$a = \frac{\Delta v}{\Delta t}$$

$$a = \frac{1.50m/s - 1.00m/s}{2.50s}$$

a = 0.20 m/s^2

F_{net} = (45kg)(0.20m/s^2)
= 9.0 N

(b) $F_{net} = F_{ax} + F_f$ or $F_f = -\mu F_N$?

9.0 N = 141 N + F_f

9.0 N - 141 N = F_f

-132 N = F_f

(c) F_{ax} = 141 N

$F_g = m\vec{g}$

(d) $F_{kf} = \mu F_N$

$F_{nety} = F_{ay} + F_g + F_N$

0 = -441 N + 149 N + F_N

F_N = -292 N

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

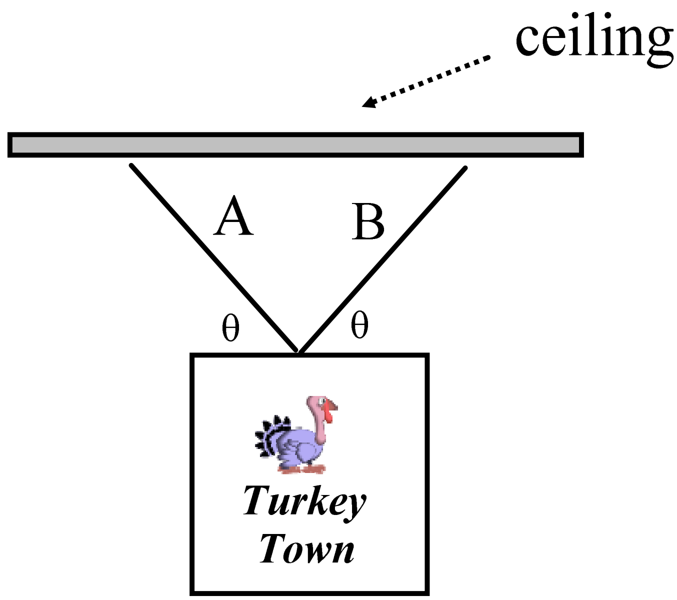
can use "+132" as the formula implies the magnitude of F_f.

$$\mu = \frac{-132N}{292N}$$

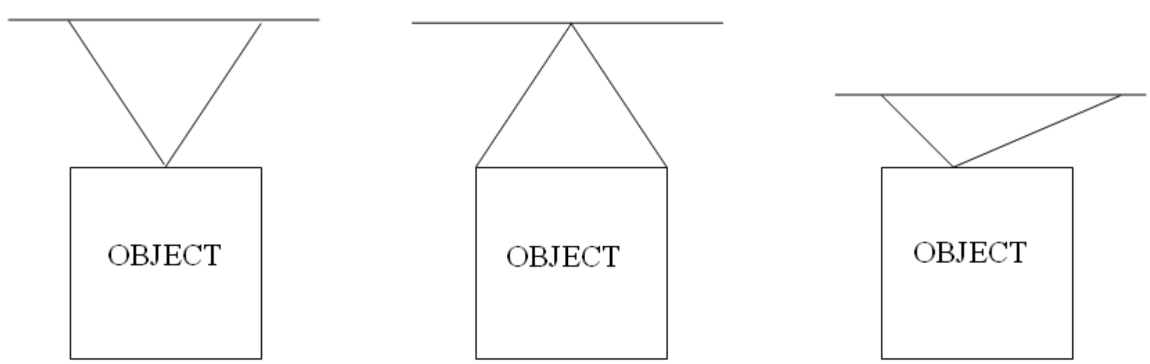
μ = -0.451

Type II - Signs/Pictures/Hanging Objects

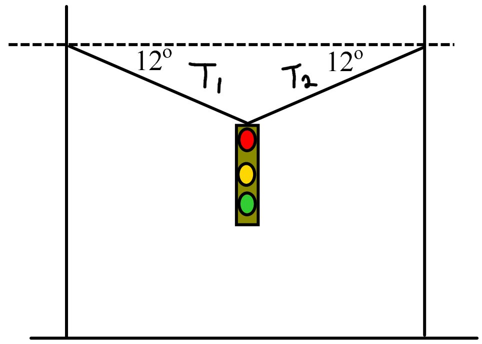
If an object is hung by a rope (wire, chain, etc.), we can resolve the force of tension along the rope.



An object can be hung in a variety of ways.



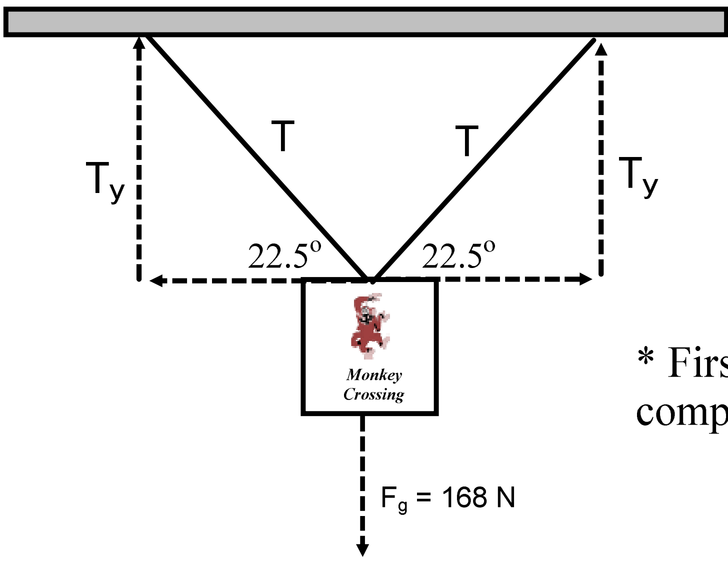
Example



A traffic light hangs in the center of the road from cables as shown in the figure. (a) If the mass of the traffic light is 65 kg, what is the magnitude of the force that each cable exerts on the light to prevent it from falling? (b) What is the tension in each cable?

(a) The y-component of the tension in each cable must add together to support the light's weight; the light is in static equilibrium. Since the angles are the same the tension in each cable and their components are the same.

(b) Use trig to solve for the tension in each cable.



A sign that weighs 168 N is supported by two ropes, A and B, that make 22.5° angles with the horizontal. Determine the tension along the ropes.

* First label the diagram to view the components of each rope's tension.

Determine y-component of tension:

Fnety = 0 N

Fnety = 2Ty + Fg

0 N = 2Ty - 168 N

Ty = 84 N

Determine tension in each rope (remember they are the same if the angles are the same):

T = (Ty)/(sin θ°)

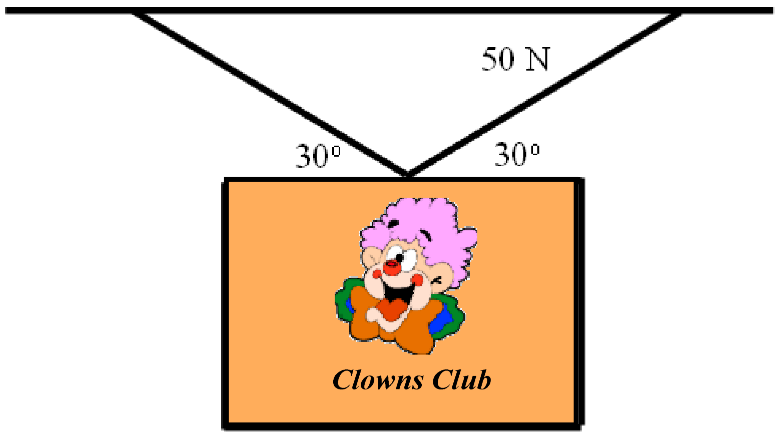
T = 84 N/sin 22.5°

T = 220 N

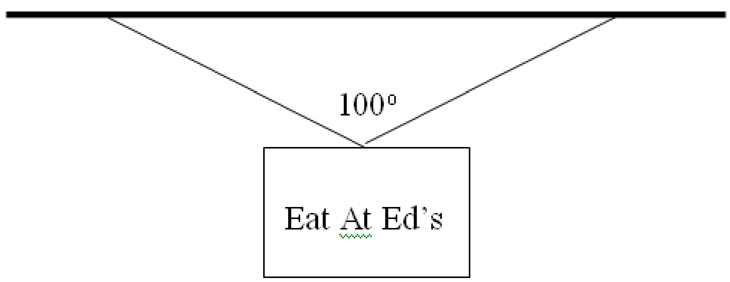
Physics 122/121

<u>Handout - Static Equlibrium -Hanging Signs</u>

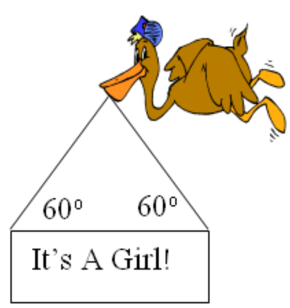
1. Find the magnitude of the weight of the clown's picture. (50 N)



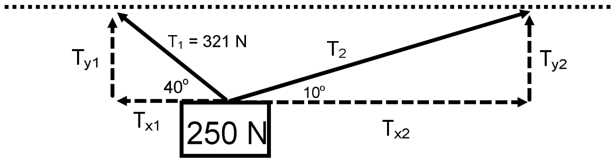
2. If the sign has a mass of 5.00 kg, what is the tension in the cables? (38 N)



3. The infamous stork announces good news. If the sign has a mass of 10 kg, then what is the force of tension in each cable? (57 N)

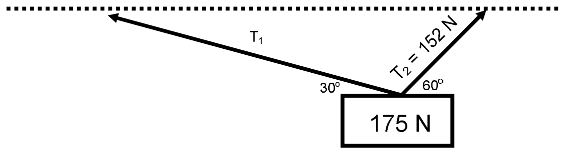


Determine T_{y1}, T_{y2}, T_2 , T_{x1}, and T_{x2} in the following sketch.



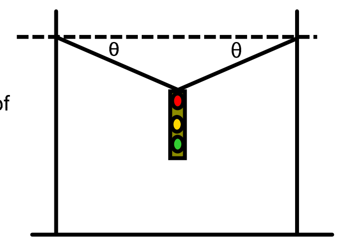
T_{y1} = 206 N
T_{y2} = 43.7 N
T_2 = 251 N
T_{x1} = 247 N (left)
T_{x2} = 247 N (right)

Determine T_1 in the following sketch.

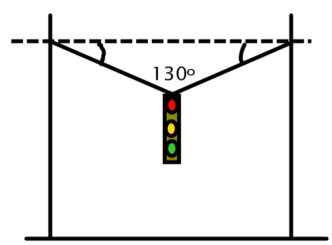


T_1 = 88 N

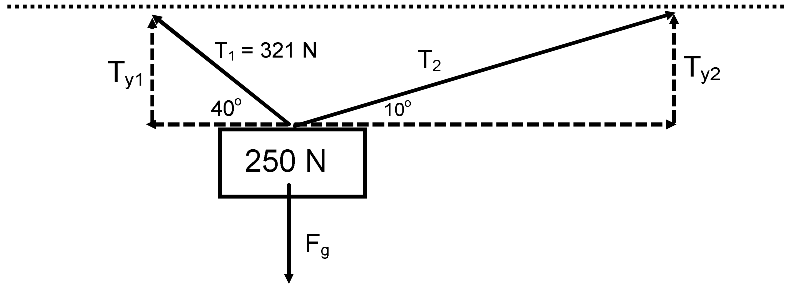
A traffic light is to be hung like in the diagram to the right (both angles are the same). The cable being used will break if their tension reaches 2100 N. What is the smallest angle that can be made if the lights have a mass of 110 kg? (Answer: 15°)



A traffic light is to be hung like in the diagram to the right. The cable being used will break if their tension reaches 1750 N. What is the largest mass that can be hung? (Answer: 151 kg)



Solution



Find T_{y1}

$$\sin(40) = \frac{T_{y1}}{T_1} = \frac{T_{y1}}{321}, \quad T_{y1} = 321\sin(40)$$

$$\boxed{T_{y1} = 206\,N}$$

Find T_{y2}

$$F_{nety} = T_{y1} + T_{y2} + F_g$$

$$0 = 206N + T_{y2} - 250N$$

$$-206N + 250N = T_{y2}$$

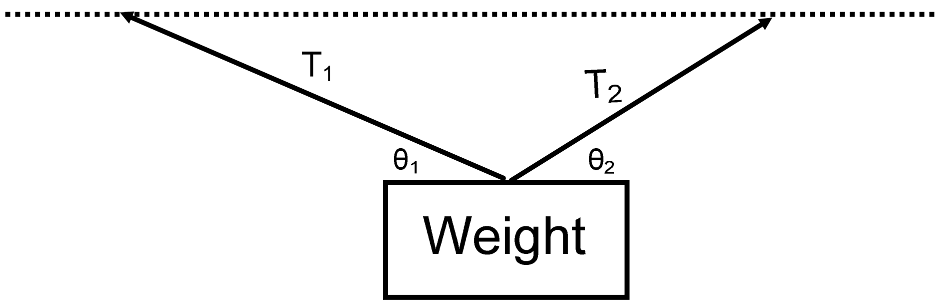
$$\boxed{44\,N = T_{y2}}$$

Find T_2

$$\sin(10) = \frac{T_{y2}}{T_2} = \frac{43.7N}{T_2}, \quad T_2 = \frac{43.7}{\sin 10}$$

$$\boxed{T_2 = 251\,N}$$

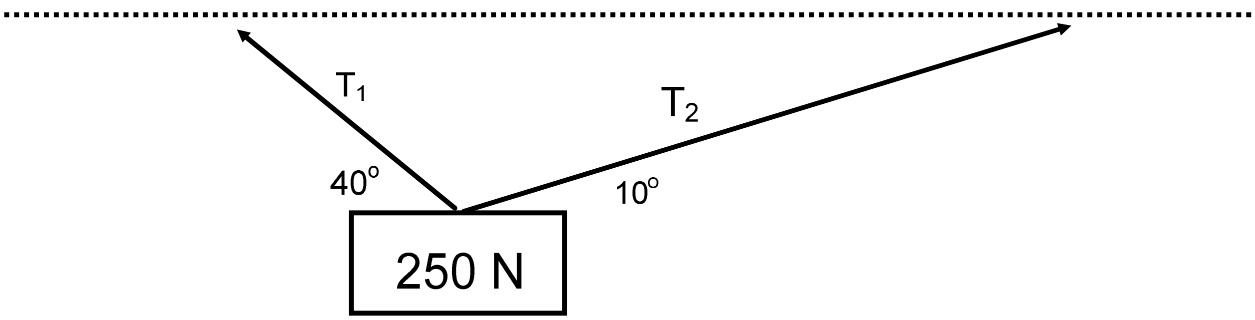
Given the following diagram, show $T_1 \cos\theta_1 = T_2 \cos\theta_2$



Don't Do

Challenge!!

Determine T_1, and T_2 in the following sketch.

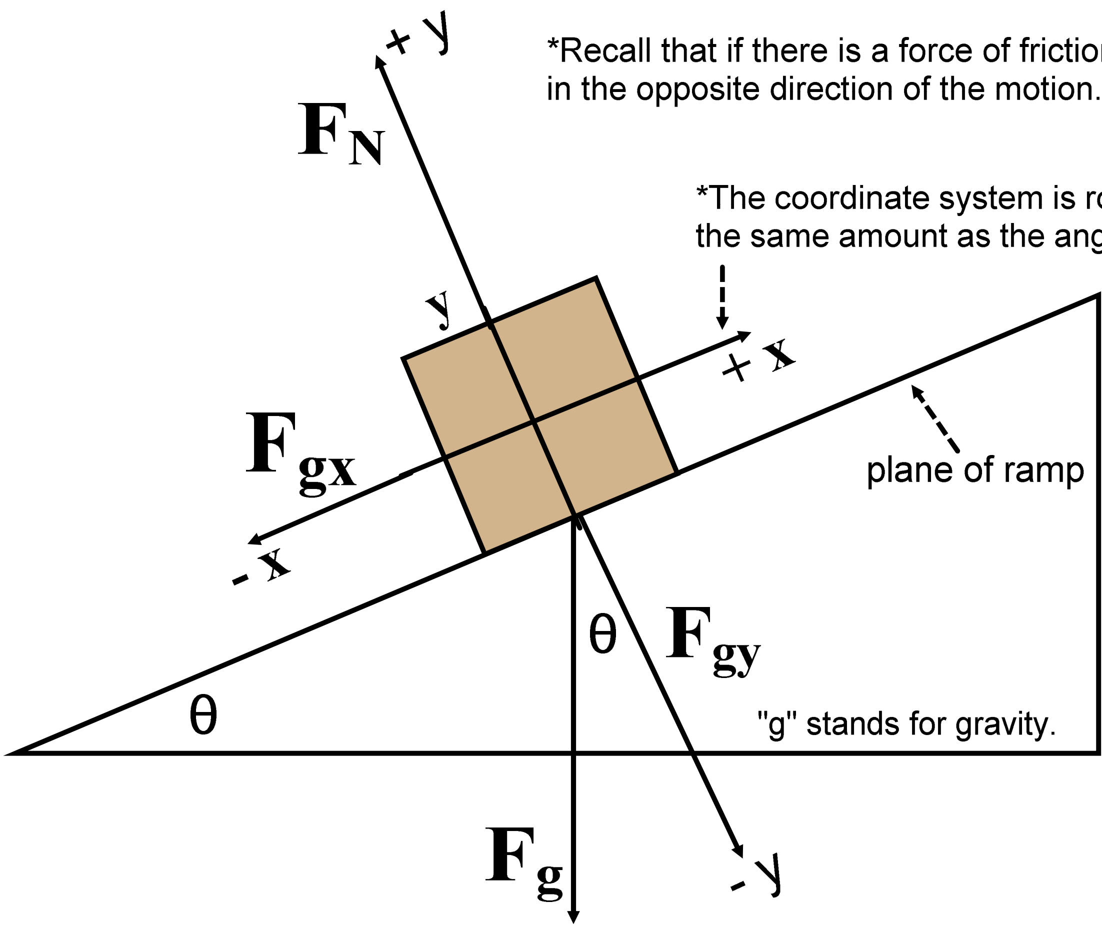


Don't Do

Type III - Inclined Planes, Hills, Ramps

(printed copy for students)

*Recall that if there is a force of friction it acts in the opposite direction of the motion.



F_{gy} and F_g are separated by θ because of two similar triangles.

$F_{gx} = F_g \sin\theta$ ⟵ component parallel to the plane.

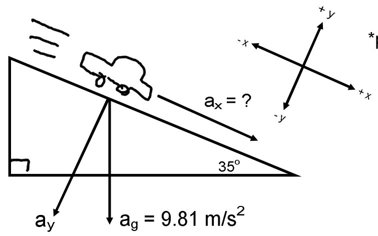
$F_{gy} = F_g \cos\theta$ ⟵ component perpendicular to the plane.

NOTE! The *sin* and *cos* have switched places. This will only happen when dealing with objects on a ramp.

NOTE FURTHER! Every ***F*** in the above diagram can be replaced with an ***a*** for acceleration.

Examples

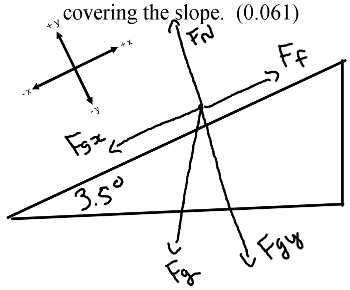
1. A 2300 kg car is rolling down a hill inclined at an angle of 35 °. What is the acceleration of the car? Neglect friction.



*positive direction is down the ramp.

Move to reveal solution

2. A skier coasts down a 3.5° slope at a constant speed. Find the coefficient of kinetic friction between the skis and the snow covering the slope. (0.061)



*positive direction is up the ramp.

$$\mu = \frac{F_f}{F_N} \xrightarrow{\text{force = mass x acceleration}} \mu = \frac{m\,\vec{a}_{fx}}{m\,\vec{a}_{Ny}}$$

a_f = acceleration from frictional force.

a_N = acceleration from normal force.

$$\vec{a}_{nety} = \vec{a}_{gy} + \vec{a}_{Ny}$$ ← "y" direction

negative vertical direction → $-(9.81)$

constant speed → 0

$$0 = -(9.81)\cos 3.5^\circ + \vec{a}_{Ny}$$

$$9.79\ \text{m/s}^2 = \vec{a}_{Ny}$$

$$\vec{a}_{netx} = \vec{a}_{gx} + \vec{a}_{fx}$$ ← "x" direction

negative horizontal direction → -9.81

$$0 = -9.81 \sin 3.5 + \vec{a}_{fx}$$

acts up the ramp, so is positive →

$$0.599\ \text{m/s}^2 = \vec{a}_{fx}$$

$$\mu = \frac{\vec{a}_{fx}}{\vec{a}_{Ny}}$$

$$\mu = \frac{0.599}{9.79} = 0.061$$

Sample Problems - Inclined Planes

Handout

1. A trunk weighing 562 N is resting on a plane inclined at 30.0° from the horizontal. Find the components of the trunk's weight parallel and perpendicular to the plane.

2. A 562 N trunk is placed on a frictionless plane inclined at 30.0° from the horizontal. Find the magnitude and direction of the trunk's acceleration.

3. A worker places a large plastic waste container with a mass of 84 kg on the ramp of a loading dock. The ramp makes an angle of 22° with the horizontal. The worker turns to pick up another container before pushing the first one up the ramp. If the coefficient of static friction is 0.47, will the crate slide down the ramp?

4. A 1975 kg car is rolling down a hill inclined at an angle of 15°. What is the acceleration of the car? Neglect friction.

5. A skier coasts down a 3.5° slope at a constant speed. Find the coefficient of kinetic friction between the skis and the snow covering the slope.

6. You slide a 325 N trunk up a 20.0° inclined plane with a constant velocity by exerting a force of 211 N parallel to the inclined plane.

   a) What is the sum of your applied force, friction and the parallel component of the trunk's weight? Justify your answer.

   b) What is the magnitude and direction of the force of friction?

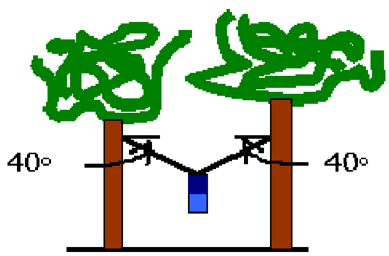
   c) What is the coefficient of friction?

Handout

Physics 122/121

Handout: Problems I, II and III

1. On a camping trip you stretch a rope between two trees and hang your backpack from the middle of it to keep it safe from bears. The mass of your backpack is 36.0 kg and each half of the rope makes an angle of 40.0° with the horizontal.
   a) Find the amount of weight supported by each half of the rope.
   b) Find the magnitude of the tension in each rope.



2. A 2.5 kg brick is pulled at a constant speed across a table by a cord that makes an angle of 20° with the horizontal. There is 7.0 N of force in the cord.
   a) Calculate the force of friction between the brick and the table.
   b) Calculate the normal force.

3. Joey moves a 26 kg wagon at a constant speed by pushing on the handle that makes an angle, theta, with the horizontal. Joey exerts a force of 54 N on the handle and the force of friction on the wagon is 34 N.
   a) Calculate the angle the handle of the wagon makes with the horizontal.
   b) What is the magnitude of the normal force acting on the wagon?

4. A 10 N block is held motionless on a frictionless inclined plane which makes an angle of 30° with the horizontal. What force would be needed to hold the block in position?

5. An object weighing 600 N is pulled up a frictionless incline at a constant speed using a rope. If the incline makes an angle of 42.0° with the horizontal, what is the magnitude of the force that is applied to the rope?

6. A 10 kg object, starting from rest, slides down a frictionless incline with a constant acceleration of 2.0 m/s^2. What angle does the incline make with the horizontal?

7. An object with a mass of 7.2 kg is allowed to slide from rest down an inclined plane. The plane makes an angle of 30° with the horizontal and is 65 m long. The coefficient of friction between the plane and the object is 0.45. What is the velocity of the object at the bottom of the plane?

8. A piano is accelerating down a ramp that is inclined at an angle of 38.5° above the horizontal. The acceleration is 4.62 m/s^2. What is the coefficient of friction between the piano and the ramp?

Answers

1. a)Each half of the rope supports half of the weight of the backpack, 176 N.
   b)The tension in each rope is 274 N.

2. a)The force of friction is 6.6 N, in a direction opposite to the motion of the brick.
   b)The magnitude of the normal force is 22 N.

3. a)The handle makes an angle of 51° with the horizontal.
   b)The normal force is 3.0×10^{2} N, up.

4. A 5.0 N force exerted up the incline would be needed.

5. It is 401 N.

6. The incline makes an angle of 12°.

7. The velocity of the object is –12 m/s.

8. The coefficient of friction is 0.19.

Practice for the Test

A 120 N weight is pushed to obtain constant speed. The applied force is 80 N at an angle of 40^o to the horizontal. What is the coefficient of static friction?

A 25 kg box is placed on an incline 33^o to the horizontal. The coefficient of friction is 0.38. Find the acceleration of the box.