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Office Hours:

M-Th 8:30am-9:00am classroom
Monday 1:10-2:40 pm, MS 157
Thursday 1:10-2:40 pm, MS 306

Introduction

Introduce yourself

Name

Major

Reason for taking this course

What would you like to get from this class

Greet classmates and collect email and phone number from 4+ of them.

Rule of thumb: 3-6 hours study

Syllabus

Units

Length, Mass, & Time

Property	SI Base Unit	Derived Property
Length	Meter (m)	Area Volume
Mass	Kilogram (kg)	Density Weight
Time	Second (s)	

Problem solving: what property?

Property	SI Base Unit	Derived Property
?	Meter (m)	Area (m^2) Volume (m^3)
?	Kilogram (kg)	Density (kg/m^3) Weight (N)
?	Second (s)	

SI Units
SI Prefixes
Unit Conversion Factors

Conversion

- What is the speed limit in residential area?
- How many meters per second is that?
- How many meters does a car move in 3 seconds when it's going at the speed limit?

Marathon

- 26.2 miles = _____ km

Volume Conversion

- 1 c.c. = _____ m^3

Problem Solving Steps

Read *3 Diagram Known/Unknown	v = 25 mi/hr v = ____ m/s
Physics	1 mi = 1.609 km = 1609 m 1 hr = 3600 s
Math	25 mi = 25 mi * 1609 m/mi 1 hr = 1 hr * 3600 s/hr 25 mi/hr = (25*1609)/3600 m/s =
Answer	11.17 m/s

Feedback for the instructor

Quarter Page Survey

Measurement Inventory

Basic Properties	Derived Concepts	Useful References	Problem Solving Skills
Length (m)	Density	SI Base Units	Unit Conversion
Mass (kg)	Area	Unit Conversion Factors	
Time (s)	Volume	SI Prefixes	

Read
Read
...
Read between the lines

How to Analyze a Problem

Read this problem

- A leaking truck might lose 2.3 kg of sand per hour. Express the mass loss rate in grams per second.

- Photo credit: animation factory

Analyze the problem

- 2.3 kg
- per hour
- Express
- Grams per second

- Mass
- Time
- Unit Conversion
- 1 kg = 1000 grams
- 1 hour = 3600 seconds

Upon reading this

Did you realize

Significant Figure

- Do the two weather men's snow report agree with each other?
- A: 12 inches
- B: 13 inches

12+/-1: [11in, 13in]
13+/-1: [12in, 14in]
They agree.

Significant Figures

- Addition Rule

The number of decimal places in the result should equal the smallest number of decimal places of any term in the sum.

- 1.2 + 21.456 = 21.6~~56~~

- Multiplication Rule
- The number of significant figures in the final product is the same as the number of significant figures in the least accurate of the facotrs being combined.
- 1.2 * 21.456 = 25.~~7472~~ = 26

Unit Conversion Quiz

_____ (city) grocery store has a loaf of bread labeled 1.5 kilo.

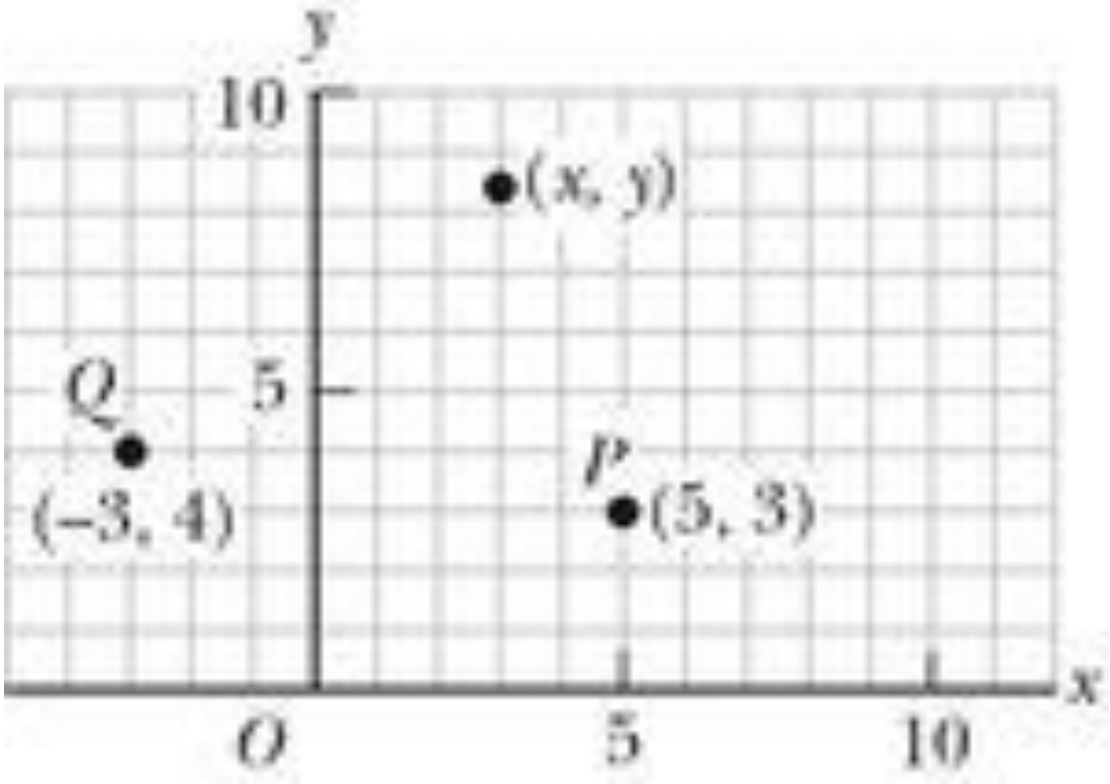
1. What physical property is given here?

   (hint: remember the three?)

2. What's corresponding US units?

3. Convert to US units.

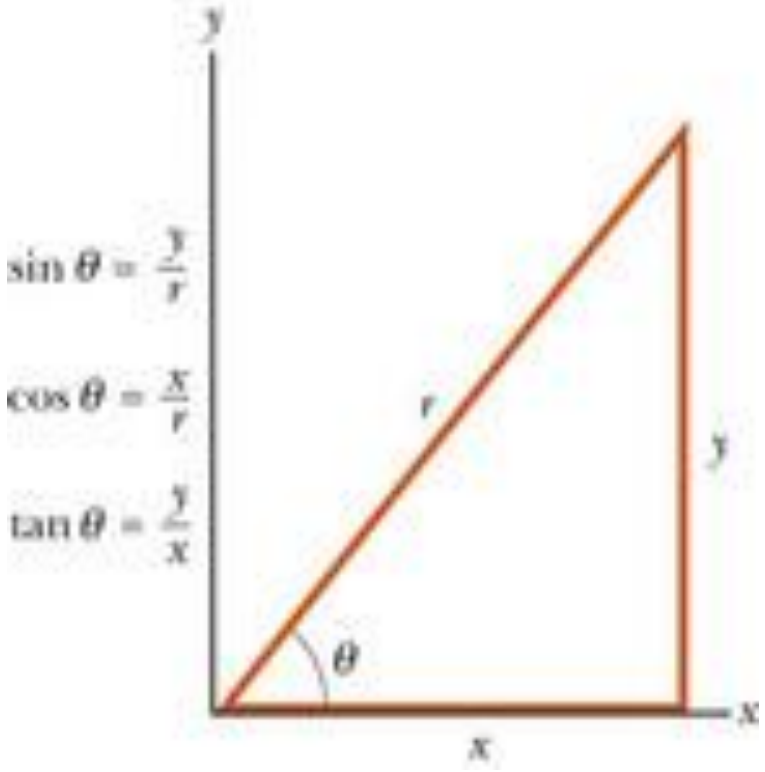
Coordinate Systems



Trigonometry

- $r^2 = x^2 + y^2$

- $x = r \cos\theta$
- $y = r \sin\theta$



Quiz

- What is 1 micrometer in meters?
- Convert 1 micrometer to centimeters.

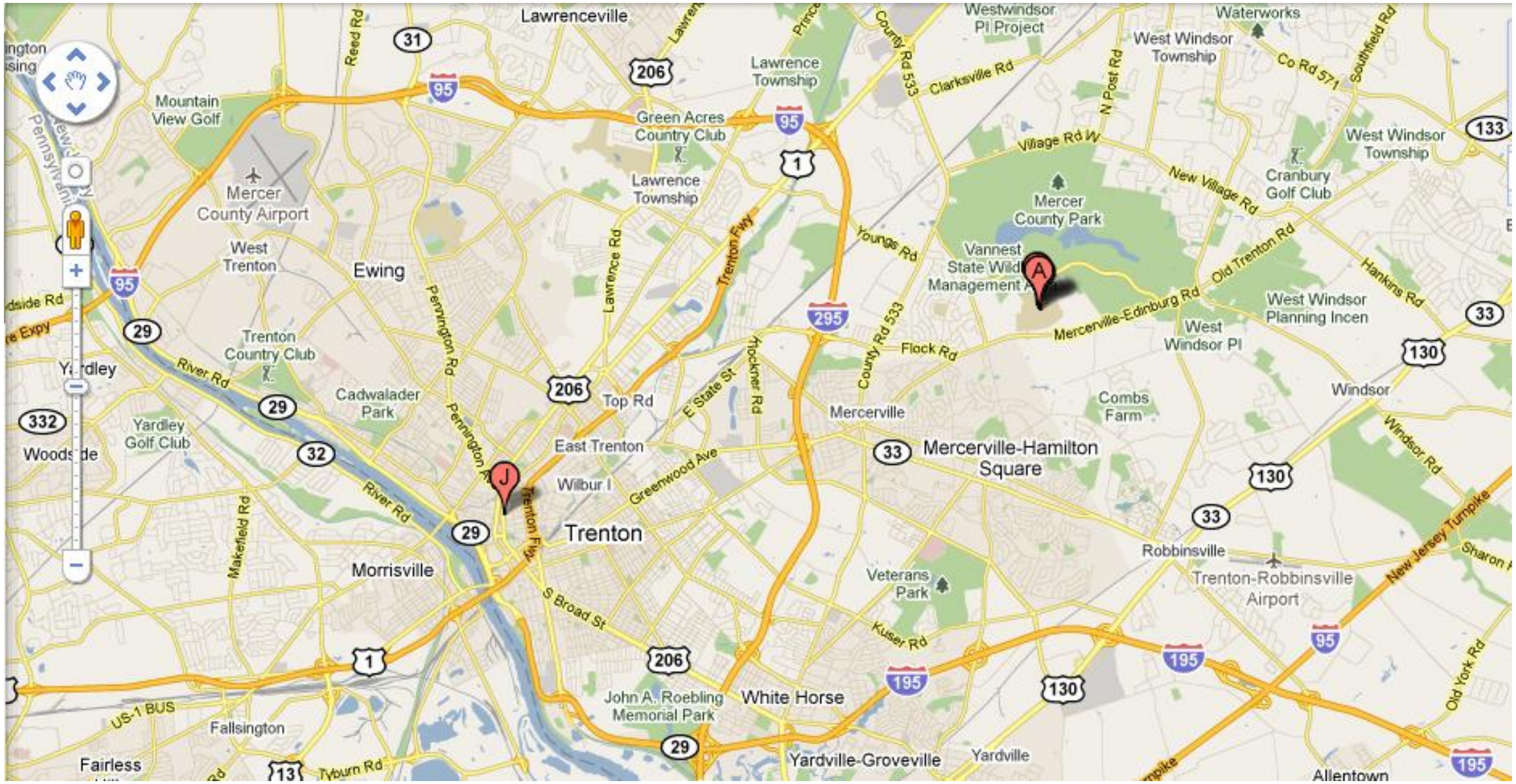
Quiz

Question:

A gallon of gasoline can be purchased with $3.50. Can one gallon of soda be purchased with the same money?

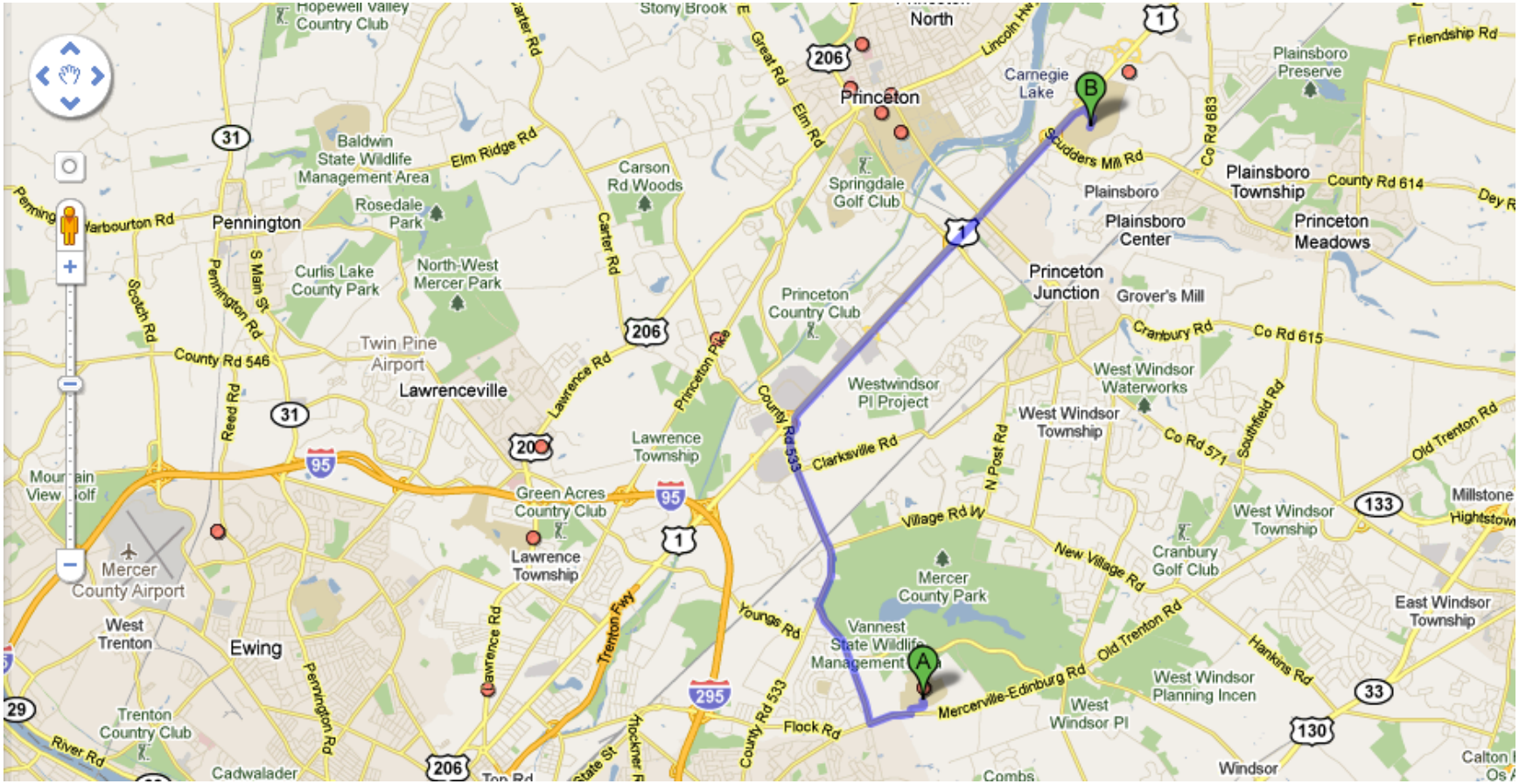
(Caferteria price: 20 oz = $1.25 pint)

Position



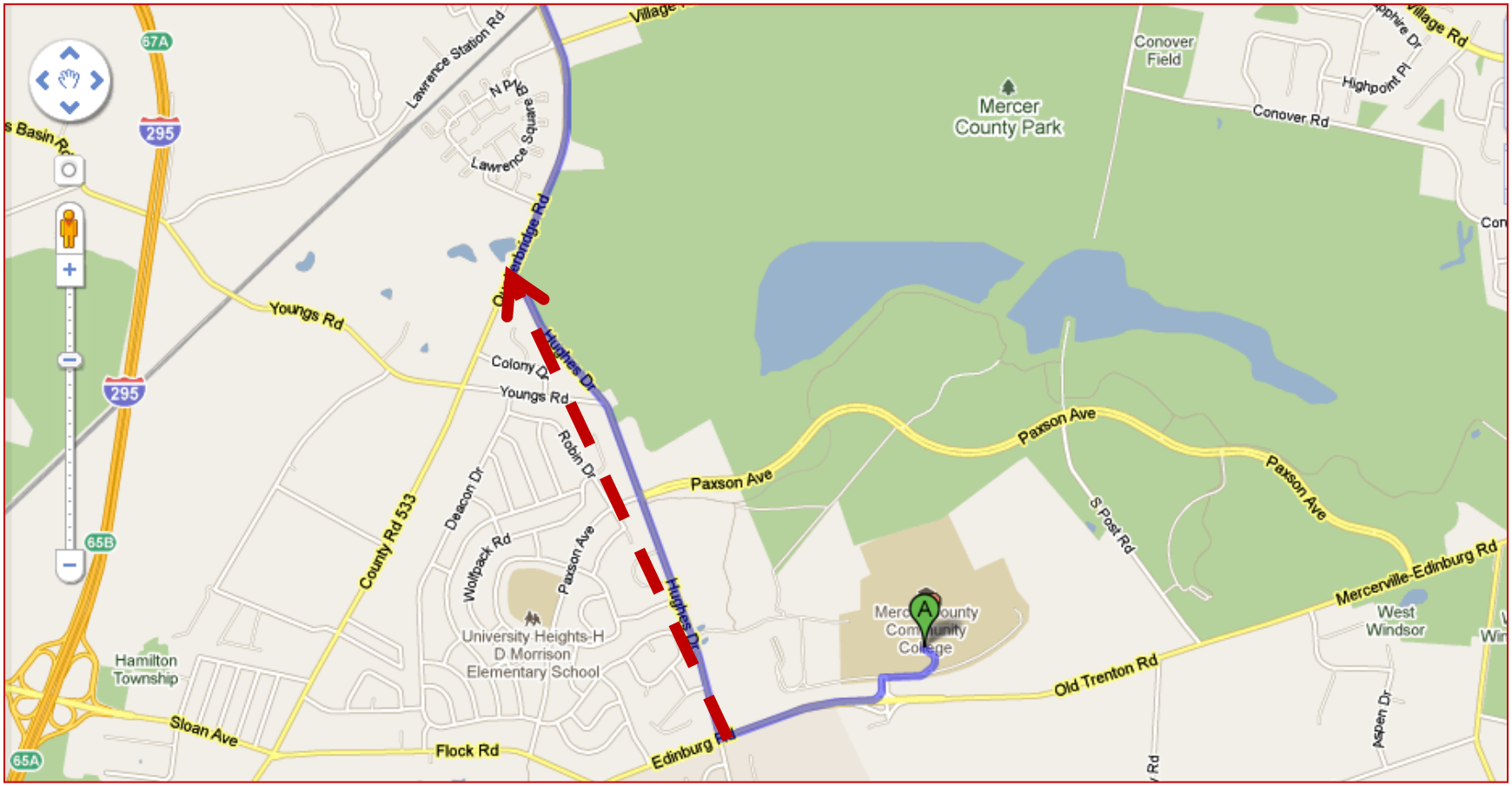
Lawrenceville
Mountain View Golf
Mercer County Airport
West Trenton
Ewing
Trenton Country Club
Cadwalader Park
Yardley Golf Club
Morrisville
Trenton
East Trenton
Lawrence Township
Green Acres Country Club
Mercer County Park
West Windsor Township
Cranbury Golf Club
Mercerville
Mercerville-Hamilton Square
Combs Farm
Windsor
Robbinsville
Trenton-Robbinsville Airport
Veterans Park
White Horse
John A. Roebling Memorial Park
Yardville-Groveville
Yardville
Allentown
Fallsington
Fairless
Woodside

Distance – 11.3 miles

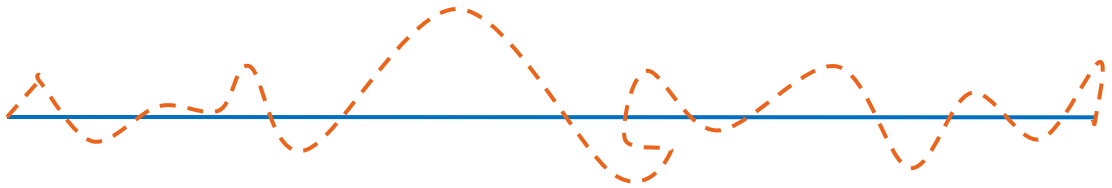


Average Speed

Displacement



Dennis walking a dog



- Dennis walked 200 meters straight.
- What displacement and distance for both?

Motion Along a Straight Line

Position:

$$x_i = 0 \text{ m}$$

$$x_f = 200 \text{ m}$$

Displacement:

$$\Delta x = x_f - x_i = 200 \text{ m}$$

Average Velocity

- Given displacement and time

$$v_{ave} = \frac{\Delta x}{\Delta t}$$

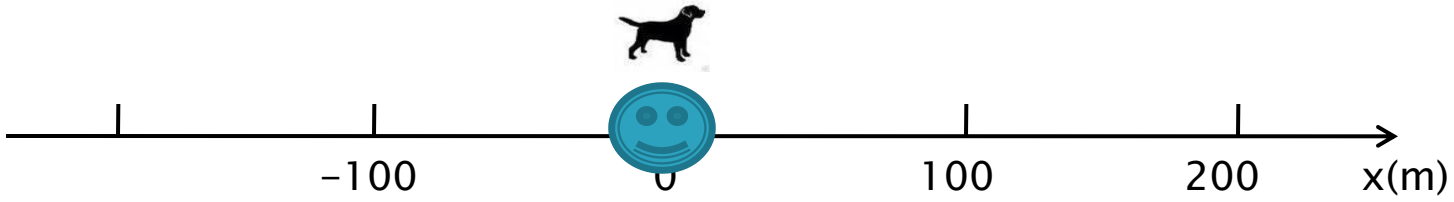
Average velocity

$$Average\ Age = \frac{Total\ Age}{Total\ Number\ of\ Students}$$

$$Average\ Gas\ Price = \frac{Total\ Price}{Number\ of\ Stations}$$

$$Average\ Velocity = \frac{v1 + v2 + v3}{3}$$

Not a straight line



	Dennis	Dog
Position:	$x_i = 0$ m	_____
	$x_f = 200$ m	_____
Displacement:	$\Delta x = x_f - x_i = 200$ m	_____
Distance:	_____	320 m

Motion with Constant Velocity

A driver may cruise at a constant velocity.

Instantaneous velocity

- The velocity can be calculated every half second.

Numerical Simulation

- http://www.walter-fendt.de/ph14e/acceleration.htm

Average Acceleration

- A car tend to go faster and faster when driven down hill.
- A falling objects falls faster and faster along the way.

$$a_{ave} = \frac{v_f - v_i}{\Delta t}$$

$$Unit: m/s^2$$

Braking

- A car moving 11.17 m/s brakes with an average acceleration of $-3\ m/s^2$. How long will take it to stop?

Acceleration is negative

$$a = -3\ m/s^2$$

$x(m)$

$$v_i = +11.1\ m/s; \qquad v_f = 0\ m/s;$$

$$t = ?$$

$$a_{ave} = \frac{v_f - v_i}{\Delta t}$$

$$\Delta t = \frac{v_f - v_i}{a_{ave}} = \frac{0 - 11.1\ m}{-3\ m/s} = +3.7\ s$$

Constant acceleration

- Enter the equations for the following relationship:

a, v_0, t, v_f _____

$a, v_0, t, \Delta x$ _____

$a, v_0, v_f, \Delta x$ _____

Instantaneous Motion

- Displacement

$$x(t)$$

- Velocity

$$v(t) = \frac{d}{dt}x(t)$$

- Acceleration

$$a(t) = \frac{d}{dt}v(t) = \frac{d^2}{dt^2}x(t)$$

When you read,

- “Stops” $v(t)=0$
- “Positve t” after an arbitrarily chosen $t=0$ momention.
- “Negative t” before an arbitrarily chosen $t=0$ moment.
- “Maximum velocity” when $a>0$ turns to $a=0$

Half Meter Free Fall

- Drop a pencil with one hand and try to catch it with the other hand half meter lower.
- Try it with a buddy.
- How much is human reaction time?

Sky Dive

Skydiving in front of Mount Everest

Free fall model

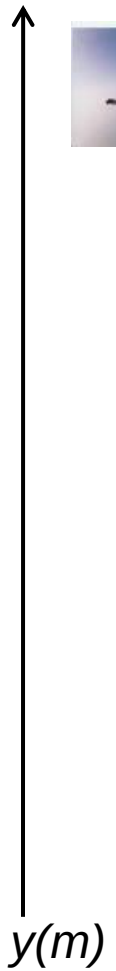
- no air resistance
- no wind

Question: what is the velocity at the end of 1 minute?

Free Fall

- Neglect air resistance and wind

$$g = 9.8\ m/s^2$$



Free Fall Path

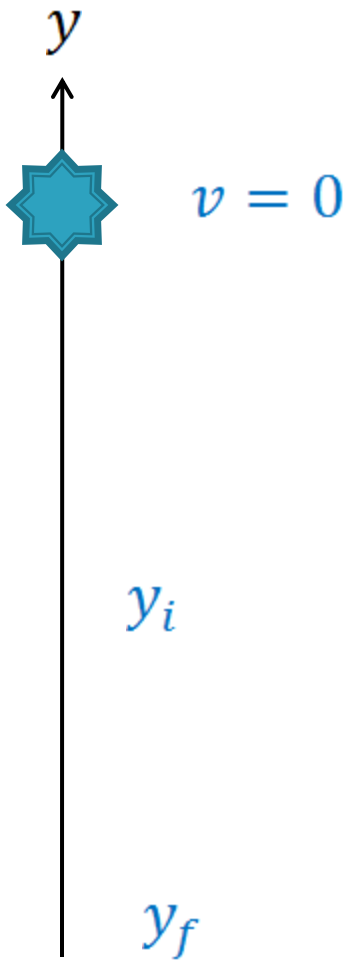
- Y-axis and Acceleration

$$g = 9.8\ m/s^2$$

- Displacement

$$\Delta y = y_f - y_i$$

- Highest point



1-D Motion

Basic Concepts	Definition	More Concepts
Position	x	
Displacement	$\Delta x = x_f - x_i$	distance
Average Velocity	$v_{ave} = \Delta x/\Delta t$	Instantaneous Velocity $v = \lim_{t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$ Average speed
Average Acceleration	$a_{ave} = \Delta v/\Delta t$	Instantaneous acceleration $a = \lim_{t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$

Analyze a problem

- P75

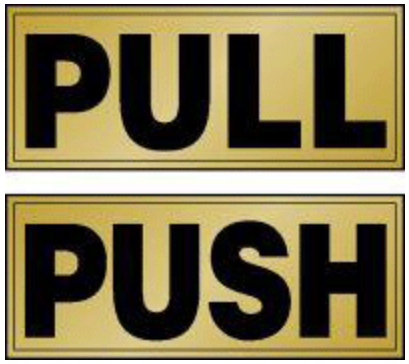
Equations of motion

- $x = 25t^2 + 5\ t + 2$ (meters)
- $v = 2*25t + 5$ (meters per second)
- $a = 2 * 25$

Quiz

- A car travels up a hill at a constant speed of 40 km/h and returns down the hill at a constant speed of 60 km/h. Calculate the average velocity and average speed of the trip.

Direction

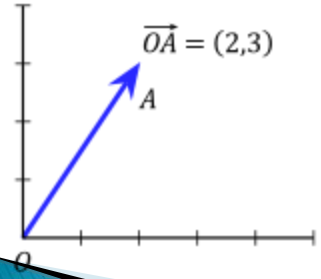


- Which property needs direction?

  mass, time, volume, color, velocity, displacement, acceleration, density, distance, speed, force

Vectors vs. Scalars

Vector	Scalar
force	mass
displacement	time
velocity	volume
acceleration	color
	density
	distance
	speed



Vector Components

$\vec{a}$ *has three components:* a_x, a_y, a_z

$$\vec{a} = a_x\hat{\imath} + a_y\hat{\jmath} + a_z\hat{k}$$

Vector Addition

Vector Multiplication

1-D Motion Models

- Const. Velocity

$$\Delta x = vt$$

- Const. acceleration 

$$\Delta x = v_0 t + \frac{1}{2} a t^2$$

- Free fall

$$\Delta x = v_0 t + \frac{1}{2} a t^2 \qquad a = -9.8\, m/s^2$$

Quiz

- A bullet is dropped in the air. How long does it take to fall 1.9 cm?

- If a bullet is shot horizontally, how long does it take for the bullet to drop 1.9 cm along the vertical direction?

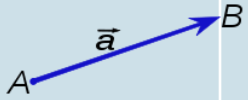
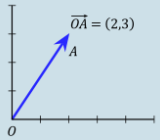
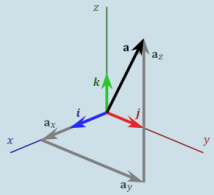
2-D and 3-D Motions

Rock or Rocket

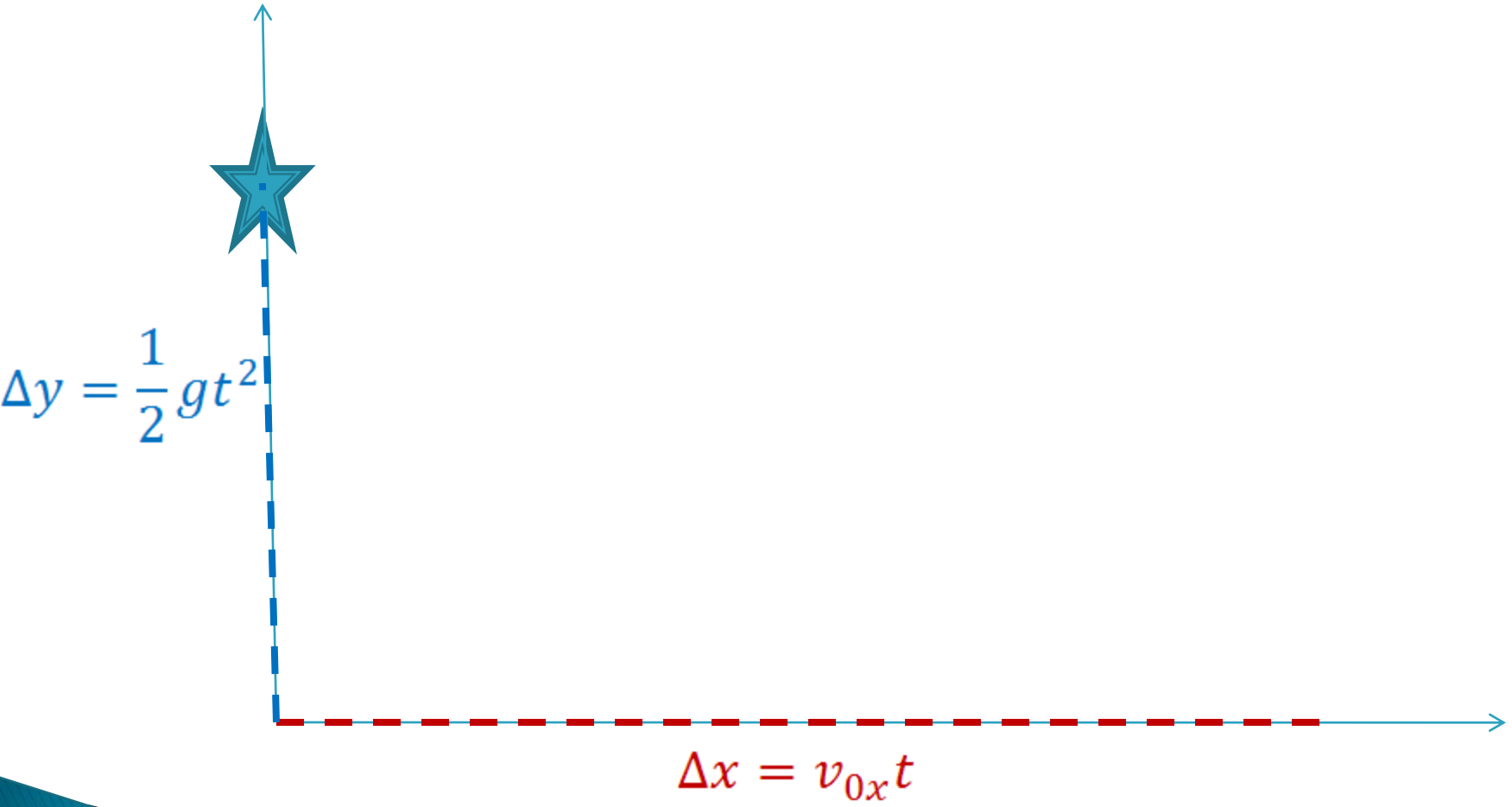
- Ski jump, basket ball, football, rock
  - 1D: forward
  - 1D: up – down
  - No left – right
- Rocket
  - 1D: forward
  - 1D: up – down
  - 1D: left & right

Image source: NASA

Motion Description

	1-D	2-D	3D
			
Time	t	**t**	t
Displacement	Δx	**Δx** **Δy**	Δx Δy Δz
Velocity	v	**v_x** **v_y**	v_x v_y V_z
Acceleration	a	**a_x** **a_y**	a_x a_y a_z

Motion in 2D: 2=1+1



Projectile motion

- A jet plane traveling horizontally at 100.0 m/s drops a rock. When the rock has fallen 1.0 km, find
- A. its velocity in the x direction
- B. its velocity in the y direction
- Neglect air resistance.

Solving two 1D motions side by side

- x
-

- y

x

y

What's wrong in this?

This is a common error in PHY 101 tests:

$$\Delta y = v_{0x}t + \frac{1}{2}a_y t^2$$

- Ball rolling of table top P22

Newton is for Forces

- Weight (Free fall, object on table)
- Tension (P15)
- Normal Force (object on table, in chair, roller coaster)
- Friction (box on table with a scale to pull)

- Force Diagram, a.k.a. free body diagram

Universal Gravitation & Weight

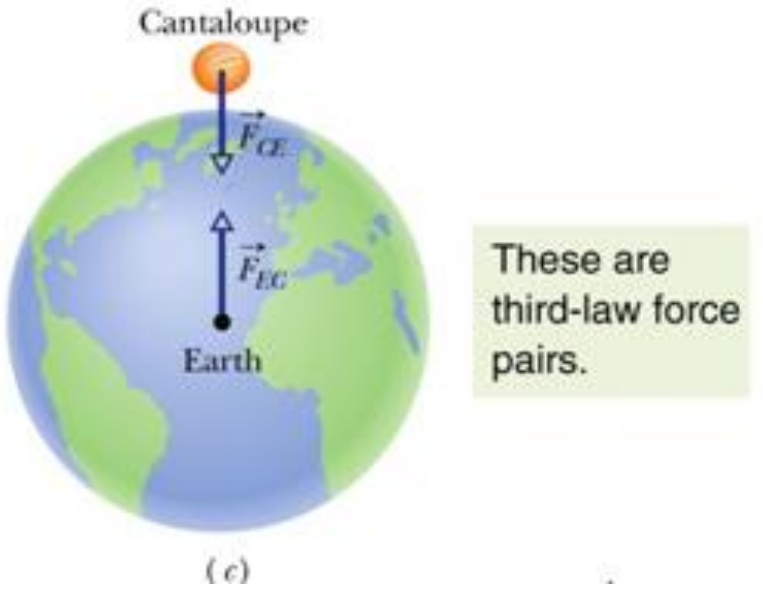
$F = G\, m_c m_E / r^2$

$F = m_c (G\, m_E / r^2)$

$F = m_c g$

$g = 9.8\ m/s^2$

Units: Newton.



Tension

- The direction is along the string or rope.
- It points away from the object
- The magnitude is the same along the entire string or rope.

Normal Force

- Normal force is pushing force against objects in contact.
- Perpendicular to contact surface
- The direction is away from the contact surface.

Newton's First Law

$$\begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \end{cases}$$

Newton's Second Law

$$\begin{cases} \sum F_x = ma_x \\ \sum F_y = ma_y \end{cases}$$

Newton's Third Law

These are third-law force pairs.

Application for Newton's Laws

- Match properties, symbols, and units.

mass	F	m/s^2
force	a	N
acceleration	v	m/s
velocity	g	kg
gravitational acceleration	m	

Apply 3 Newton's Laws

- Match the scenario with the equation:

- One object in equilibrium — $F = m\,a$

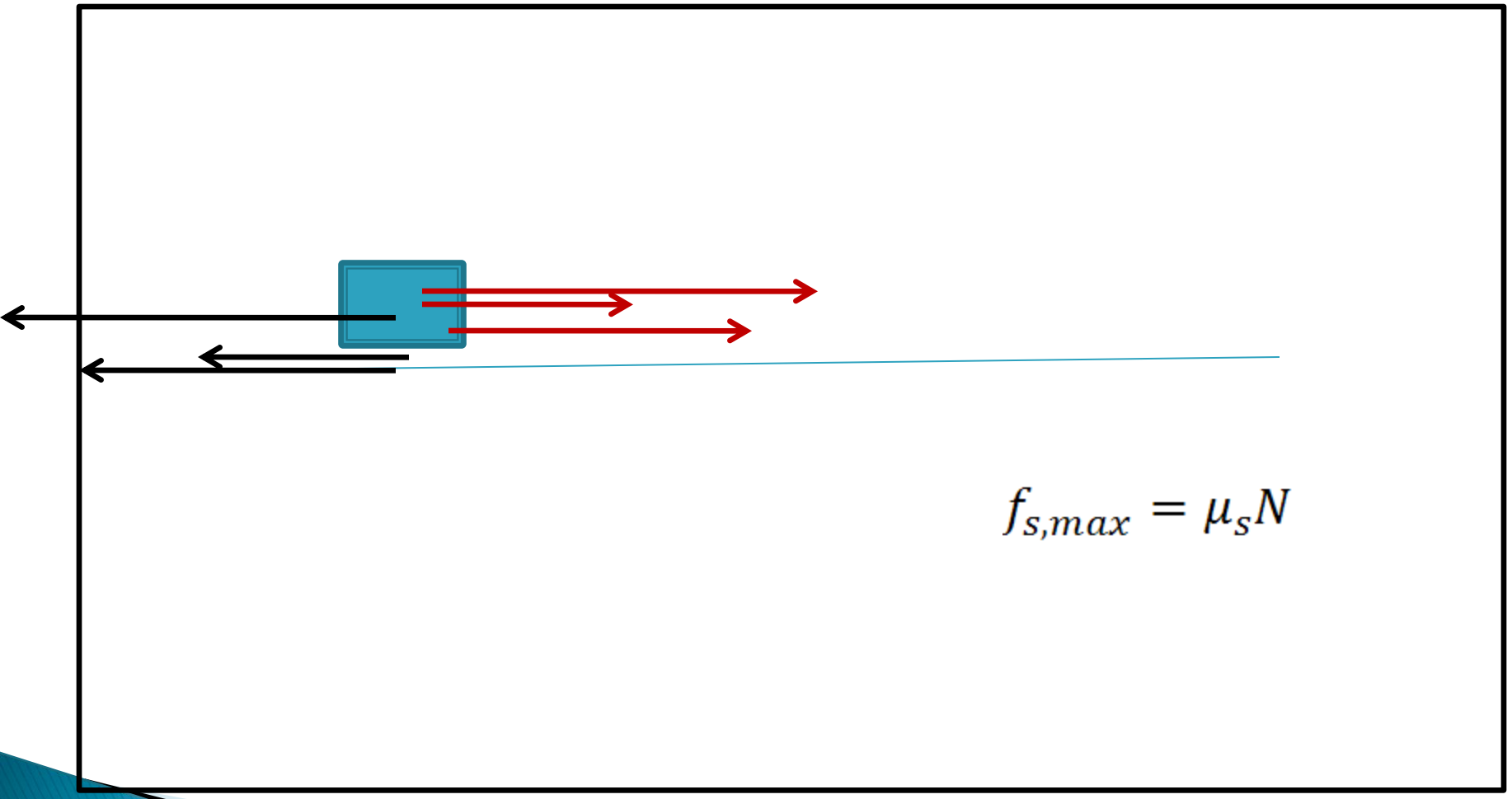
- One object with (constant) acceleration — $F = 0$

Two objects — $F_1 = -F_2$

Kinetic friction

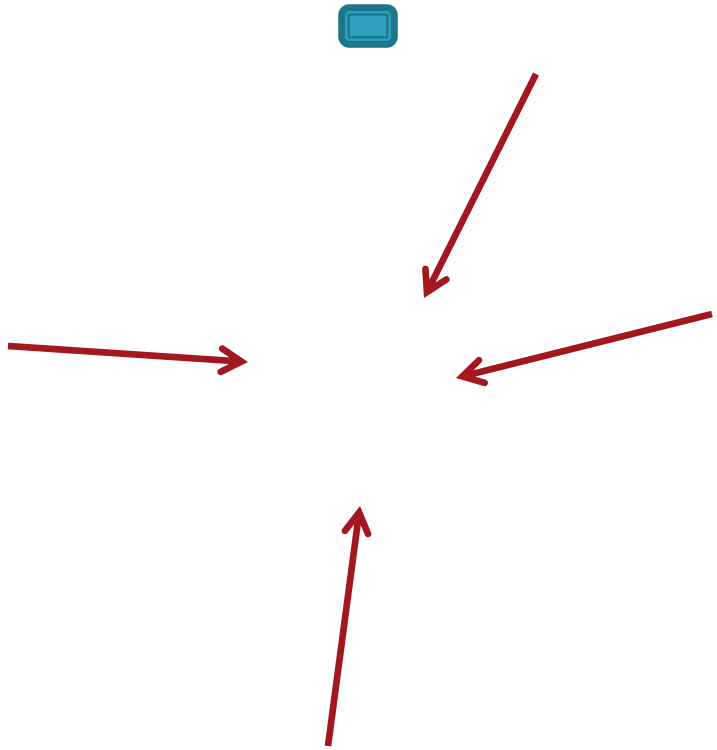
$$f = \mu_k N$$

Static friction



$$f_{s,max} = \mu_s N$$

Uniform Circular Motion



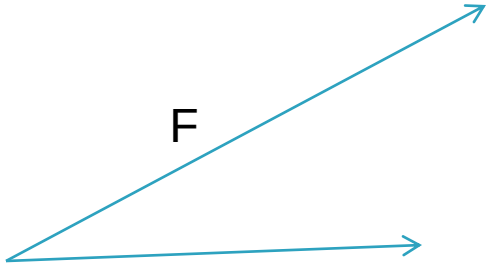
$$\sum F = m\frac{v^2}{R}$$

Centripetal Force

J is for Work

- When there is an angle between F and x

$$W = (F\cos\theta)\,\Delta x$$



- SI Unit

$$1 \text{ Joule (J)} = 1 \text{ N m} = 1 \text{ kg m}^2/\text{s}^2$$

Calorie

- 1 calorie = 4.186 J
- 1 Calorie = 1000 calorie

Kinetic Energy

- What's kinetic energy of a bullet?
- Mass = 50 g
- Velocity = 400 m/s

- $KE = \frac{1}{2} mv^2$

- Does a bag of snack contains more or less energy?

Work-Energy Theorem

- The net work done on an object is equal to the change in the object's kinetic energy.

$$W_{net} = \frac{1}{2} mv^2 - \frac{1}{2} mv_0^2$$

Friction does dissipative work

- When a car brakes, where did the kinetic energy go?

$$-f\,\Delta x = EK_f - EK_i$$

Braking

- A 1000 kg car is moving at 11.17m/s. What is it's kinetic energy?

- If the car is brought to a full stop through friction. How much work is done by friction?

Gravitational Potential Energy

- Object near earth surface
- Mass: m
- Height: y

$$PE = mgy$$

- SI Units

$$1 \text{ Joule (J)} = 1 \text{ kg m}^2/\text{s}^2$$

Conservation of Mechanical Energy

- (Condition) If an object has only gravitational force doing work, (Law) its mechanical energy is conserved.

$$\tfrac{1}{2} mv_1^2 + mgy_1$$

$$=$$

$$\tfrac{1}{2} mv_2^2 + mgy_2$$

What's wrong here?

- An object's kinetic energy is always conserved.

$$\tfrac{1}{2} mv_1 + mgy_1$$

$$=$$

$$\tfrac{1}{2} mv_2 + mgy_2$$

What's wrong here?

- (Condition) If an object has only gravitational force doing work, (Law) its mechanical energy is conserved.

$$mv_1^2 + mgy_1$$

$$=$$

$$mv_2^2 + mgy_2$$

What is wrong here?

- (Condition) If an object has only gravitational force doing work, (Law) its mechanical energy is conserved.

$$\tfrac{1}{2} m v_1^2 + m g y_1^2$$

$$=$$

$$\tfrac{1}{2} m v_2^2 + m g y_2^2$$

Slide

Spring Potential Energy

- The force exerted by the spring

$$F = -kx$$

X – displacement from equilibrium

- The work done by the spring force is

$$W_s = -1/2kx^2$$

- Elastic potential energy

$$PE_s = 1/2\ kx^2$$

- P31 a&b

Power

- Average Power

$$P = W/t$$

- SI Unit

$$1 \text{Watt} = 1 \text{ J/s}$$

$$1 \text{ horsepower (hp)} = 756 \text{ W}$$

- p54

A Seemingly Difficult Problem

- Andy and his son Brian out having a walk with dog Max. They played a game: Andy and Brian are 500 feet apart and walk toward each other at speed of 20 ft/min and 15 ft/min. The dog runs between them at 50 feet/min and turn back every time it meets the father or the son.
- How far will each walk when they all meet?

Motions Studied

MOTION	MATH DESCRIPTION
1-D Motion w CONSTANT velocity	$v = \text{const}$ $x = vt$
1-D Motion w. CONSTANT acceleration (Free Fall)	$a = \text{const}$ $v = v_0 + at$; $x = v_0t + \frac{1}{2} at^2$ $v = gt$; $x = \frac{1}{2} gt^2$
2-D motion	$R^2 = R^2_x + R^2_y$ $\text{Tan } \theta = R_y/R_x$
1,2,3-D Motion under ONLY gravity	$KE_1 + mgy_1 = KE_2 + mgy_2$
1-D, 2- object collision	???

Collisions

1. Contact of two objects – m_1, m_2

2. during small time period – t

3. With large Force – F

Momentum and Impulse

- The Linear Momentum and Impulse

$$P = mv$$

$$I = F\,\Delta t$$

- SI Units

$$1\,\text{kg m/s} = 1\ \text{N s}$$

Impulse Momentum Theorem

(Condition) for a collision process

$$I = P_f - P_i$$

$$F \Delta t = m (v_f - v_i)$$

Dynamics – how force change motion

- Impulse – Momentum Theorem (short Δt)

$$F_{ave}\,\Delta t = P_f - P_i$$

Work – Energy Theorem (sizable time period)

$$F_{net}\,\Delta x = KE_f - KE_i$$

Newton's Second Law (instantaneous moment)

$$F = ma$$

Conservation of Momentum

- When no net external force acts on a system, the total momentum of the system remains constant in time.

  - $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$