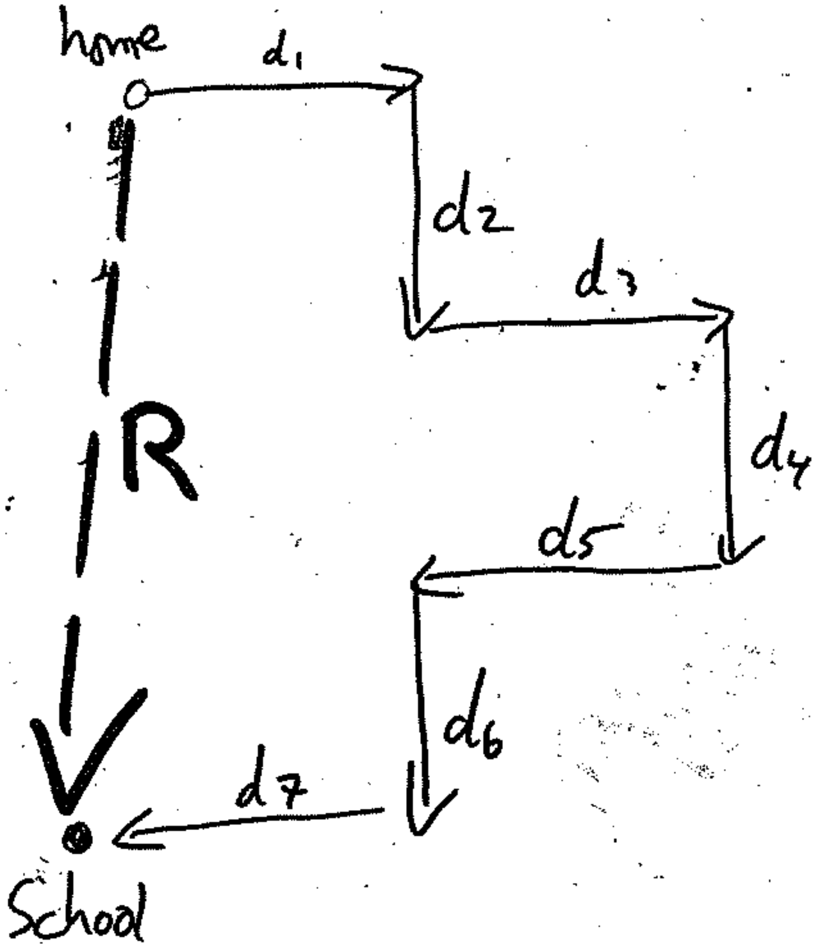
#1

Intro to Vectors

D = Distance travelled $= d_1 + d_2 + d_3 + d_4 \cdots$
$=$ 3mi + 2mi + 4mi + ...
= arithmetic sum of individual dists.

R = Displacement = how far from starting
(resultant) = vector sum of individ disps.



Vectors

Definitions

1. Vector Quantity – Has both magnitude (Quantity) AND direction

   eg.s 30m east (displacement) 12 m/s South (velocity) 9.8 m/s² downward (acceleration)

2. Scalar Quantity – A quantity completely described by its magnitude

   eg.s 30m (distance) 12 m/s (speed) 106 seconds

Magnitude – the amount OR size of a Quantity

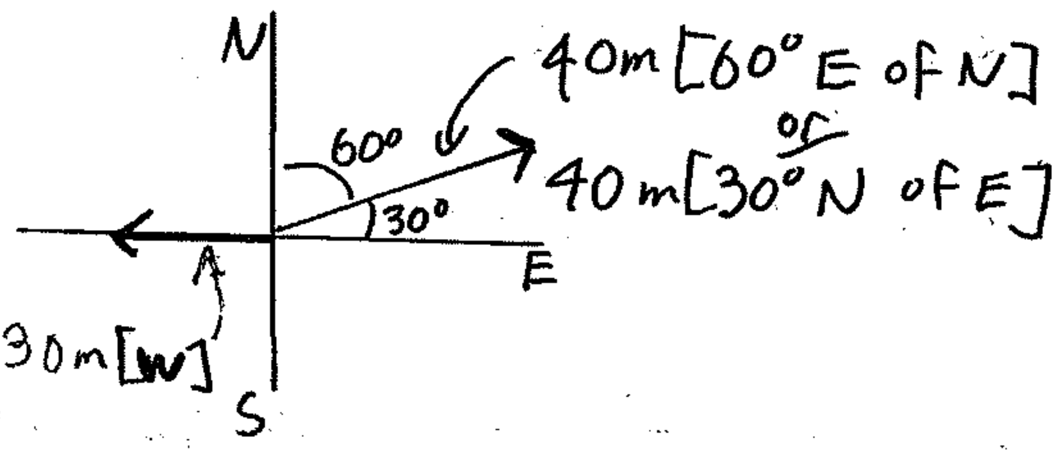
Drawing Vectors we can represent a vector quantity with an arrow. when drawn to scale the arrow's length represents the Magnitude AND the way it points represents the direction:

eg. scale 1cm = 10m

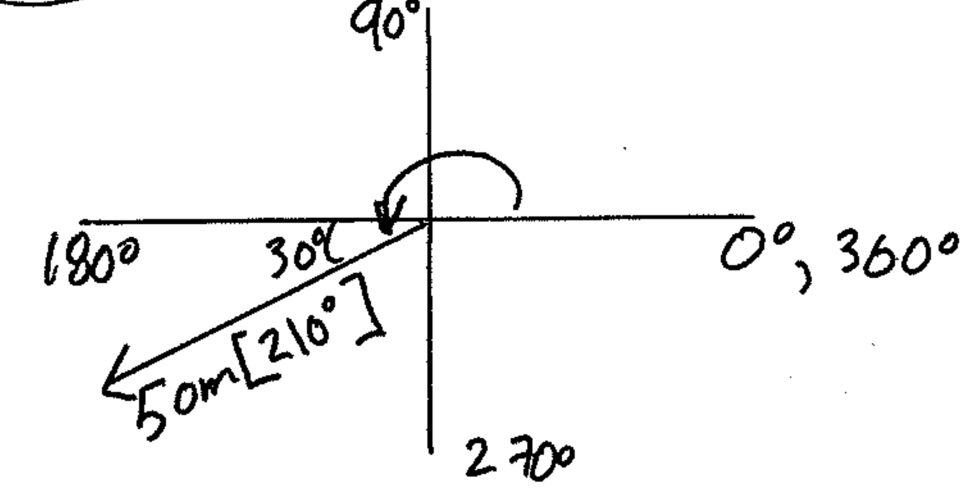
30m East

Compass directions There are 2 main ways of describing directions:

Method 1 : compass directions

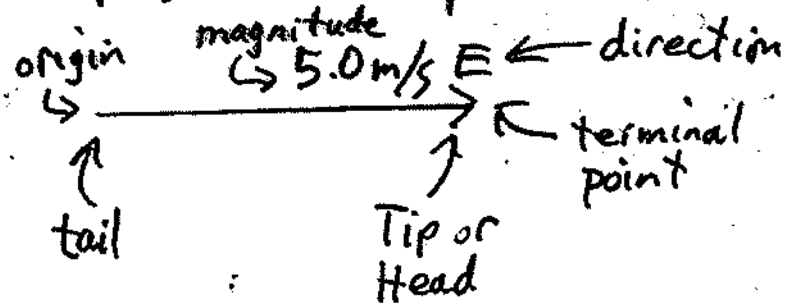


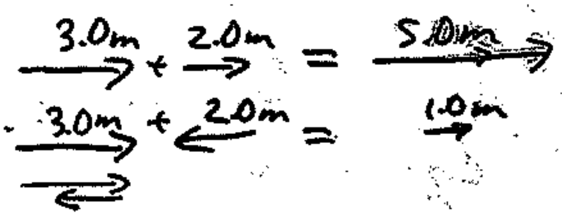
METHOD2: 360° circle

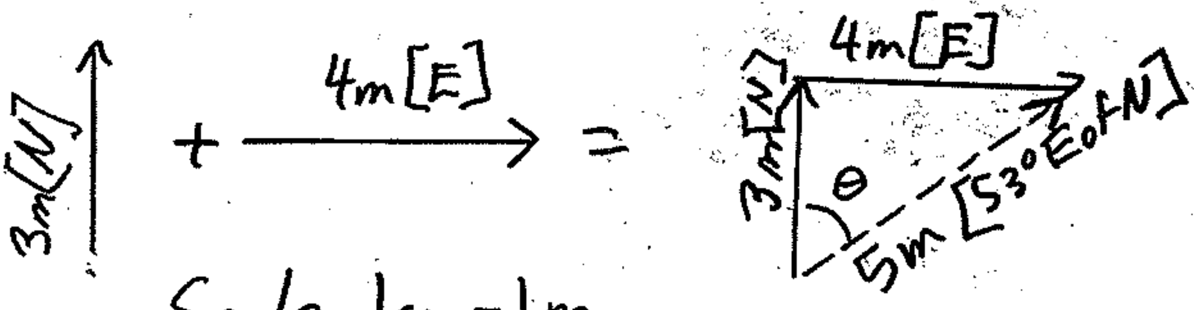


Adding Vectors – "Graphically"

Vectors are added "Tip" to "Tail". A dashed arrow is then drawn from the first "Tail" to the last "Tip" and is called the "Resultant". The resultant represents the "Sum" of the vectors.





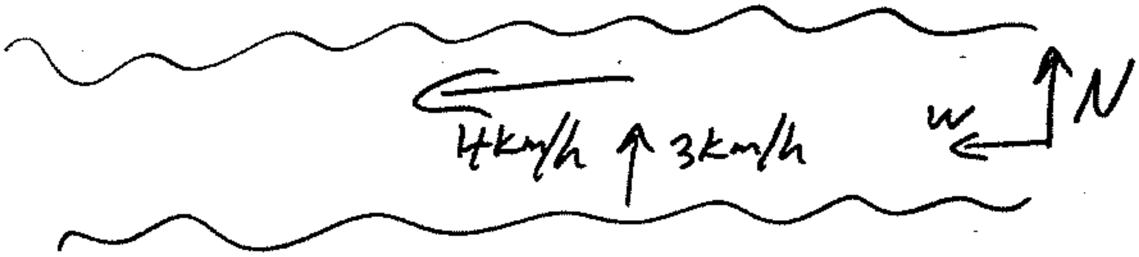


Scale 1cm=1m

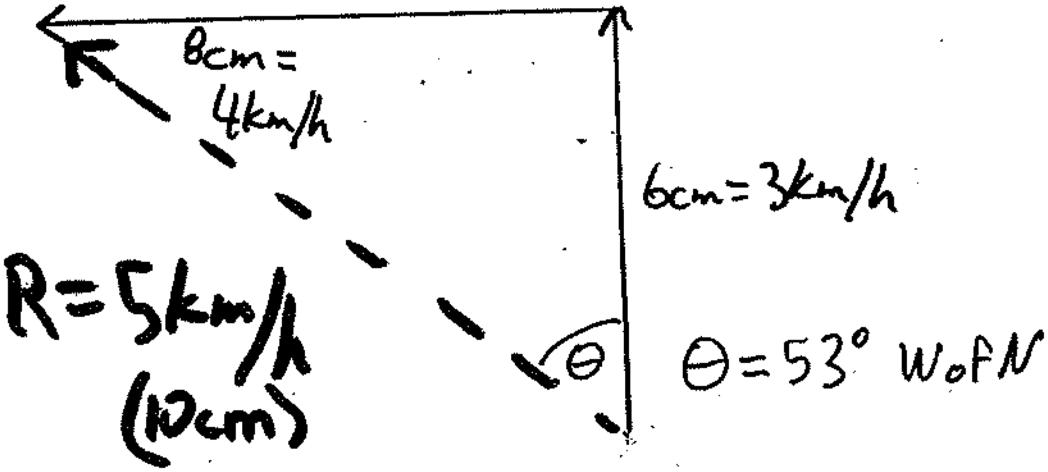
Measure θ with a protractor.

River Crossing Example:

A swimmer crosses a river at 3 km/h (N) North is straight across. The rivers current is 4 km/h (W). What is the swimmers actual (resultant) velocity?



Scale: 2cm = 1km/h



$$R = 5\,\frac{km}{hr}\left[53^\circ\, W\, of\, N\right]$$

VECTORS

Name ______________________

1. Imagine that the scale (ratio) of my vector diagram is 1 cm = 10 m. Now lets say that I measure the length of some vector from a drawing and made the following readings.

a) vector #1 = 5cm [N]
b) vector #2 = 2.6 cm [60 N of W]
c) vector #3 = 10 cm [E]
d) vector #4 = .5 cm [54 W of N]

Question: what is the actual value of the vector represented in my drawing.

a)
b)
c)
d)

2. Define the position and direction of each of the vectors below (assume they are position vectors and the scale is 1 cm = 20 m):

a)

c)

d)

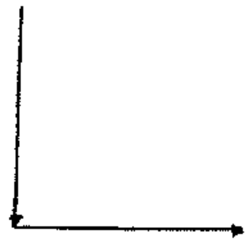
b)

3. Using the notation of the text what is another way to define the position of the following vectors.

a) 125 m [60 S of W]	a)
b) 50 m [35 W of N]	b)
c) 55 m [16 S of E]	c)
d) 12 m [12 E of S]	d)

4. What are the two possible positions for a vector described as 35 m [S of N]. (assume a scale of 1 cm = 10 m). Because there are two possible positions for thi vector we would never describe a vector's position this way. What are the t better ways?

5. Graphically add the following vectors. Scale 1cm=20m

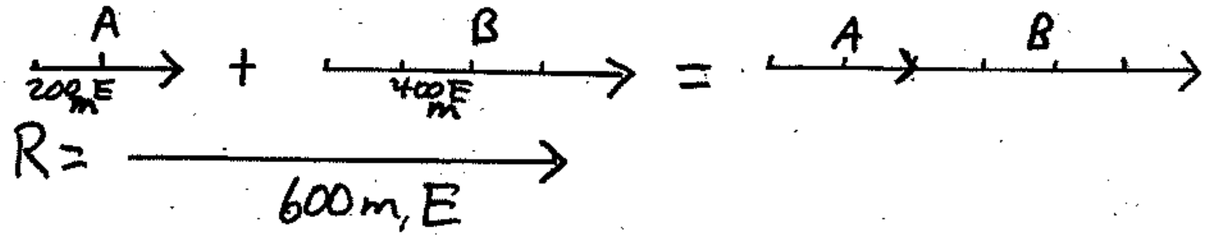


6. Bob leaves the house and travels 50 km north, 35 km east. Draw this trip with the proper scale in the space below and answer the following questions.

a) How far has Bob walked?
b) How far is Bob from his home? (scale 1 cm = 10 m)
c) specify the direction.

Adding Vectors: Linear
(one dimension)

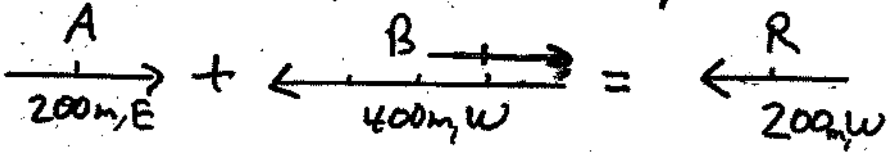
1) A woman walks 200m, E, then 400m, E, what is her displacement? scale 1 div = 100m



Note: displacements <u>add</u> if in <u>same</u> direction

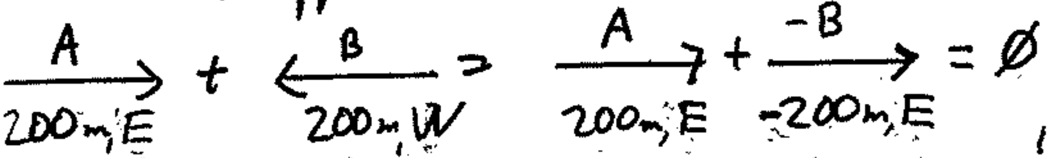
"Tip" to "Tail" - Applies to <u>ALL</u> vectors

2) A man walks 200m E, then turns around and walks 400m W, what is his displacement? 1div. = 100m



Note: displacements (all vectors) <u>subtract</u> if in <u>opposite</u> direction.

N.B. Adding in one direction is same as subtracting in opposite direction:



ie. 200m W = -200m E

Notation: $V_{A/B}$ = Velocity of object A relative to obj. B.

ie. $V_{A/G}$ = Vel. airplane relative to ground.

Train Problems and River Crossing Problems

Trains:

1. A baseball pitcher is warming up on an airplane on the way to a game. The plane is flying at 400 km/h [W] and the pitch can throw the ball at 150 km/h. What is the velocity of the ball relative to the round, if the pitcher throws the ball...
   a. Towards the front of the plane?
   b. Towards the back of the plane?
2. A jet plane travelling horizontally at 1200 km/h [E] fires a rocket forwards at 1100 km/h relative to itself. What is the velocity of the rocket relative to the ground?
3. A blower is practising his game on a railway flatcar travelling at 50 km/h [N]. If the velocity of the ball is 60 km/h [S] relative to the flatcar, what is its velocity relative to the ground?

River Crossing:

1. A swimmer jumps into a river and swims straight for the other side at 3 km/h [N]. There is a current in the river of 4 km/h [W]. What is the swimmers velocity?
2. A conductor in a train travelling at 12.0 km/h [N] walks across the aisle at 5.0 km/h [E] to punch a ticket. What is his velocity relative to the ground?
3. A small plane with a top speed of 100.0 km/h in still air is flown straight north. Unknown to the pilot, a 50.0 km/h wind is blowing to the west. What is the plane's velocity relative to the ground?

Answers:

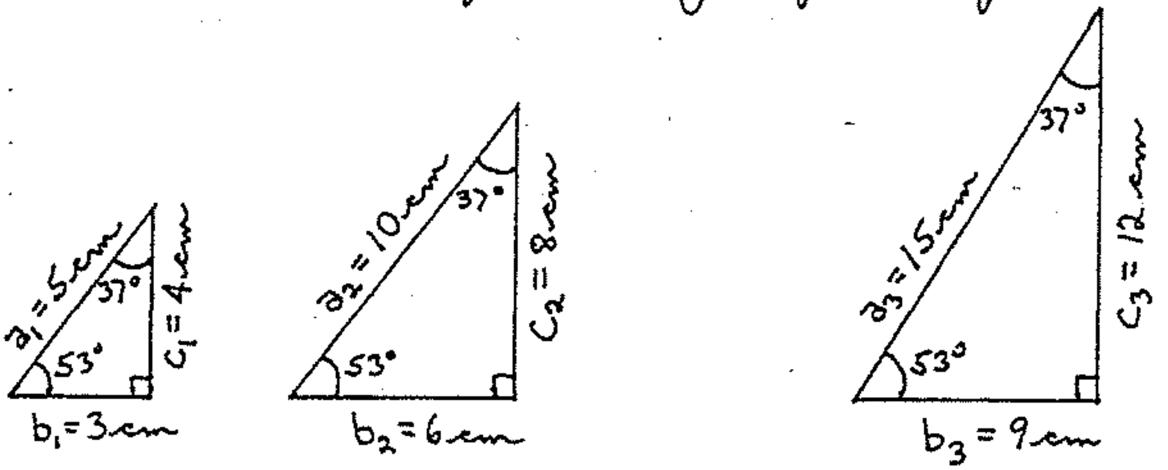
1a. 550 km/h [W]
b. 250 km/h [W]
2. 2300 km/h [E]
3. 10 km/h [S]

1. 5 km/h [53° W of N]
2. 13 km/h [23° E of N]
3. 112 km/h [27° W of N]

PHYS. 11 TRIGONOMETRY

Trigonometry basically deals with some simple concepts involving right angled triangles. The main problem of trigonometry is the finding of unknown parts of a triangle from given data.

Consider the following right angled triangles.



These triangles are similar, therefore the ratio of the sides is equal. In other words:

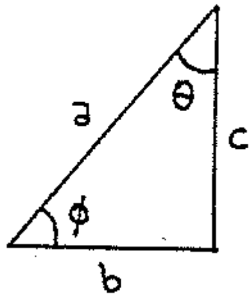
$$\frac{c_1}{a_1} = \frac{c_2}{a_2} = \frac{c_3}{a_3} \qquad \text{Check: } \frac{4}{5} = \frac{8}{10} = \frac{12}{15}$$

$$\text{Also } \frac{b_1}{a_1} = \frac{b_2}{a_2} = \frac{b_3}{a_3} \qquad \text{Check: } \frac{3}{5} = \frac{6}{10} = \frac{9}{15}$$

$$\text{Also } \frac{c_1}{b_1} = \frac{c_2}{b_2} = \frac{c_3}{b_3} \qquad \text{Check: } \frac{4}{3} = \frac{8}{6} = \frac{12}{9}$$

Rather than talking about sides a, b or c we are going to give these sides a name with respect to an angle in the triangle. With respect to the angle 53°, the sides labelled c are called <u>opposite sides</u>. The sides labelled b are called <u>adjacent sides</u>. The sides labelled a are obviously the <u>hypotenuse</u>.

Consider now, any general right triangle.



ϕ is the Greek letter "phi"

θ is the Greek letter "theta"

With respect to angle ϕ:	With respect to angle θ
c is opposite	b is opposite
b is adjacent	c is adjacent
a is the hypotenuse	a is the hypotenuse

With respect to the angle ϕ, any right triangle with an angle equal to ϕ (see page 1):

the ratio $\frac{c}{a}$ will always be constant

the ratio $\frac{b}{a}$ will always be constant

the ratio $\frac{c}{b}$ will always be constant

(See page 1 for "proof" of this)

These constant values for the ratios have been worked out for all angles of ϕ from 0° to 90° and are available in tables of trigonometric functions or some calculators.

Rather than talking about ratio c/a, b/a or c/b for a given angle ϕ, they have been given names.

Abbreviation

The ratio with respect to angle ϕ:

$$\frac{c}{a} = \frac{\text{opposite side}}{\text{hypotenuse}} = \text{sine } \phi = \sin \phi$$

$$\frac{b}{a} = \frac{\text{adjacent side}}{\text{hypotenuse}} = \text{cosine } \phi = \cos \phi$$

$$\frac{c}{b} = \frac{\text{opposite side}}{\text{adjacent side}} = \text{tangent } \phi = \tan \phi$$

You must memorize these:

$$\boxed{\sin \phi = \frac{\text{opposite}}{\text{hypotenuse}}} \quad \boxed{\cos \phi = \frac{\text{adjacent}}{\text{hypotenuse}}} \quad \boxed{\tan \phi = \frac{\text{opposite}}{\text{adjacent}}}$$

Going back to page 1, we see that if $\phi = 53°$ (first triangle)

$$\sin \phi = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{4}{5} = .8 \quad \text{OR} \quad \sin 53° = .8$$

$$\cos \phi = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{3}{5} = .6 \quad \text{OR} \quad \cos 53° = .6$$

$$\tan \phi = \frac{\text{opposite}}{\text{adjacent}} = \frac{4}{3} = 1.33 \quad \text{OR} \quad \tan 53° = 1.33$$

Also, if $\theta = 37°$, then:

$$\sin \theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{3}{5} = .6 \quad \text{OR} \quad \sin 37° = .6$$

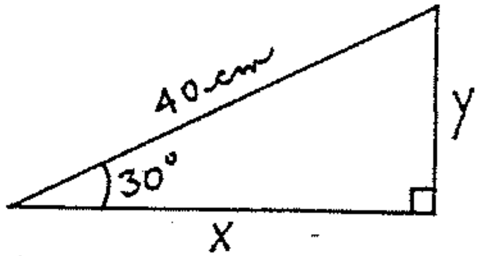
$$\cos \theta = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{4}{5} = .8 \quad \text{OR} \quad \cos 37° = .8$$

$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{3}{4} = .75$ OR $\tan 37° = .75$

Sine, cosine and tangent are called trigonometric functions. The values of the trig functions are ratio values and therefore are independent of units.

Sample problem:

Find X and y:



$\sin 30° = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{Y}{40\text{cm}}$

$\therefore\ y = 40\text{cm}(\sin 30°)$

$= 40\text{cm}(.5)$

$y = 20\text{cm}$

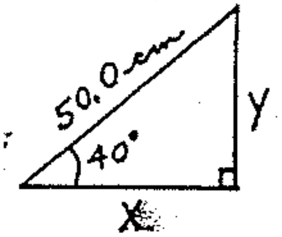
$\cos 30° = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{X}{40\text{cm}}$

$X = 40\text{cm}(\cos 30°)$

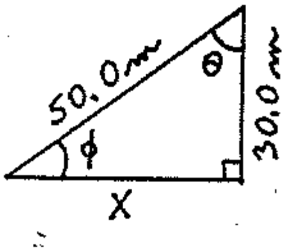
$= 40\text{cm}(.866)$

$X \doteq 35\text{cm}$

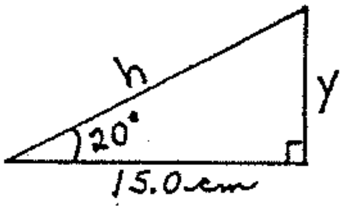
Solve for the unknowns in the following:



ANS: $X = 38.3$ cm
$y = 32.1$ cm



ANS: $\phi = 36.9°$
$\theta = 53.1°$
$X = 40.0$ m

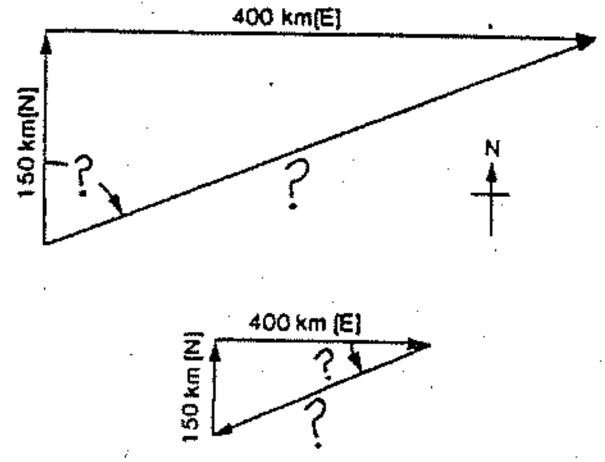


ANS: $y = 5.46$ cm
$h = 16.0$ cm

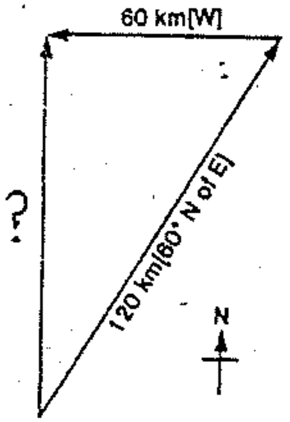
PHYS. 11 CHAP. 3 REVIEW PROBLEMS

The following vector diagrams are for certain review problems. You are to solve for the unknowns using Pythagorus' theorem and trigonometry.

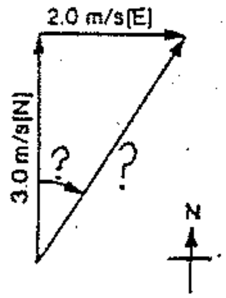
1. (a)



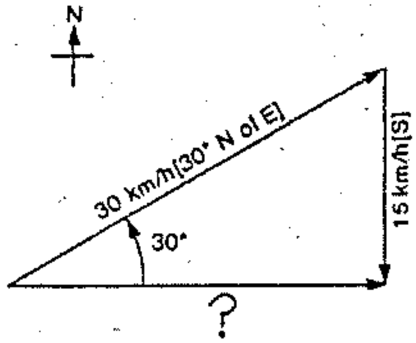
2.



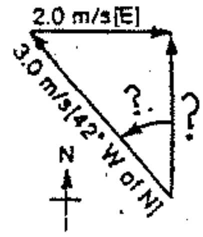
7. (a)



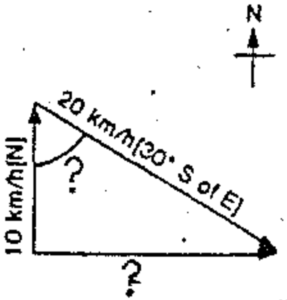
8.



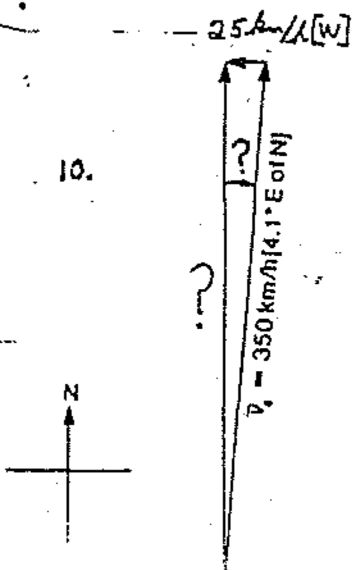
(b)



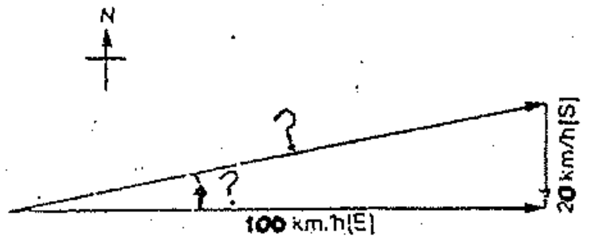
9.



10.



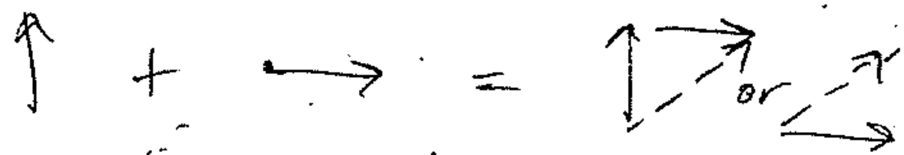
11.

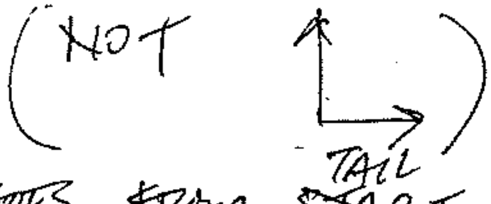


ADDING VECTORS

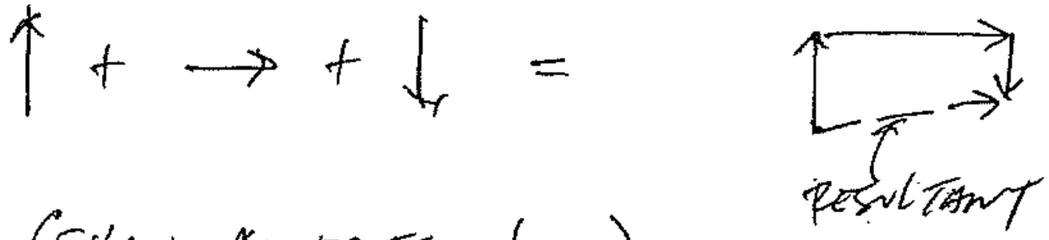
RULE. ADD THEM HEAD TO TAIL

EG





RULE: RESULTANT GOES FROM ~~START~~ TAIL OF FIRST VECTOR TO ~~BA~~ HEAD OF LAST VECTOR



(SHOW AS DOTTED LINE)

RIVER CROSSING

USE SYMBOLS

${}_{P}V_{B}$ = VELOCITY OF PERSON RELATIVE TO BOAT

${}_{B}V_{R}$ = " " BOAT RELATIVE TO RIVER

${}_{P}V_{R}$ = PERSON " " RIVER

$${}_{P}V_{B} + {}_{B}V_{R} = {}_{P}V_{R}$$

Funsheet #3-1 – Vector Problems

Note: Drawing vector diagrams can help solve each problem.

1. After walking 11 km due north from camp, a hiker then walks 11 due east.
    a. What is the total distanced walked by the hiker?
    b. Determine the total displacement from the starting point.
2. Two boys push on a box. One pushes with a force of 125 N to the east. The other exerts a force of 165 N to the north. What is the size and direction of the resultant force on the box?
3. An explorer walks 13 km due east then 18 km north and finally 3.0 km west.
    a. What is the total distance walked?
    b. What is the resulting displacement of the explorer from the starting point?
4. A motorboat heads due east at 16 m/s across a river that flows due north at 9.0 m/s.
    a. What is the resultant velocity (speed and direction) of the boat?
    b. If the river is 136 m wide, how long does it take the motorboat to reach the other side?
    c. How far downstream is the boat when it reaches the other side of the river?
5. While flying due east at 120 km/h, an airplane is also carried northward at 45 km/h by the wind blowing due north. What is the plane's resultant velocity?
6. Three teenagers push a heavy crate across the floor. Deon pushes horizontally with a force of 185 N at 0°. Shirley exerts a horizontal force of 165 N at 30°, while Joan pushes horizontally with 195 N at 300°. What is the resultant force on the crate?
7. A 110 N force and a 55 N force both act on an object at point P. The 110 N force acts at 90°. The 55 N force acts at 0°. What is the magnitude and direction of the resultant force?
8. A motorboat travels at 8.5 m/s. It heads straight across a river 110 m wide.
    a. If the water flows downstream at a rate of 3.8 m/s, what sit he boat's resultant velocity?
    b. How long does it take the boat to reach the opposite shore?
9. A boat heads directly across a river 41 m wide at 3.8 m/s. The current is following downstream at 2.2 m/s.
    a. What is the resultant velocity of the boat?
    b. How much time does it take the boat to cross the river?
    c. How far downstream is the boat when it reaches the other side?
10. A 42 km/h wind blows toward 215° while a plane heads toward 125° at 152 km/h. What is the resultant velocity of the plane?
11. A heavy box is pulled across a wooden floor with a rope. The rope makes an angel of 60° with the floor. A force of 75 N is exerted on the rope. What is the component of the force parallel to the floor?

Funsheet #3-1 – Vector Problems

12. An airplane flies toward 149° at 525 km/h. What is the component of the plane's velocity:
    a. Toward 90°?
    b. Toward 80°?

13. A student exerts a force of 72 N along the handle of a lawn mower to push it across the lawn. Find the horizontal component of this force when the handle is held at an angle with the lawn of:
    a. 60.0°
    b. 40.0°
    c. 30.0°

14. A hiker walks 14.7 km at an angle of 305° from east. Find the east-west and north-south components of the walk.

16. Three people are pulling on a tree. The first person pulls with 15 N at 65.0°, the second with 16 N at 135°, the third with 11 N at 195°. What is the magnitude and direction of the resultant force on the three?

17. A net force of 55 N acts due west on an object. What added single force on the object produces equilibrium?

18. Two forces act on an object. One force is 6.0 N horizontally. The second force is 8.0 N vertically.
    a. Find the magnitude and direction of the resultant.
    b. If the object is in equilibrium, find the magnitude and direction of the force that produces equilibrium.

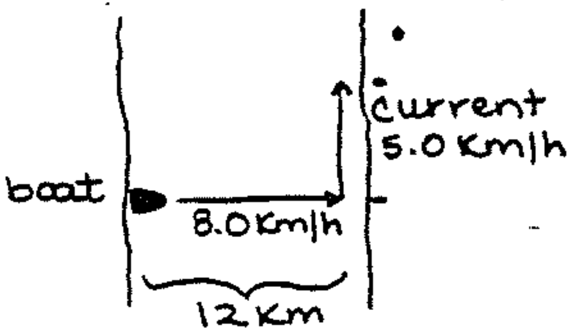
19. A 62 N force acts at 30.0° and a second 62 N force acts at 60.0°
    c. Determine the resultant force.
    d. What is the magnitude and direction of the force that produces equilibrium?

20. Two forces act on an object. A 36 N force acts at 225°. A 48 N force acts at 315°. What would be the magnitude and direction of their equilibrant?

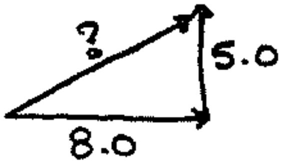
River-crossing Problems

Ex #1: A motorboat heads east at 8.0 Km/
across a river that is 12 Km wide.
The current of the river is flowin
north at 5.0 Km/h.

*** make sure all units are same!**



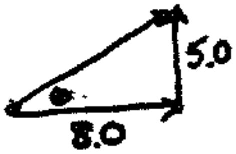
a) What is the boat's velocity relative to the shore?



$$c^2 = a^2 + b^2$$

$$\begin{aligned} c &= \sqrt{a^2+b^2} \\ &= \sqrt{8^2+5^2} \\ &= \sqrt{64+25} \\ &= \sqrt{89} \\ &\doteq \underline{9.4 \text{ Km/h}} \end{aligned}$$

b) At what angle does the boat move (to the original direction)?



$$\tan\theta = \frac{5.0}{8.0} \quad \therefore \theta = \tan^{-1} .625$$

$$\theta \doteq \underline{32^\circ \text{ N of E}}$$

c) How long does it take to cross the river?

width of river

$$v = \frac{d}{t} \quad \therefore t = \frac{d}{v} = \frac{12 \text{ km}}{8.0 \text{ km/h}} = \underline{1.5 h}$$

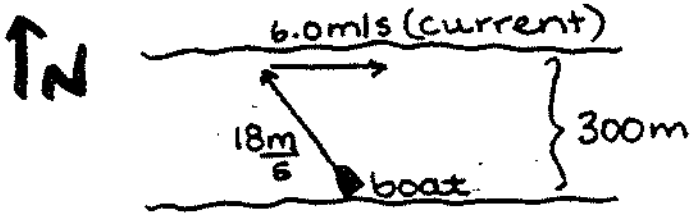
d) How far downstream will you land?

same time as crossing

$d = vt = (5.0)(1.50) = \underline{7.5\ \text{Km}}$

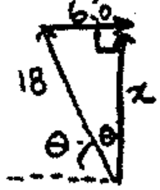
velocity of current

Ex. #2: A boat moving at 18 m/s at an angle[NW] upstream is being carried downstream by a current[E] at 6.0 m/s. The river is 300 m wide.



SOH CAH TOA

a) At what angle must the boat be pointed upstream in order to meet passengers directly across the river?



$\sin\theta = \frac{6.0}{18} \quad \therefore \theta = \sin^{-1} 0.3\overline{3} \doteq \underline{19°}$

[W of N]

b) What will the boat's resultant speed be?

$$x^2 = 18^2 - 6.0^2$$
$$x = \sqrt{324 - 36}$$
$$x = \sqrt{288}$$
$$x \doteq \underline{17\ \text{m/s}}$$

c) How long will the passengers be waiting?

$$t = \frac{d}{v} = \frac{300\text{m}}{17\text{m/s}} \doteq \underline{18\text{s}}$$

Assignment:

* ① A boat heads directly across a river 41m wide at 3.8m/s. The current is flowing downstream at 2.2m/s.

a) What is the resultant velocity of the boat? (4.4 m/s)
b) How much time does it take the boat to cross the river? (11s)
c) How far downstream is the boat when it reaches the other side? (24m)

② A swimmer swims across a river to meet a friend directly opposite him. The swimmer swims at an angle upstream at 5km/h. The current is moving at 3 km/h downstream. The river is 2 km wide.

a) At what angle must he point upstream in order to meet his friend directly across the river? (37°)
b) What will his resultant speed be? (4km/h)
c) How long will it take him to cross? (0.5h = 30 min)

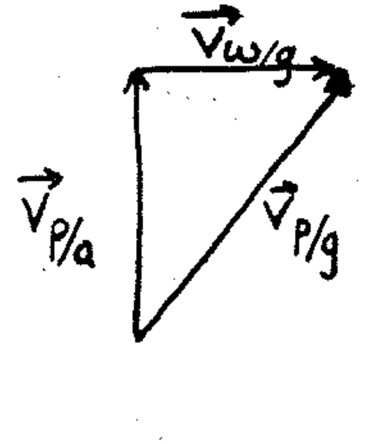
3.6 Airplane Navigation Problems

Flying objects are affected by the wind in the same way that floating or swimming objects are carried downstream by a current.

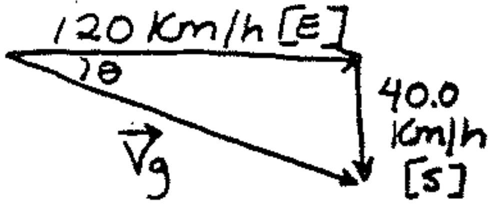
Pilots have special names for the vectors involved in airplane navigation.

SYMBOL	VELOCITY VECTOR	SPEED	DIRECTION
$\vec{V}_{p/a}$	plane's velocity relative to air	airspeed	heading
$\vec{V}_{w/g}$	wind velocity relative to ground	windspeed	wind direction
$\vec{V}_{p/g}$	plane's velocity relative to ground	ground speed	track

Air navigation problems are solved in the same way as river-crossing problems when the vectors are at right angles to each other.



Ex. #1: An airplane is heading east with an airspeed of 120. km/h. A 40.0 km/h wind is blowing towards the south. Calculate the groundspeed and the track for the plane's trip.

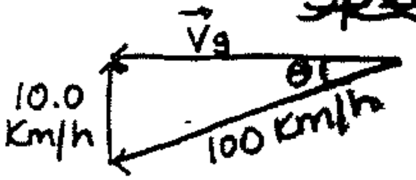


groundspeed ($\vec{V}_g$):

$$\vec{V}_g = \sqrt{120^2 + 40.0^2} \doteq 126 \text{ km/h}$$

track (θ): $\tan\theta = \frac{40.0}{120}$ $\therefore \theta = \tan^{-1} 0.\bar{3} \doteq 18.4°$ [S of E]

Ex. #2: A pilot wants to fly west. The airplane has an air speed of 100. km/h. There is a 10.0 km/h wind blowing north. Calculate the pilot's heading and ground speed.



$$\vec{V}_g = \sqrt{100^2 - 10^2} = \sqrt{9900} \doteq 99.5 \text{ km/h}$$

heading: $\sin\theta = \frac{10.0}{100}$

$$\theta = \sin^{-1} 0.1 \doteq 5.74° \text{ [S of W]}$$

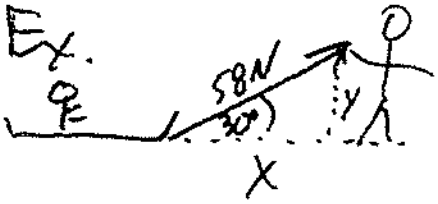
Resolving A vector into its components

We have seen that two vectors acting in different directions may be replaced by a single vector, the resultant.

It is also possible to begin with a single vector and think of it as a resultant of two vectors which are called components of the original vector.

Finding the X (horizontal) and y (vertical) components is called vector resolution or resolving a vector into its components.

Ex.



A sled is being pulled with a force ($\vec{F}$) of 58N (newtons) at an angle of 30° from the ground.

What are the X + Y components of the force?

$$X(\text{horiz})\ (\vec{F}_x):\ \cos 30° = \frac{\vec{F}_x}{58N} \Rightarrow \vec{F}_x = \cos 30°(58)$$

$$= 50N$$

$$Y\ (\text{vert})\ (\vec{F}_y):\quad \vec{F}_y = (\sin 30°)(58N) = 29N$$

ADDING VECTORS AT ANY ANGLE

Vector resolution can also be used to add two or more vectors that are not perpendicular to each other.

① Each vector is resolved into its X and Y components

② Add together all X components of all vectors

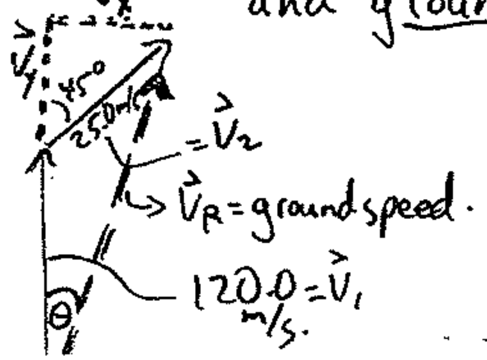
③ Add together all y components of all vectors

④ The resulting horizontal (X) and vertical (Y) components are used to find the resultant. $A^2+B^2=C^2$

⑤ Use trigonometry to find the final direction.

Ex: An airplane is flying with an airspeed of 120.0 m/s north. The wind is blowing at 25.0 m/s from the south west 45.0° East of North

a) What is the aircraft's resultant direction and ground speed?



① $\vec{V}_{wx} = (\sin 45.0°)(25.0) = 17.7$ m/s

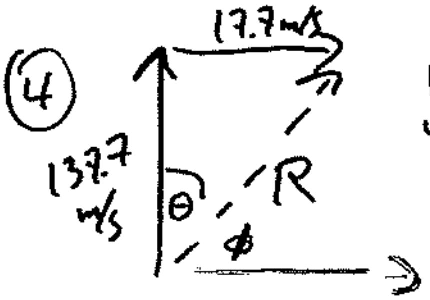
$\vec{V}_{wy} = (\cos 45.0°)(25.0) = 17.7$ m/s

Adding Vectors at any angle.

② X: $\underset{\text{wind}}{\vec{V}_{Wx}} + \underset{\text{airplane}}{\vec{U}_{Ax}} = 17.7\,m/s + 0 = 17.7\,m/s$

③ Y: $\vec{V}_{Wy} + \vec{V}_{Ay} = 17.7\,m/s + 120\,m/s = 137.7\,m/s$

④



$\sqrt{A^2+B^2}=C \Rightarrow \sqrt{137.7^2+17.7^2}$

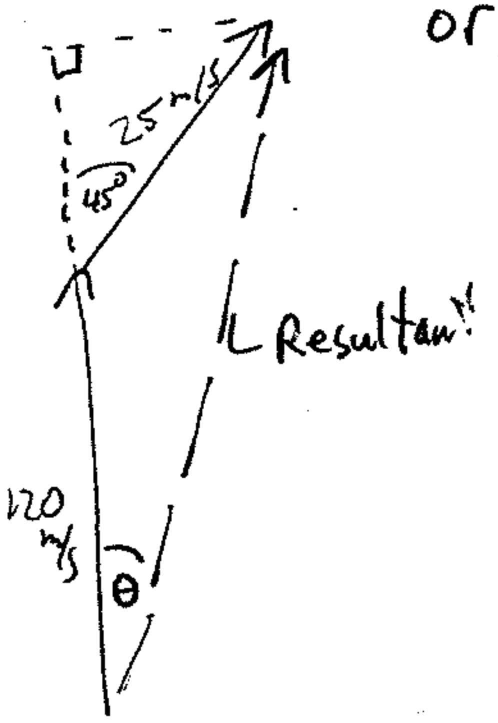
$\vec{V}_R = 138.8\,m/s$

⑤ $\tan\theta = \frac{17.7}{137.7} \therefore \theta = \tan^{-1}\frac{17.7}{137.7} = 7.32°$

$\vec{V}_R = 138.8\,m/s\ [7.32°\ E\ of\ N]$

or [82.68°]

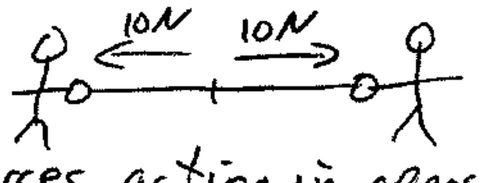
0 - 360°



Applications of Force Vectors

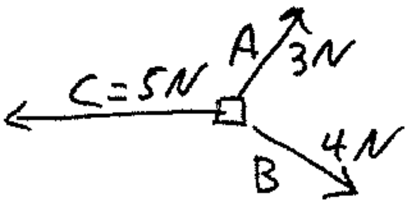
When the net force (net sum of all forces) is zero, the object is in equilibrium and will not move.

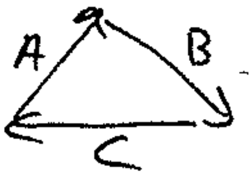
Ex1: tug of war



(two equal forces acting in opposite dir.)

Ex2.



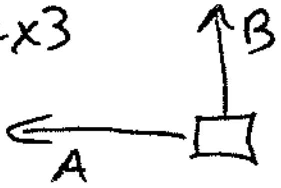


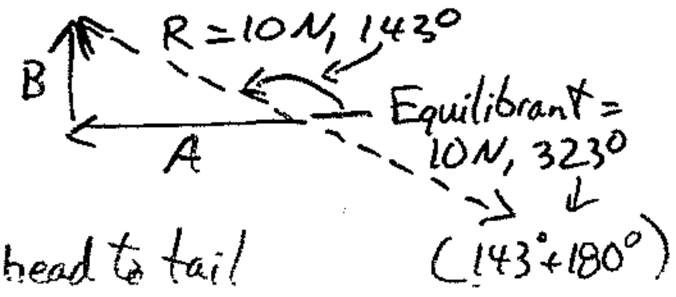
The 3 Forces form a closed triangle when the vectors are added head to tail. The resultant force on the object is zero. The object is in equilibrium.

But when the vector sum of forces acting at one point is not zero, a force can be applied that will produce equilibrium. This force is called the equilibrant force

To find the equilibrant force, first find the resultant force. The equilibrant force is equal in magnitude but opposite in direction to the resultant.

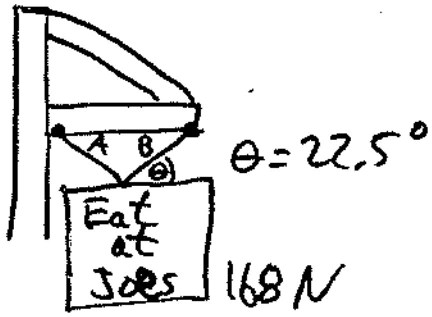
Ex3





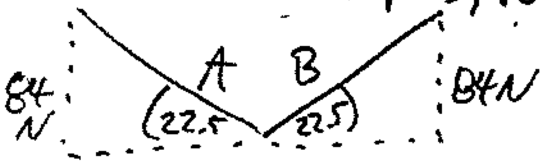
Sometimes the equilibrant is exerted by two or more forces.

Ex. 4.



A sign weighing 168N is supported by ropes A + B that make 22.5° angles with the horizontal. The sign is <u>not</u> moving. What forces do the ropes exert on the sign?

<u>Given</u>: Sign is not moving ⇒ equilibrium
∴ total vertical forces of ropes up = vertical force (weight) down = 168 N
2 ropes, ∴ each rope has vertical force of 84 N



$$\sin 22.5^\circ = \frac{84}{A}$$

$$A = \frac{84N}{\sin 22.5^\circ} = 220N$$

$$B = 220N$$

Notice that the force in each rope is Larger than the weight of the sign.

What would happen to the force if the angles were increased? decreased? Since the ropes must always have a vertical component equal to 168N, they can never be totally horizonta

Demo: 1m string, 1kg + 2 dynamometers

Can't make string straight! no matter what the horizontal force!

Funsheet #7 – An Airplane

7. An airplane has an airspeed of 550 km/h. However there is a strong wind blowing to the north at 100 km/h.
    a. If the plane heads east, find the magnitude and direction of the resulting velocity (sketch it and write a vector equation).
    b. How far and in what direction will the plane travel if it flies for 4.0 hours under the conditions of part a?
    c. The pilot of the plane wants to fly directly to the east. What direction must he head in order to end up going directly east?
    d. Under the conditions of part c, what will be the plane's speed in the eastward direction?

Projectile Motion

Projectile motion refers to the motion of an object that is projected into the air at an angle. Examples include a thrown ball, a speeding bullet or an athlete doing the high jump.

It was Galileo who first accurately described projectile motion by analysing the horizontal and vertical components separately (ignoring air resistance). One result of this analysis is that an object projected horizontally will reach the ground in the same time as an object dropped vertically (free fall). * see p 134 of text

Definitions

1. projectile - any object projected into the air without the ability to move itself
2. trajectory - the path of the projectile
3. range - horizontal distance travelled

Analysis is done by assuming air resistance is zero therefore the horizontal velocity remains constant. We then analyse the horizontal and vertical velocities separately remembering that gravity always acts downward.

A. Projectiles Launched Horizontally

Example #1: A stone is thrown horizontally at 15 m/s from the top of a cliff 44 m high.

a) How long does it take to hit the ground?(time)

b) How far from the base of the cliff does the stone strike the ground?(range)

c) How fast is it going (vertically) when it hits the ground?(vertical v)

d) How fast is it going at impact?(impact v)

e) At what angle does it hit the ground?(impact angle)

Given:	Unknowns:
v_i (vertical) = 0 m/s	t = ? *key value
v_i (horizontal) = 15 m/s	d (horizontal) = ?
d (vertical) = 44 m	v_f = ?
$g = 9.8\ m/s^2$	

a) Remember that a projectile launched horizontally takes the same amount of time to hit the ground as the object in free fall, so we use:

$$d = v_i t + 1/2\ gt^2 \dashrightarrow -44 = (0)(t) + (1/2)(-9.80)t^2$$

$t^2 = (2)(-44)/ (-9.80)$ $t = [(2)(-44)/ (-9.80)]^{½}$
$= 3.0$ s

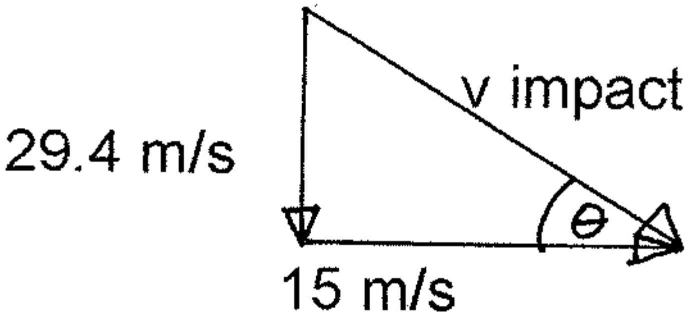
b) While the stone is falling, it is travelling horizontally at a constant velocity of 15 m/s.

$d = vt = (15)(3.00) = 45$m

c) Again, we treat a horizontal projectile like an object in free fall.

$v = v_i + gt = 0 + (-9.80)(3.00)$
$= -29.4$ $= 29.4$ m/s towards Earth

d) $v = (29.4^2 + 15^2)^{½} = 33$ m/s



e) $\tan \Theta = 29.4/15 \Rightarrow \tan^{-1} (29.4/15) = 63° = \theta$

Assignment: W/S: Physics Funsheet #4-1
ques 1 - 4, 8

Physics 11

Physics Funsheet #4-1

1. A stone is thrown horizontally at a speed of 5.0 m/s from the top of a cliff 78.4 m high.
   a) How long does it take the stone to reach the bottom of the cliff? **(4.00 s)**
   b) How far from the base of the cliff does the stone strike the ground? **(20. m)**
   c) What are the horizontal and vertical components of the velocity of the stone at impact?
   (v_x = 5.0 m/s and v_y = 39.2 m/s)

2. A steel ball rolls with constant velocity across a tabletop 0.95 m high. It rolls off and hits the ground 0.352 m horizontally from the edge of the table. How fast was the ball rolling? **(0.80 m/s)**

3. A car, moving too fast on a horizontal stretch of mountain road, slides off the road, falling into deep snow 43.9 m below the road and 87.7 m beyond the edge of the road.
   a) How long did the car take to fall? **(2.99 s)**
   b) How fast was it going when it left the road? (in m/s and km/h) **(29.3m/s; 105km/h)**
   c) What was its acceleration 10 m below the edge of the road? **(always at -9.80 m/s^2)**

4. A hunter standing at the edge of a 200.0m high cliff shoots an arrow horizontally at 30.0m/s.
   a) Time to reach ground? **(6.39s)**
   b) Vertical velocity at impact? **(62.6m/s)**
   c) Range? **(192m)**
   d) Impact velocity? **(69.4m/s)**
   e) Impact angle? **(64.4°)**

5. A player kicks a football from ground level with a velocity of 27.0 m/s at an angle of 30.0° above the horizontal.
   a) What is the football's "hang time" (time in the air)? **(2.76s)**
   b) What horizontal distance does the ball travel ? **(64.4m)**
   c) What is the ball's maximum height? **(9.30m)**

6. The kicker now kicks the ball with the same speed, but at 60.0° from the horizontal.
   Find: a) Its hang time. **(4.77s)**
   b) Horizontal distance (range). **(64.4m)**
   c) Maximum height. **(27.9m)**

7. Using the results from questions 5 & 6, qualitatively compare the flight times, ranges, and maximum heights for projectiles launched with the same initial velocities and complementary launch angles.

8. A rude tourist throws a peach pit horizontally with a 7.00 m/s velocity out of an elevator cage.
   a) If the elevator is not moving, how long will the pit take to reach the ground, 17.0m below? **(1.86s)**
   b) How far (horizontally) from the elevator will the pit land? **(13.0m)**

PHYSICS 11 - PROJECTILE MOTION LAUNCHER PROJECT

Mission:

To design and build a projectile launcher for launching a golf ball.

Regulations:

1. Materials: no restrictions - use anything! But total length of elastic/spring limited to 30cm.
2. Propulsion: mechanical only - electrical/chemical/explosive type propulsion is **NOT** permitted. Device must be activated, ie. string cut, switch flipped. Not thrown/dropped/hit.
3. Size: if disassembled, must fit into a shoe box - 30.0 cm x 16.0 cm x 10.0 cm

Requirements:

1. You are to work in groups of 3
2. A working model to be demonstrated to the class (note: you only have one chance to launch your golf ball - make sure you test it and practice up!)
3. A poster (approximately 60.0 cm x 90.0 cm) describing the key features of your design (including calculations done). It should contain diagrams and notes which describe such things as:
    - a. the operation (how your device works)
    - b. possible launch angles (show calculations used to determine best angle)
    - c. effects of gravity (what will gravity do to your ball's trajectory)
    - d. effects of air resistance (what will air resistance do to your ball's trajectory)
    - e. golf ball path with key parts labelled - launch angle, maximum height, impact angle and velocity , etc.
4. You provide your own golf ball - no special or trick golf balls allowed.

Evaluation: (Project will include a 25% peer evaluation)

1. Performance of launcher (12 marks)

Launch distance exceeds 12 meters (1 mark for each meter up to 12)
5 mark bonus for the greatest distance in class
3 mark bonus for the second greatest distance in class
2 mark bonus for the third greatest distance in class

2. Poster (4 marks)

a. poster includes all required information (as specified above)
b. diagrams are well labelled
c. shows attention to detail and consideration (calculation) of all possible factors involved with a successful launch
d. visually appealing presentation (neat, colourful, legible, organised...)

3. Construction (4 marks): Shows attention to detail, is well built with consideration of all possible factors involved for a successful launch (Don't forget the size limit!!)

4. Design (4 marks): Well thought out with use of innovative design/materials for launcher construction (ease of use, accurate launch angle control, stability, size limit...)

Evaluation Form

PROJECTILE LAUNCHER PROJECT - Physics 11

Group Members: ______________________________ Block:_____

____

Range mark _____+ {3x(my mark_______) + (peer mark______)}/4 = Total Mark_____/24

Performance:

Range of Launcher:

launch distance: ____________meters _____ marks (/12)

(1 mark for each meter up to 12)

5 mark bonus for the greatest distance in class
3 mark bonus for the second greatest distance in class
2 mark bonus for the third greatest distance in class _____ marks

Presentation:

Poster:

a. poster includes information on key features

the operation	possible launch angles
effects of gravity	effects of air resistance

golf ball path with key parts (maximum height, impact, etc.)

b. shows attention to detail and consideration (calculation) of all possible factors involved with a successful launch

c. visually appealing presentation (neat, colourful, legible, labelled, organised...)

_____marks (/4)

Construction:

Shows attention to detail, is well built with consideration of all possible factors involved for a successful launch

_____ marks (/4)

Design:

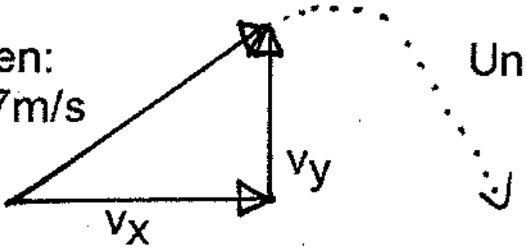
Well thought out with use of innovative design/materials for launcher construction (ease of use, accurate launch angle control, stability, size limit, spring/elastic length,...) _____ marks (/4)

B. Projectiles Launched at an Angle

Example #2: A ball is thrown into the air with an initial velocity of 4.47 m/s at an angle of 66° from the ground.

a) How long will it take the ball to land?
b) What maximum height will the ball reach?
c) What will the ball's range be?

Given:
4.47m/s



Unknowns:
$t = ?$
d (vertical) = ?
d (horizontal) = ?

For projectiles launched at an angle, you first need to calculate the horizontal and vertical components of the initial velocity:

V_x= (cos 66°)(4.47) = 1.8 m/s (horizontal component)

V_y = (sin 66°)(4.47) = +4.1 m/s (vertical component)

a) When it lands, the net vertical displacement is 0 m. Use vertical component of initial velocity.

$d = v_i t + 1/2gt^2 \dashrightarrow 0 = (4.1)t + 1/2(-9.80)t^2 \dashrightarrow$

$-1/2(-9.80)t^2 = 4.1t \dashrightarrow \quad -1/2(-9.80)t = 4.1 \dashrightarrow$

$t = [(-2)(4.1)]/(-9.80) = 0.83$ s

b) Maximum height is reached at half the flight time (0.415 s) after launch. Use vertical component of initial velocity.

$d = v_i t + 1/2gt^2$

$d = (4.1)(0.415) + 1/2(-9.80)(0.415)^2$

$d = 0.85$ m

c) Range is horizontal distance travelled during entire flight time. (Use horizontal component of initial velocity.)

$d = v_x t = (1.8)(0.83) = 1.5$ m

Assignment: Physics Funsheet #4-1: ques # 5 - 7

Projectile Motion Problems

1. A bullet fired horizontally from the top of a building has a muzzle velocity of 500 m/s. A similar bullet dropped from the top of the same building takes 4.00 s to reach the ground. How far forward does the first bullet go before it hits the ground?

2. A ball is thrown horizontally from the roof of a building at a speed of 20 m/s and hits the ground 3.0 s later.
   a. Make a table showing how far the ball falls during each second of it's fall.
   b. In a parallel column, show how far the ball moved forward during each second of its motion.

3. A package in an airplane moving horizontally at 150 m/s is dropped when the altitude is 490m.
   a. How long does it take the package to fall to the ground?
   b. How far forward from the spot over which it was dropped does the package land?
   c. What kind of path does the package follow?

4. A boy standing on top of a hill throws a stone horizontally. The stone hits the ground at the foot of the hill 2.5 s later. How high is the hill?

5. The muzzle velocity of a projectile fired from a gun has an upward component of 49.0 m/s and a horizontal component of 60.0 m/s.
   a. Make a table showing the vertical and horizontal displacements of the projectile at the end of each second of its flight and plot its path.
   b. How long does it take for gravity to reduce the upward component of the projectile's velocity to zero?
   c. How far upward does the projectile go?
   d. How far forward does it go?

6. A projectile is shot upward at 60° angle with the ground and a speed of 200 m/s.
   a. Obtain the vertical and horizontal components of its velocity.
   b. How far has the projectile gone horizontally at the end of the first 4.00s?

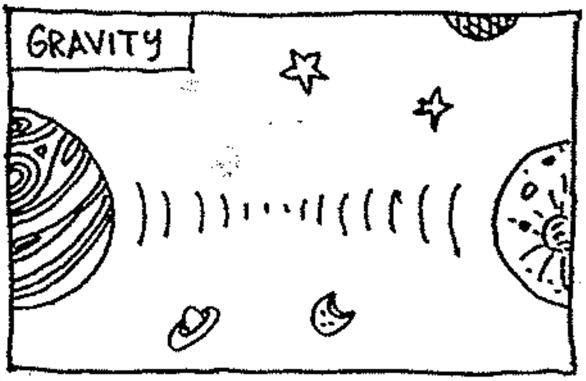
Projectile Problems

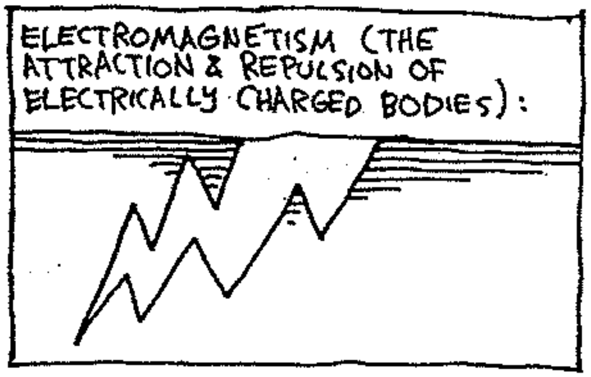
1. A softball player winds up and pitches underhand. She released the ball at her hip (which is 0.80 above the ground) with a velocity of 86 m/s [10°]. Home plate is 11.58 m away.
    a. Find V_H and V_V.
    b. How long will the ball take to reach home plate?
    c. At the point when the ball crosses the plate, what will V_V be? What will V_R be?
    d. If the strike zone is from the knees to the shoulders (0.50 – 1.25 m) and the ball goes right up the middle, will it be a strike?
    e. Assume the magnitude of the pitch (the speed) is 86 m/s. What must the direction be so that the ball will cross the plate at hip level (0.80 m – the same height that it left the pitchers hand)?

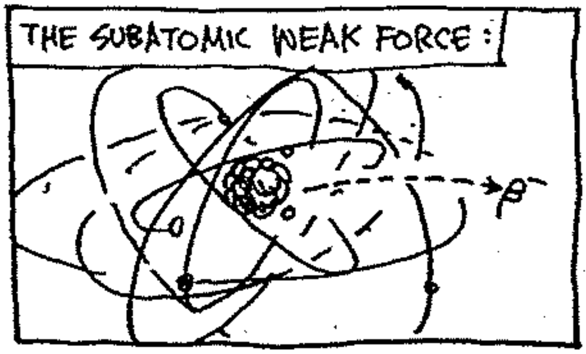
2. A cannon can be aimed anywhere from 0 – 90°. The muzzle velocity of the cannon is 200 m/s.
    a. If aimed at 60°, what height will it reach?
    b. How far will it land from where it is fired?
    c. What angle should it be fired to reach the maximum height? Prove it. What is that height?
    d. At what angle should it be fired to reach its maximum horizontal displacement? Prove it. What is that displacement?

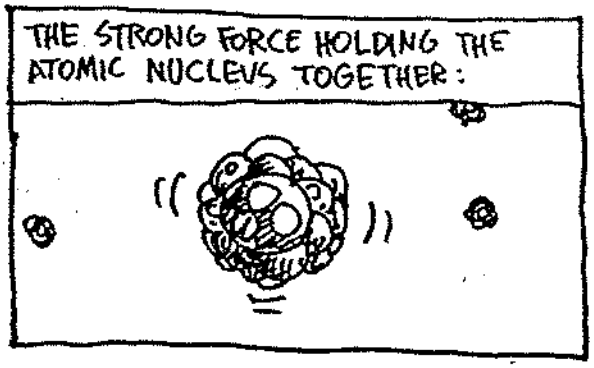
WE SEE SUCH A VARIETY OF FORCES, THAT IT MAY SEEM HOPELESS TO TRY AND ORGANIZE THEM. NEVERTHELESS, PHYSICISTS HAVE BEEN ABLE TO SHOW THAT **ALL** THE KNOWN EFFECTS IN THE UNIVERSE ARE THE RESULT OF THESE

4 BASIC FORCES:

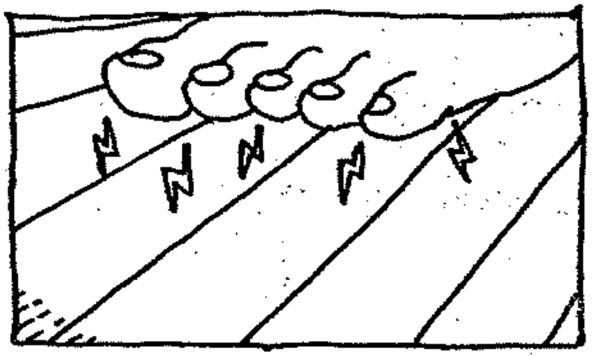

GRAVITY


ELECTROMAGNETISM (THE ATTRACTION & REPULSION OF ELECTRICALLY CHARGED BODIES):


THE SUBATOMIC WEAK FORCE:


THE STRONG FORCE HOLDING THE ATOMIC NUCLEUS TOGETHER:

BY THE WAY, THE ONLY ONE OF THE BASIC FORCES YOU'VE EVER FELT IS ELECTROMAGNETISM!! WHEN YOU PUSH THE WALL (AND IT PUSHES BACK), YOU'RE FEELING ELECTRIC REPULSION BETWEEN ATOMS. YOU HAVE NEVER FELT GRAVITY—ONLY THE ELECTRIC FORCES OF THE FLOOR THAT SUPPORT YOU AGAINST GRAVITY.



FORCES

Defined as PUSH or PULL on matter.

Measured in Newtons (N) after Isaac Newton.

FUNDAMENTAL FORCES

A) GRAVITY - force between objects (ie. holds planet and moons together)

B) ELECTROMAGNETIC - holds atoms and nucleus together

C) NUCLEAR (STRONG)
In nucleus of atoms
D) NUCLEAR (WEAK)

FORCE OF GRAVITY - exists between Earth and objects on Earth or in space.

Gravitational Field Strength (G.F.S.) = amount of force acting on an object per kg of mass (measured in N/kg)

A person standing on the Earth's surface holding a spring scale with a 1 kg mass --> scale reads 9.8 N

So on Earth the G.F.S. = 9.8 N/kg

NB. G.F.S. changes with distance between centre of Earth and object (ie. G.F.S. is lower as object moves further from the Earth)

INVESTIGATION: MASS AND THE FORCE OF GRAVITY

PROBLEM: How does the force of gravity on an object depend on its mass?

DATA TABLE:

MASS (Kg)	FORCE OF GRAVITY (N)

QUESTIONS:

1.Determine the slope of your graph. This is the value of the *gravitational field strength*. What are the units of this slope? You have seen this value before in connection with gravity, but with different units. What were those units?

2. Make up an equation for calculating ***F***, the force of gravity when you are given ***m***, the mass of the object, and ***g***, the gravitational field strength.

3. If you did this investigation on top of Mount Everest, would the line be straight? Would it have the same slope? Explain your answers.

MASS AND WEIGHT

MASS - Amount of matter making up an object; regardless of location kg

WEIGHT - measure of gravitational force on a body; depends on location N

$$F_g = mg$$

where F_g = gravitational force (N), m = mass (kg)

g = gravitational field strength (N/kg)

Question: Robin has a mass of 55.0kg. What is her weight?

$F = mg = (55.0\text{kg})(9.80\text{N/kg}) = 539\text{N}$

Question: A 3.5 kg Martian experiences a gravitational force of 5.6 N on the surface of the Moon. Calculate the gravitational field strength of the Moon.

$F = mg$ $g = F/m = 5.6\text{N}/3.5\text{kg} = 1.6\text{ N/kg} = 1.6\text{ m/s}^2$

VARIATION IN GRAVITATIONAL FIELD STRENGTH

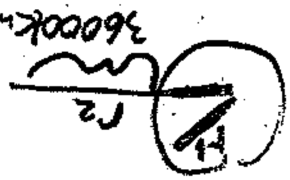
INVERSE SQUARE LAW FOR FORCE

Force of gravity on an object varies with distance from centre of Earth, $F \propto 1/r^2$ $\quad F = \frac{k}{r^2}$ or $F_1 = \frac{k}{r_1^2}$

So $\frac{F_2}{F_1} = \frac{k}{r_2^2} \times \frac{r_1^2}{k} =$ $F_2/F_1 = (r_1/r_2)^2$ $\quad F_2 = \frac{k}{r_2^2}$

where r = distance from centre of Earth

Question: If you weigh 600.N on the Earth's surface (radius 6400.km), what will you weigh at an altitude of 36 000.km?



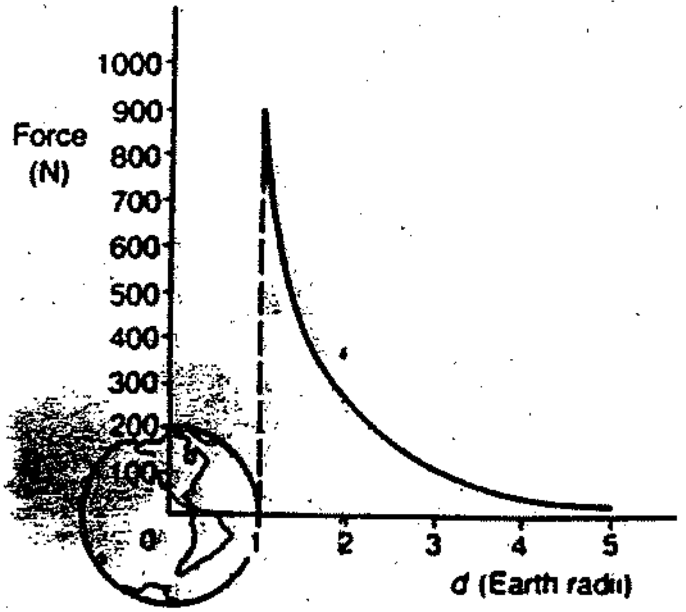
F_1 = 600.N $\quad F_2$ = ? $\quad r_1$ = 6400.km

r_2 = 6400. + 36000. = 42 400.km

$F_2/F_1 = (r_1/r_2)^2$

F_2 = ? = (600.)(6400./42400.)^2 = 13.7N

Distance to centre of Earth (Earth radii)	Force of gravity (N)
→ 1	900
2	225
3	100
4	56
5	36
6	25
7	18
8	14
10	9
30	1



The force of gravity on a 92 kg object at various distances from the Earth

Astronaut's location	Astronaut's mass	Astronaut's weight
On the surface of the Earth	60 kg	590 N
150 km above the Earth	60 kg	560 N
9/10 of the way to the moon	60 kg	0 N
On the surface of the moon	60 kg	98 N

Latitude (°)	g* (N/kg)	Distance to centre (km)*
0 (equator)	9.7805	6378
15	9.7839	6377
30	9.7934	6373
45	9.8063	6367
60	9.8192	6362
75	9.8287	6358
90 (north pole)	9.8322	6357

*all measurements made at sea level

Location	Latitude (°)	g at sea level (N/kg)	Altitude (m)	g (N/kg)
Toronto	44	9.8054	162	9.8049
Mount Everest	28	9.7919	8848	9.7647
Dead Sea	32	9.7950	−397	9.7962

NEWTON'S LAW OF UNIVERSAL GRAVITATION

$F = \frac{k}{r^2}$

Any two masses in the universe exert a gravitational force on each other; depends on masses of bodies and distance between them.

$$F_g = (Gm_1m_2)/d^2$$

$$N = \frac{\cancel{kg^2}}{\cancel{m^2}} \frac{N\cancel{m^2}}{\cancel{kg^2}}$$

where F_g = force of attraction between masses (N)

G = universal constant of gravitation (6.67×10^{-11} Nm^2/kg^2)

m_1 = mass of object 1 (kg)

m_2 = mass of object 2 (kg)

d = distance between 2 masses (m)

$F_g \propto \frac{1}{d^2}$ $F \propto \frac{1}{r^2}$ $F = \frac{k}{r^2}$

Question: Two bowling balls whose mass, m, is 7.3 kg, are placed with their centres a distance r = 50.cm apart. What gravitational force does each ball exert on the other?

$F_g = (\underline{G}m_1m_2)/d^2$

$= (6.67 \times 10^{-11}\ \mathrm{Nm^2/kg^2})(7.3\mathrm{k\underline{g}})(7.3\mathrm{k\underline{g}})/(0.50\mathrm{\underline{m}})^2$

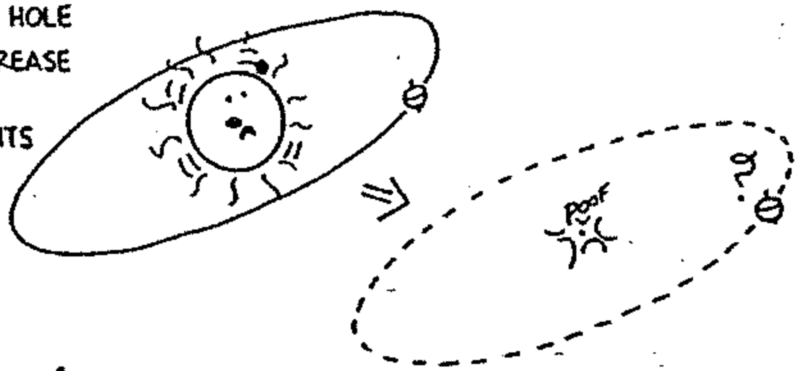
$= 1.4 \times 10^{-8}\mathrm{N}$

THINK If there is an attractive force between all objects, why do we not feel ourselves gravitating towards massive buildings in our vicinity?

Forces between you and buildings are relatively quite small because the masses are small compared to the mass of the Earth.

IF THE SUN SUDDENLY COLLAPSED TO BECOME A BLACK HOLE, THE EARTH WOULD

a) LEAVE THE SOLAR SYSTEM IN A STRAIGHT-LINE PATH
b) SPIRAL INTO THE BLACK HOLE
c) UNDERGO A MAJOR INCREASE IN TIDAL FORCES
• d) CONTINUE TO CIRCLE IN ITS USUAL ORBIT



THE ANSWER IS d:

WE CAN SEE FROM NEWTON'S EQUATION,

$$F = G\frac{mM}{d^2}$$

THAT THE INTERACTION F BETWEEN THE MASS OF THE EARTH AND THE SUN DOESN'T CHANGE. THIS IS BECAUSE THE MASS OF THE EARTH DOES NOT CHANGE, THE MASS OF THE SUN DOES NOT CHANGE EVEN THOUGH IT IS COMPRESSED, AND THE DISTANCE FROM THE CENTERS OF THE EARTH AND THE SUN, COLLAPSED OR NOT, DOES NOT CHANGE. ALTHOUGH THE EARTH WOULD VERY SOON FREEZE AND UNDERGO ENORMOUS SURFACE CHANGES, ITS YEARLY PATH WOULD CONTINUE AS IF THE SUN WERE ITS NORMAL SIZE.

Funsheet #5-1

Use the following: radius of the earth = 6.37×10^{6} m
$g = 9.80$ m/s^2
$G = 6.667 \times 10^{-11}$ Nm^2/kg^2

1. A certain person weights 800.0 N on the earth's surface. What is his weight at an altitude 6.40 x 106 m above the earth's surface?

2. What would the weight of an 85.0 kg astronaut on an asteroid which has a gravitational field strength on its surface of 2.22 N/kg?

3a. What is the acceleration due to gravity at an altitude of 5000.0 km from the earth's surface?
b. How much would an 85 kg personal weight at that altitude?
c. Why does an astronaut have a weight of 0 N at a distance of 9/10 away from the earth to the moon?

3. At what altitude about the earth's surface would you weight only one-eighth as much as *on the surface of the earth?*

4. Two objects are separated by a distance of 4.0 m. One object has a mass of 2.0 kg and the other has a mass of 6.0 kg. What is the gravitational force acting on the 2.0 kg mass?

5. How far apart are two objects each with a mass of 1 metric tonne (1000. kg) if there is a mutual gravitational attraction of 0.00010 N?

6. The planet Jupiter has a mass of 2.0×10^{27} kg and a radius of 6.0×10^{4} km. What is the gravitational field strength on the surface of Jupiter?

7. The coefficient of static friction between an object with a mass of 9.0 kg and a horizontal surface is 0.45. Could a force of 45 N applied to the object parallel to the surface cause it to move?

8. A crate is pulled horizontally along the floor with a uniform velocity by a horizontal force of 500.0 N. If the mass of the crate is 250.0 kg, what is the coefficient of friction between the crate and the floor?

9. If the spring constant is 175 N/m, a force of 26.0 will strength the spring by how many centimetres?

10. If the spring constant is 755 N/m, what force is required to stretch a wire 3.75 cm?

Answers:

1. 1.99×10^{2} N
2. 189 N
3a. 8.68 m/s^2
3b. 7.4×10^{2} N
4. 1.80×10^{7} m
5. 5.0×10^{-11} N
6. 8.17×10^{-1} m
7. 28 N/kg
8. Yes
9. 0.204
10. 14.9 cm
11. 28.3 N

ELASTIC FORCES

- are forces that attempt to stretch or compress a solid.

If an elastic material is stretched (<-- -->) or compressed (--> <--) beyond a critical amount, called its elastic limit (the "point of no return"), it will be permanently distorted or break.

HOOKE'S LAW

$$F = kx$$

where x = change in length of spring in m,

k = spring constant that is characteristic of the material, in N/m

Question: What elastic force will stretch an 8cm spring to 25cm if the spring constant is 0.12N/m?

$F = kx = (0.12\text{N/m})(0.25\text{m} - 0.08\text{m}) = 2.0 \times 10^{-2}\text{N}$

illustrates one application of a spring.

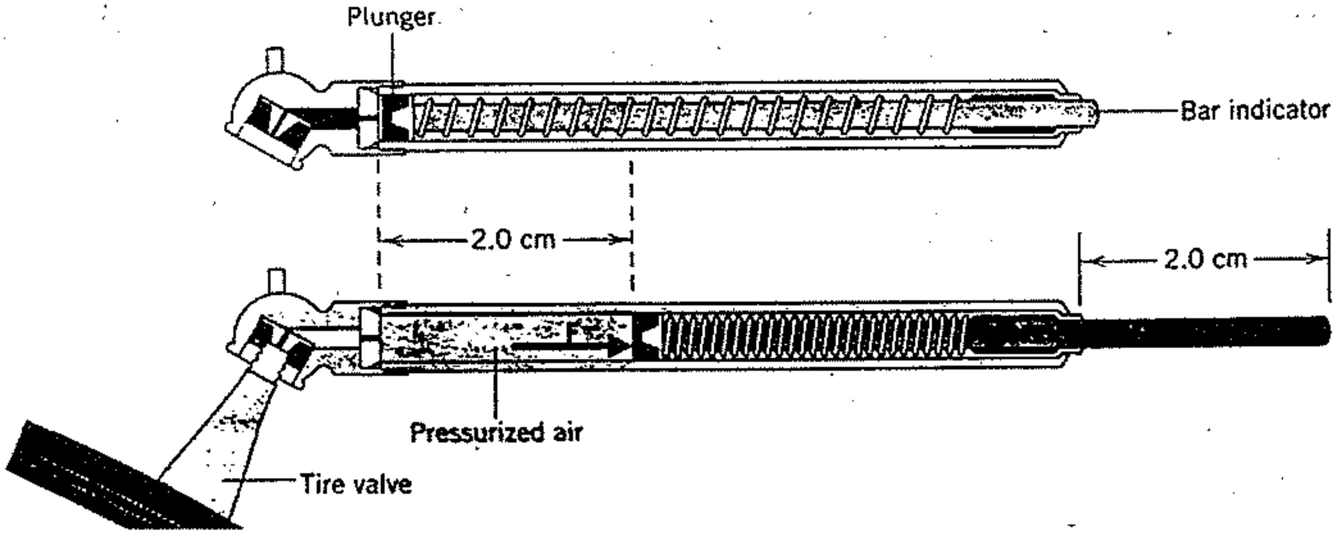
Example 4 A Tire Pressure Gauge

In a tire pressure gauge, the air in the tire pushes against a spring when the gauge is attached to the tire valve, as in Figure 10.11. Suppose the spring constant of the spring is $k = 320$ N/m and the bar indicator of the gauge extends 2.0 cm when the gauge is pressed against the air valve. What force does the air in the tire apply to the spring?

REASONING AND SOLUTION Since the spring constant is known, the force applied to the spring can be obtained from Equation 10.4:

$$F = kx = (320\ \text{N/m})(0.020\ \text{m}) = \boxed{6.4\ \text{N}}$$

Thus, the exposed length of the bar indicator gives a measure of the force that the air pressure in the tire exerts on the spring. Since pressure is force per unit area and the area of the plunger surface (see drawing) is fixed, the bar indicator can be marked in units of pressure.



Spring Constants

Material	Spring constant (N/m)
rubber	700
plastic	140 000
wood	1.4×10^6
lead	1.5×10^6
bone	2.8×10^6
magnesium	4.2×10^6
glass	6.9×10^6
aluminum	7.0×10^6
copper	12×10^6
mild steel	21×10^6
diamond	120×10^6

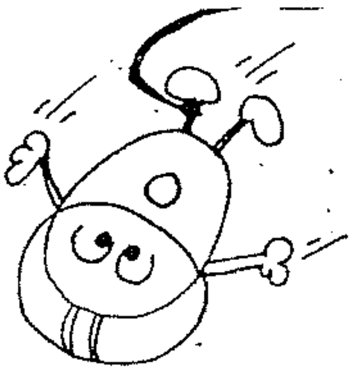
for a 1cm x
1cm x 1m
bar

Coefficients of Friction

Materials	μ
oak on oak, dry	0.30
steel on steel, dry	0.41
greasy	0.12
steel on ice	0.010
rubber on asphalt, dry	0.40
wet	0.20
rubber on concrete, dry	1.02
wet	0.97
rubber on ice	0.005
leather on oak, dry	0.50

PHYS 11

BUNGY JUMP PROJECT



To be done in **pairs** (or 3's only if necessary). Your mission if you choose to accept....

Students will **design** and **build** a bungy jump for an egg. The jump will be from a height of 2 meters to the water surface. There will be a tub of water on the floor 0.1 meters deep. Must be+80% 'stretchy' material.

Students will be responsible for:

(1) A **working model** to be demonstrated in class, one chance!
(2) Their *own* egg, NOT hard-boiled!!!
(3) A **poster** describing the vital statistics of their bungy (include all your calculations).

- length (unstretched, and must be shorter than distance to water surface)
- types of material(s) used
- the spring constant of their bungy
- mass of egg (& attachment)
- force of gravity on the egg (& attachment)
- diagram of fastening device -----tape or glue is PROHIBITED!
- no protective cover on egg

HOOKE'S LAW: F = KX

Teams have only **ONE** chance to show their bungy.

EVALUATION CRITERIA

I. Performance of Bungy: (14marks)

- egg remains attached to bungy during demonstration drop
- egg must "bounce" back up

+2 mark for "splashing" the egg, lose 4 marks for damage to the egg.

II. Poster - Description & Presentation: (14marks)

- poster includes all required information (as specified above)
- diagrams are labelled
- use of innovative design/materials for bungy construction
- shows attention to detail & consideration of all possible factors involved for a successful jump
- visually appealing presentation

Physics 11

BUNGEE JUMP PROJECT
Evaluation Form

Total Marks:_____ /28

Group Members: block________

____

____

____

Performance:

a. construction of bungee jump apparatus _____ marks (/8)

b. egg remains attached to bungee during test drop _____ marks (/3)

c. egg bounces back _____ marks (/3)

+2 mark bonus for "splashing" your egg (without becoming unattached) _____ marks
+3 mark bonus for the the biggest splash
+2 mark bonus for the second biggest splash
+2 mark bonus for the lightest apparatus to "splash" the egg

-4 mark deduction egg didn't drop within 10 cm of water
-4 mark deduction damaged egg [____ marks]

2 possible mark bonus for innovative materials _____ marks

Poster / Presentation:

1. poster includes information on key features _____ marks (/8)
   - a. length of apparatus
   - b. types of materials used
   - c. the spring constant of the apparatus
   - d. total mass of the egg and apparatus
   - e. total force of gravity on the egg and the apparatus
   - f. diagram of fastening device
   - g. calculation of required length of apparatus (2 marks)
2. diagrams are well labeled _____ marks (/2)
3. shows attention to detail and consideration of all possible factors involved for a successful jump _____ marks (/2)
4. visually appealing presentation _____ marks (/2)

Hooke's Law Investigation

Purpose:

To determine the relationship between the extension of a spring and forces applied to it.

Materials:

- Spring
- Meter stick
- Weights
- C-clamp

Procedure:

1. Attach C-clamp to a table.
2. Hook one end of the spring to the C-clamp and orient the spring vertically.
3. Stand the meter stick next to the spring.
4. Recording the unexpended length of the spring.
5. Attach weights to the free end of the spring and record the overall extension. (Try at least seven combinations of weights ranging from 100 g to 500 g.)
6. Calculate the stretch and plot the graph of force (N) against extension (cm). (Note: you must convert the mass to force using the formula, $F = mg$.)
7. Determine the spring constant, k.

Data:

1. Make and complete a data table as shown below (minimum seven entries).

Trial No.	Mass (kg)	Force (N)	Distance (cm)	Extension (cm)
1				
...				

2. Calculate the slope of the graph. The calculated value is known as the spring constant and is denoted by the letter k. (Note: the equation that relates the stretching force to the distance stretched is known as Hooke's Law: $F = kx$).

Questions:

1. What would the graph look like if a stronger, thicker spring were used?
2. What would happen to the spring constant if a stronger, thicker spring was used?

Practice:

1. A steel spring has a spring constant of 40 N/m. How much force would it take to stretch it by 10 cm?
2. A garage door has a spring constant of 600 N/m. How much will it stretch if a 150 N force is applied to it?
3. What is the spring constant of a car spring, if a 2500 N force compresses it from a length of 50 cm to a length of 40 cm?

FRICTION FORCES

- always acts opposite to the direction of motion

Static Friction - force preventing an object at rest from moving (a rock from rolling down a hill)

Sliding Friction - also called Kinetic Friction, is the force opposing the motion of a sliding object (a puck sliding on ice)

Rolling Friction - force resisting motion of a rolling object (a bicycle wheel on road)

Air Resistance - force opposing movement through air (airplane)

Viscous Force - force opposing movement through fluids (fish through water)

INVESTIGATION 5.3 : FRICTION CAN BE A REAL DRAG!!

In this two-part experiment, you will investigate the effects of two variables on sliding friction: (1) the force of gravity on the sliding object and (2) the surface area of the sliding object.

PART 1

Problem: When an object slides over a "smooth" horizontal surface, how does the force of friction (F_f) depend on the force of gravity (F_g) on the object?

Materials: spring balance
wooden blocks

Procedure:

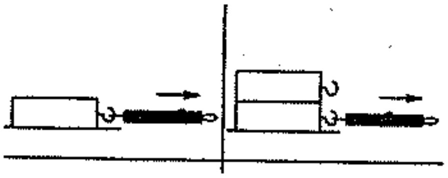
1. To measure the force of sliding friction, measure the smallest force needed to keep the block sliding at a slow, steady speed along the bench top. You will have to give the block a small nudge to get it moving. Once it is moving, however,a steady force equal to the force of sliding friction should keep it moving at a steady speed. Do several trials until you are satisfied you have a meaningful average friction force. Record your data.

Table 1 - Surface = benchtop

Number of blocks	Total Force of Gravity (N)	Force of Friction (N)

Table 2 - Surface = ____________

Number of blocks	Total Force of Gravity (N)	Force of Friction (N)



2. Plot a graph with force of sliding friction, F_f on the Y-axis and force of gravity, F_g on the X-axis. Determine the slope of the graph and write a specific equation for your graph. Include the units for your slope, if there are any.

3. Repeat the procedure, on a different horizontal surface and record your data in Table 2.

Questions:

1. When you doubled the force of gravity on the object sliding over the bench, what happened to the force of sliding friction?

2. The slope of your graph is called the coefficient of friction, and is given the special symbl,

μ, which is the Greek letter *mu*. What is the coefficient of kinetic friction between the block and the table top you used? How does that compare to the second surface used?

3. (a) Name three real-life situations where you need a low coefficient of friction.
   (b) Name three real-life situations where you need a high coefficient of friction.

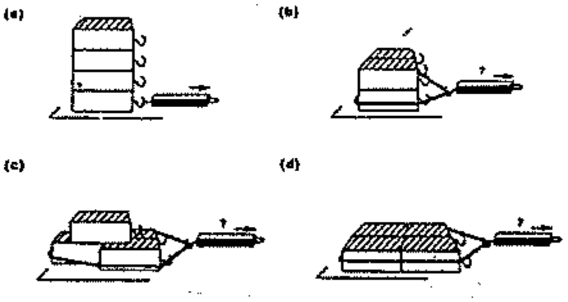
Part 2

Problem: How does the force of sliding friction vary with the area of contact between two smooth, flat surfaces, when all other factors are controlled?

Procedure:
1. Arrange the blocks so that your get various surface area in contact between the horizontal benchtop. Notice that the force of gravity is the same, only the area has changed. Loop a string around the blocks, attach a spring blance (properly "zeroed") and measure the force of friction as in Part 1. Measure it several times until your are satisfied that you have an acceptable average.) Record your results.

Table 3

Surface Area (cm^2)	Force of Friction (N)



Questions:

1. After comparing your results for Part 2 with several other groups doing the same experiment, write a conclusion regarding the effect that varying the surface area has on the amount of friction between a smooth flat object of constant force of gravity and another smooth surface.

2. Discuss sources of error in this experiment.

COEFFICIENT OF FRICTION (u)

is the number used to calculate the force of friction acting on two objects in contact.

If the objects are NOT in relative motion it is the coefficient of STATIC friction that is used, if the two objects are in relative motion it is the coefficient of KINETIC friction that is used.

$$u = F_f/F_N$$

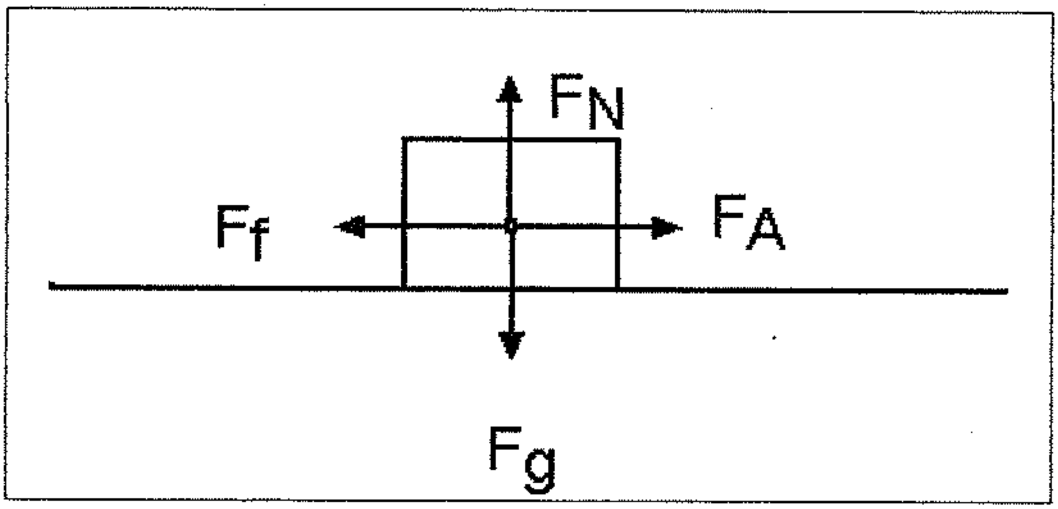
where F_f = force of friction (N)

F_N = force pushing the two surfaces together (the NORMAL force) (N)

u = coefficient of friction (NO units)

note: "Normal" means perpendicular

If the surfaces are horizontal, the normal force will often be equal to F_g, which is the force due to gravity (weight).



If not horizontal, F_N is equal to the force pushing the two objects together.

Eg. If I'm pushing chalk against the chalkboard with force F_{chalk}, and the chalkboard isn't moving it must be pushing back in the opposite direction with a force perpendicular to it's surface. This force is F_N and is equal to F_{chalk}. $F_{chalk} = F_N$

In general, for two objects with flat surfaces sliding over on another (at constant speed), the force of friction is proportional to the NORMAL force and the constant of proportionality is called the coefficient of friction.

$$F_f = uF_N$$

Coefficient of friction depends on the type of materials in contact and their smoothness and cleanliness.

It is INDEPENDENT of the surface areas

Question: The coefficient of kinetic friction between a wooden box and a concrete floor of 0.30. With what force must you push to slide the box across the floor at a steady speed if the force of gravity on the box is 450 N?

$F_f = uF_N = uF_g = (0.30)(450N) = 135N = 140N$

Question: Susan applies a 220.N horizontal force to a 55kg crate to push it across a level floor. The coefficient of kinetic friction is 0.37. Calculate the sliding friction force.

$F_N = F_g = mg = (55kg)(9.8\ N/kg) = 540N$

$F_f = uF_N = (0.37)(540N) = 2.0 \times 10^2\ N$

Friction Funsheet

1. The coefficient of kinetic friction between a steel block and an ice rink surface is 0.0100. If a force of 24.5 N keeps the block moving at a steady speed, what is the force of gravity on the block?

2. A 70. kg hockey player is skating on steel skates. What is the force of friction on the ice?

3. The driver of a 1500 kg car puts on the brakes on a concrete road. Calculate the forces of friction on:
   a. A dry road.
   b. A wet road.

4. A tractor ploughing a field is pulling with a force of 880 N on a 100 kg plough. What is the coefficient of friction?

5. A crate is pulled horizontally along the floor with a uniform velocity by a horizontal force of 500.0 N. If the mass of the crate is 250.0 kg, what is the coefficient of friction between the crate and the floor?

6. The coefficient of static friction between an object with a mass of 8.0 kg and a horizontal surface is 0.45. Could a force of 45 N applied to the object parallel to the surface cause it to move?

7. A copper block has dimensions 1 cm x 2 cm x 4 cm. A force of 0.10 N will pull the block along a table surface at a steady speed if the 1 cm x 4 cm side is face down on the table. What force will be needed to pull the same block along when its 2 cm x 4 cm side is face down?

Materials		**Coefficient of Friction, μ**
oak on oak,	dry	0.30
steel on steel,	dry	0.41
	greasy	0.12
steel on ice		0.010
rubber on asphalt,	dry	0.40
	wet	0.20
rubber on concrete,	dry	1.02
	wet	0.97
rubber on ice		0.005
leather on oak,	dry	0.50

Answers:

1. 2.45×10^3 N
2. 6.9 N
3a. 1.5×10^4 N
3b. 1.4×10^4 N
4. 0.90
5. 0.204
6. Yes

ISAAC NEWTON'S LAWS OF MOTION

1) FIRST LAW OF MOTION: LAW OF INERTIA

A body will remain in a state of rest, or in uniform motion in a straight line unless acted upon by an unbalanced (net) force.

* inertia is the tendency to resist change in motion (more mass = more inertia), Every object in the universe that has mass has inertia. Because a logging truck has more mass than a bicycle, it has much more inertia and is therefore more difficult to start moving, to stop moving and to turn.

* net force is the sum of all individual forces acting on an object.

2) SECOND LAW OF MOTION

If an unbalanced force acts on an object, the object accelerates in the direction of the force.

“a”varies <u>directly</u> with net F

“a”varies <u>inversely</u> with mass of object

$$F = ma$$

where F = unbalanced force (N)
m = mass of object (kg)
a = acceleration of object (m/s^2)

Units of force: one Newton is the magnitude of the force that will cause an object with a mass of 1 kg to accelerate at a rate of 1 m/s^2

Because $F = ma$, then $1\ N = 1\ kg\ m/s^2$

Question: A car of mass 1200 kg is being pushed along a level road with a force of 700 N. If the force of friction is 500N, what will the acceleration of the car be?

$F_A = 700N$, $F_f = 500N$, $m = 1200kg$, $a = ?$

$F_{net} = F_A - F_f = 700 - 500 = 200N = ma = (1200kg)a$
solve for $a = 0.2\ m/s^2$

Question: An electron is accelerated from rest to a speed of 3.0×10^7 m/s in 10.s. What unbalanced force was applied to the electron? (mass of electron = 9.1×10^{-31} kg)

$v = 3.0 \times 10^7\ m/s$, $t = 10.s$, $m = 9.1 \times 10^{-31}\ kg$, $F_{net} = ?$

$F_{net} = ma = m(\Delta v/\Delta t) = 9.1 \times 10^{-31}\ kg\ (3.0 \times 10^7\ m/s/10.s)$
$= 2.7 \times 10^{-24} N$

Question: What is the mass of a rock if a $2.4 \times 10^3 N$ force makes it accelerate at a rate of $4.0 \times 10^{-1}\ m/s^2$?

$F = 2.4 \times 10^3 N = (m)4.0 \times 10^{-1}\ m/s^2$ solve for $m = 6.0 \times 10^3 kg$

Question: A box with a mass of 26kg is resting on a wooden table. The coefficient of friction is 0.27. Find the horizontal force necessary to give the box an acceleration of 1.2 m/s^2

m = 26kg, u = 0.27, a = 1.2 m/s^2, F_A = ?

$F_f = uF_N = uF_g = umg = (0.27)(26kg)(9.80N/kg) = 68.8N = 69N$

Unbalanced force = Applied force - Friction force
Newton's second: ma = Applied F - Friction F

ma + Friction F = Applied F

$(26kg)(1.2\ m/s^2) + 69N = 1.0 \times 10^2 N$

3) THIRD LAW OF MOTION: ACTION - REACTION LAW

When one body exerts a force on a second body, the second body exerts an equal and opposite force on the first.

$$F_A = -F_B$$

* Action - Reaction forces do NOT cancel. If A acts on B, then the action force acts on B and the reaction force acts on A.

Example: recoil in a cannon; cannon exerts action force on cannonball but cannonball exerts reaction force (recoil) on cannon.

See text pages 88 - 93

Funsheet #6-1

1. When a shot-putter exerts a net force of 140. N on a shot, the shot has an acceleration of 19 m/s^2. What is the mass of the shot?
2. Together a motorbike and a ride have a mass of 275 kg. The motorbike is slowed down with an acceleration of -4.50 m/s^2.
    a. What is the net forced on the motorbike?
    b. Describe the direction of this force and the meaning of the negative sign.
3. A car with a mass of 1225 kg is traveling at 105 km/h and slows to a stop in 53 m. What is the size and direction of the force that acted on the car? What provided the force?
4. Imagine a spider with a mass of 7.0×10^{-5} kg moving downward on its thread. The thread exerts a force that results in a net upward force on the spider of 1.2×10^{-4} N. What is the acceleration of the spider?
5. Suppose you exert a force on a block and measure its acceleration. You then exert the same amount of force on another block. Its acceleration is three times that of the first block. What can you conclude about the masses of the blocks?
6. Suppose Joe, who weights 625 N, stands on a bathroom scale calibrated in Newtons.
    a. What force would the scale exert on Joe? In which direction?
    b. If Joe now holds a 50. N cat in his arms, what force would the scale exert on him?
    c. After Joe puts the cat down, his father comes up behind him and lifts upwards on his elbows with a 72 N force. What force does the scale now exert on Joe?
7. A 52 N sled is pulled across a cement sidewalk with a constant speed. A horizontal force of 36 N is exerted.
    a. What is the coefficient of sliding friction between the sidewalk and the metal runners of the sled?
    b. Suppose the sled now runs on packed snow. The coefficient of friction is now only 0.12. If a person weighing 650. N sits on the sled, what force is needed to slide the sled across the snow at a constant speed?
8. The coefficient of sliding friction between rubber tires and wet pavement is 0.50. The brakes are applied to a 750. kg car traveling 30. m/s, and the car skids to a stop.
    a. What is the size and direction of the force of friction that the road exerts on the car?
    b. What would be the size and direction of the acceleration of the car? Why would it be constant?
    c. How far would the car travel before stopping?
9. A rubber ball weights 49 N.
    a. What is the mass of the ball?
    b. How far would the car travel before stopping?
10. A small weather rocket weighs 14.7 N.
    a. What is its mass?
    b. The rocket is carried up by a balloon. The rocket is released from the balloon and fired, but its engine exerts an upward force of 10.2 N. What is the acceleration of the rocket?

Answers:

1. 7.4 kg
2. -1.24×10^3 N
3. -9.8×10^3 N
4. 1.7 m/s^2
7a. 0.69
7b. 84 N
8a. -3.7×10^3 N
8b. -4.9 m/s^2
8c. 92 m
9a. 5.0 kg
9b. 4.0 m/s^2
10a. 1.50 kg
10b. -3.00 m/s^2

FORCES REVIEWSHEET

1. What is the weight of the force of gravity on a 4.5 kg block of concrete?

2. The force of gravity on a 250. kg spacecraft on the moon is 408 N. What is the gravitational field strength there?

3. A 20. kg object out in space is attracted to the Earth by a force of gravity of 100. N. How fast will this object accelerate towards the Earth, if it is falling freely?

4. A 20.0 kg toboggan is pulled along horizontally at a *uniform speed* by a force of 30.0 N.
   (a) What is the force of gravity on the toboggan?
   (b) What is the coefficient of friction?
   (c) How much force is needed to pull the toboggan if two 60.0 kg girls are sitting on it?

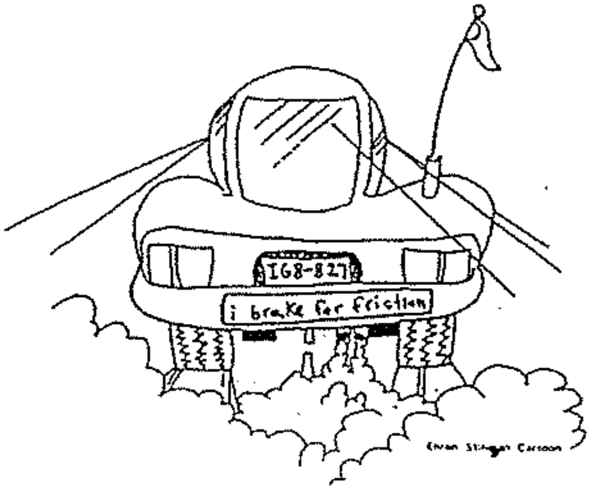
5. It takes a 5.0 N force to pull a 2.0 kg object horizontally along the ground at a *constant speed*. What is the coefficient of friction?

6. A 10. N force stretches a length of fishing line by 10 cm. What is the line's spring constant?

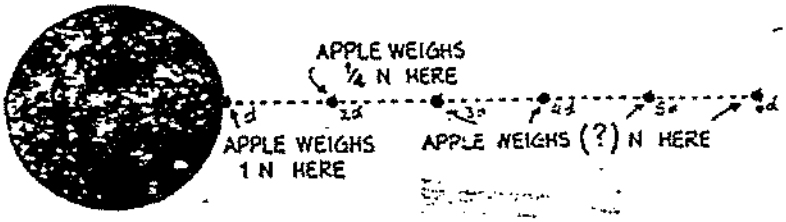
7. An archer pulls back on the bow with a force of 240 N. If the spring constant is 4.0 x 10^2 N/m, then how far will the arrow move?

8. A tractor ploughing a field is pulling with a force of 880 N on a 100. kg plough. What is the coefficient of friction?

9. The driver of a 1500 kg car puts on the brakes on a concrete road. Calculate the force of friction (a) on a dry road and (b) on a wet road.



GRAVITATIONAL INTERACTIONS FUNSHEET



An apple at the top of a tree is pulled by earth's gravity. If the tree were twice as tall, what is the force of gravity on the apple?

Ans: $F = \frac{G m_1 m_2}{d^2} = \frac{G m_1 m_2}{(2d)^2} = \frac{G m_1 m_2}{4d^2} = 1/4 \frac{G m_1 m_2}{d^2} = 1/4 F_{old}$

Practice predicting changes with the following problems. Write the equation & make the appropriate substitutions.

(1) If both masses are doubled, what happens to the force?

(2) If the masses are not changed, but the distance of separation is reduced to 1/2 the original distance, what happens to the force?

(3) If the masses are not changed, but the distance of separation is reduced to 1/4 the original distance, what happens to the force?

(4) If both masses are doubled, and the distance of separation is doubled, show what happens to the force.

(5) If one of the masses is doubled, the other remains unchanged, and the distance of separation is tripled, show what happens to the force.

(6) Consider a pair of binary stars that pull on each other with a certain force. Would the force be larger or smaller if the mass of each star were three times as great and if their distance apart were three times as far? Show what the new force will be compared to the first one.

(7) Calculate the gravitational field strength at 2500.km above the Earth's surface.

(8) What is the force of gravity on a 4500.kg boat floating in water?

(9) What is the mass of a 1.4 N box?

(10) What is the weight of a 70.kg astronaut on the moon (the pull of gravity is 1/6 of the earth's)?

(11) Two students are sitting 1.5 m apart. One student has a mass of 70.0 kg and the other has a mass of 52.0 kg. What is the gravitational force between them?

(12) If two objects, each with a mass of 2.0 x 10^2 kg, produce a gravitational force between them of 3.7 x 10^{-6} N, what is the distance between them?

(13) The gravitational force between two objects that are 2.1 x 10^{-1} m apart is 3.2 x 10^{-6} N. If the mass of one objecg is 5.5 x 10^1 kg, what is the mass of the other object?

CHAPTER 10 WORK & ENERGY

[Text p. 198-203

WORK : applied force moved over distance in tha direction.

$\boxed{W = \vec{F}d}$ measured in Joules (J
(N)(m) after James Joule

$1\ J = 1\ Nm$

1\.

object does not move over a distan

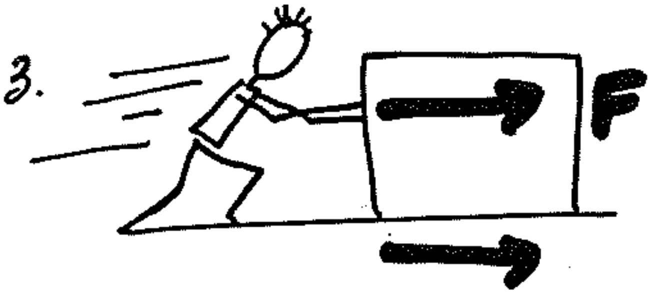
$\boxed{W = 0}$

2\.

Object moves at 90° to F applie

$\boxed{W = 0}$

3\.



Object moves in directio of F over distance

$\boxed{W = Fd}$

Q. A force of 825 N is needed to push a car across a 35 m lot. How much work is done?

F = 825 N
d = 35 m

$W = Fd = (825)(35)$
$= \boxed{2.9 \times 10^4\ J}$

Elastic Potential Energy

When a spring is stretched or compressed, energy is stored in the spring. The elastic potential energy in the spring is equal to the work done on the spring.

A) **Force**: The force required to stretch or compress a spring is written as

$$F = kx \text{ (Hooke's Law)}$$

where k is the spring constant of the spring and x is the distance over which F is applied.

The force is directly proportional to the amount of stretching or compression (within definite limits).

B) **Work:** The work done on the spring varies directly with the amount stretching. The total amount of work, therefore, is by the equation

$$W = Fx / 2$$

where **F** is the force exerted on the spring at the end of stretch or compression through distance **x**. Because the force varies zero to **F**, the equation uses the average of these two values or **F / 2**

Substituting we get:

$$W = kx^2 / 2$$

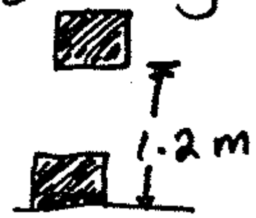
C) **Elastic potential energy:** But work done requires an equivalent amount of energy. So W = E and we get the equation:

$$E_p = kx^2 / 2$$

where $\mathbf{E_p}$ is the elastic potential energy.

This equation represents ideal conditions. In actual practice, a small fraction of the work of stretching or compression is converted into heat energy in the spring and thus does not show up elastic potential energy.

Q. What work is done by a forklift raising a 583 kg box 1.2 m?



* Force applied to lift box upward (at constant speed) is <u>equal</u> to the weight (force of gravity) of the box.

$$\text{Work} = mg \cdot d$$
$$= (583)(9.8)(1.2)$$
$$= 6.9 \times 10^{3}\ \text{J}$$

POWER: <u>Rate</u> at which work is done

$$\boxed{P = \frac{\text{Work}}{\text{time}}}$$

measured in Watts (W) after James Watt.

1 W = 1 J/s

1 kW = 1000 W

1 horsepower = 746 W

WS 8-1: Q 1, 2a, 3, 4, $\underbrace{5, 6}_{1^{st}\text{ ones}}$

Q: A box that weighs 575 N is lifted a distance of 20.0 m straight up by a rope. The job is done in 10.0 s. Calculate the power.

$$P = \frac{W}{t} = \frac{F \cdot d}{t} = \frac{(575)(20.0)}{(10.0)}$$

$$= 1.15 \times 10^3 \text{ W}$$

Do Review Problems

p. 213 #2,3,4,13.

Practice Probs p.199 #2+4
202 5+6
203 10+11

Physics 11 Chapter 8: Work, Energy and Power

UNSHEET #8-1

1. A force of 825 N is needed to push a car across a lot. Two students push the car 35m. How much work is done? **(2.9×10^4 J)**

2. A forklift raises a 583 kg box 1.2 m.
   a) How much work was done by the forklift? **(6.9×10^3 J)**
   b) How much gravitational potential energy did the box gain? **(6.9×10^3 J)**

3. You and a friend each carry identical boxes to a room one floor above you and down the hall. You choose to carry it first up the stairs, then down the hall. Your friend carries it down the hall, then up the stairwell. Who does more work?

4. An electric motor develops 65 kW of power as it lifts a loaded elevator 17.5 m in 35.0 s. How much force does the motor exert? **(1.3×10^5 N)**

5. How long does it take a 1.5 kW electric motor to do 6.0×10^4 J of work? **(40. s)**

6. How much work (in kilowatt hours) is done by a 10, 000. W turbo generator running continuously for a year? **(87600 kWh)**

5. A shotputter heaves a 7.26 kg shot with a final speed of 7.50 m/s.
   a) What is the kinetic energy of the shot? **(204 J)**
   b) If the shot was initially at rest, how much work was done? **(204 J)**

[illegible]. A 90. kg rock-climber first climbs 45 m upward to the top edge of a quarry, then, from the top, descends 85 m to the bottom. Find the potential energy of the climber at the edge and at the bottom, using the initial height as the reference level. **(4.0×10^4 J ; -3.5×10^4 J)**

7. A compact car and a semi-truck are both travelling at the same velocity. Which has more E_k?

8. A 5.0×10^5 kg railroad car moving at 8.0 m/s, collides with a stationary railroad car of equal mass. After the collision, the two cars lock together and slide forward.
   a) What is the final velocity of the wrecked cars? **(4.0 m/s)**
   b) How much kinetic energy was lost in the collision? **(8.0×10^6 J)**
   c) What percent of the original energy was lost? **(50 %)**
   d) Into what forms did this energy most likely go?

9. Calculate the specific heat capacity of 400. g of gold if 1.3 kJ of energy is required to raise its temperature from 50.°C to 75°C. **(1.3×10^2 J/kg°C)**

10. 11.97 kJ of heat is transferred to what mass of water when it is heated from 52°C to 90.°C? **(7.5×10^{-2} kg)**

11. Nancy's furnace burns 1.8×10^3 J of natural gas in one month. This results in heat being added to her house. The heat energy is measured to be 1.4×10^3 J per month.
   a) How efficient is Nancy's furnace? **(78 %)**
   b) Where does the "lost" energy go?

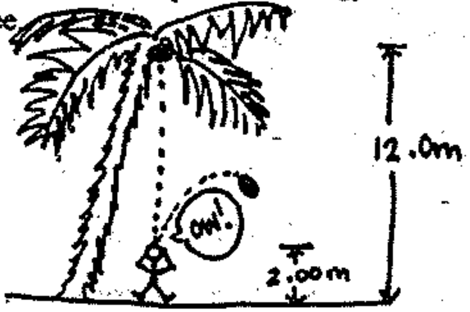
WORK, POWER & ENERGY PRACTICE PROBLEMS

* Do **Funsheet 8-1** Questions #1-6

1. What is the kinetic energy of a 6.0 kg curling stone sliding at 4.0 m/s? (48 J)

2. A 5.0 kg stone is released 20.0 m above the ground. What is its speed when it hits the ground? (20. m/s)

3. A coconut falls out of a tree 12.0 m above the ground & hits a bystander 2.00 m tall on top of his head. The mass of the coconut is 2.00 kg. Calculate the potential energy of the coconut relative to the ground while it is still in the tree.
   (235 J)



4. A baseball of mass 152 kg is thrown from ground level straight up into the air with an initial speed of 15.0 m/s. While it is in the air, the force of friction on it is about 0.44 N.
   a. What is its potential energy relative to the ground when it is on the ground, immediately before it is thrown? (0 J)
   b. What is its kinetic energy immediately after it is thrown? (1.71×10^4 J)
   c. Therefore, what is its total energy relative to the ground? (1.71×10^4 J)
   d. By the time it has risen to a height of 8.00 m, what is the potential energy of the baseball relative to the ground? (1.19×10^4 J)
   e. By the time it has risen to a height of 8.00 m, how much heat energy has been produced because of friction? (5.2×10^3 J)
   f. Therefore, how much kinetic energy does the ball have at a height of 8.0 m? (0 J)
   g. Therefore, what is the ball's speed at this height? (0 m/s)

5. A roller coaster train, of mass 1250 kg, coasts a distance of 29 m along the track. As it does so, it rises from an initial height of 9.4 m above the ground to a final height of 10.5 m above the ground and slows down from 9.4 m/s to 6.6 m/s.
   a. How much gravitational potential energy relative to its initial height does the train have at the beginning of the 29 m? (0 J)
   b. How much kinetic energy does the train have at the beginning of 29 m? (5.5×10^4 J)
   c. Therefore, how much total energy does the train have relative to its initial height? (5.5×10^4 J)
   d. How much gravitational energy does the train have relative to its initial height at the end of the 29 m? (1.3×10^4 J)
   e. How much kinetic energy does the train have at the end of the 29 m? (2.7×10^4 J)
   f. Therefore, how much energy has been changed to heat energy because of friction? (2.8 × 1

Fd

ENERGY

J WORK = TRANSFER OF ENERGY J

KINDS OF ENERGY:

A. POTENTIAL ENERGY: (E_p) = stored energy with the potential for doing work, eg. stretched rubber band.

B. KINETIC ENERGY: (E_k) = energy of motion, eg. skydiver

C. THERMAL ENERGY: (E_H) = energy of heated particles

GRAVITATIONAL POTENTIAL ENERGY = due to an object's elevated position above some reference level. The amount of energy is equal to the work done in lifting it to that height.

F·d

Since W = Fd = (mg)d then

$$E_p = mgh$$

expressed in Joules, where h = height or distance above some reference level.

KINETIC ENERGY = as object falls from a height, it loses its potential energy and gains energy of motion

$$E_k = 1/2mV^2$$

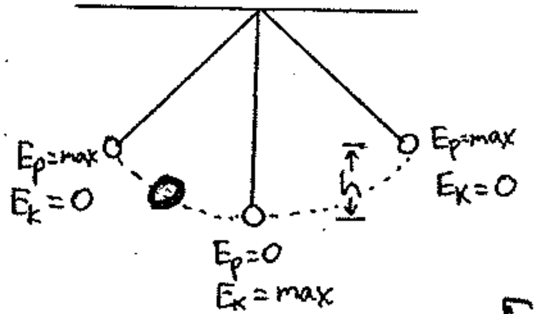
where m = mass of object (kg) and V = velocity of object (m/s)

CONSERVATION OF ENERGY = Energy cannot be created nor destroyed. It can only be transferred from one form to another, but the total amount of energy never changes.

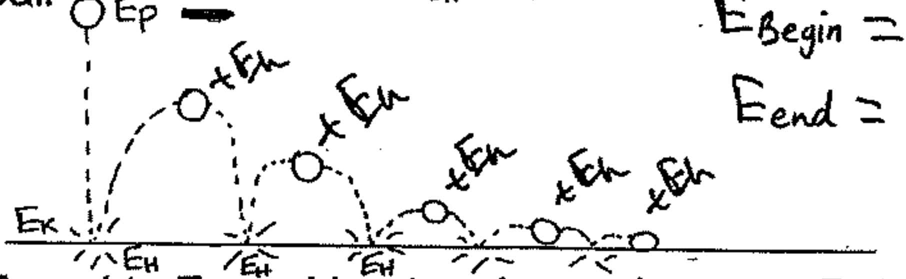
$E = mc^2$
[illegible]

$E_{Before} = E_{After}$ or $E_{Beginning} = E_{end}$ or

Ex. Pendulum



Bouncing Ball



Falling Ball

$E_{Beginning} = E_p$

$E_{End} = E_K + E_H + E$

Rising Ball

$E_{Begin} = E_K$

$E_{end} = E_p + E_H + E_s$

E_p is transferred to E_k and heat and sound energy. But total energy is constant.

PROBLEM: A ping pong ball of mass 52 g falls to the floor from a height of 1.5 m with an initial velocity of zero. While it falls, the force of friction on it is 0.23N

m = 52g = 0.052kg, V_i = 0, d = h = 1.5m

a) How much gravitational potential energy relative to the floor does it have at the instant it begins to fall?

E_p = mgh = (0.052kg)(9.8m/s^2)(1.5m) = 0.76J

b) How much kinetic energy does it have at the instant it begins to fall?

E_k = 1/2mV^2 = 0, because V = 0

c) What is the total energy relative to the floor?

$E_T = E_p + E_k$ = 0.76J + 0 = 0.76J

d) How much gravitational energy relative to floor does it have when it lands?

E_p = mgh = 0 because h = 0

e) How much heat energy has been produced because of friction by the time it lands?

"Work done by friction is equal to heat energy"

E_H = W = Fd = (0.23N)(1.5m) = 0.35J

f) How much kinetic energy does it have when it lands?

Since the stored (potential) energy is converted to heat and movement (kinetic energy) $\underline{E_p} = \underline{E_k} + \underline{E_H}$ so $E_p - E_H = E_k$

E_k = (0.764J) - (0.354J) = 0.410J

g) What is it's speed at the instant before impact?

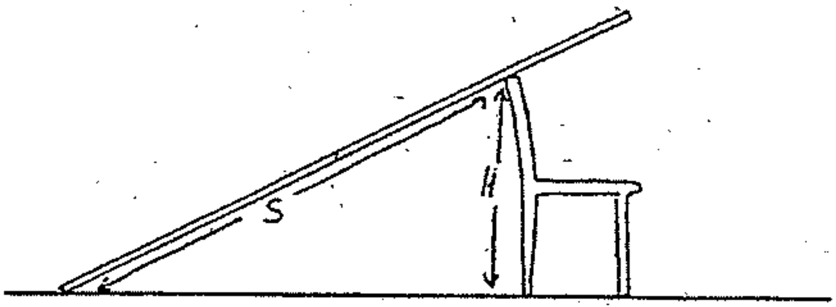
$E_k = 1/2mV^2$ so $V = (2E_k/m)^{½} = \{2(0.410J)/0.052kg\}^{½}$ = 4.0 m/s

WS 8.1: 2b, 5+6(2nd), 7, 8

Chapter 10 - Making the Grade

One of the simplest machines that makes doing work easier is the inclined plane, or ramp. It is much easier to push a heavy load up a ramp than it is to lift it vertically to the same height. When it is lifted vertically, a greater lifting force is required but the distance moved is less. When it is pushed up a ramp, the distance moved is greater but the force required is less. This fact illustrates one of the most powerful laws of physics, the law of energy conservation.

Equipment:



Wooden board
Spring scale (Newtons)
Meterstick
Toy truck
String
Protractor

Procedure:

Step 1: Place the board against the back of a chair so that there is a 30^0 angle between the board and the floor. Measure the distance S and the vertical height H.

Step 2: Attach a string to the back of the toy truck and tie the other end to the hook of the spring scale. Pull the truck, backwards, gently up the slope, reading the force required from the scale.

Step 3: Change the angle of the board to 40^0 and measure the new distance S. Has the vertical height H changed too? Again pull the truck backwards up the slope, reading off the required force.

Step 4: Repeat this procedure for the angles shown in the data table. (Careful! the board is heavy and must be supported by a student, especially at the highest angles.

Step 5: Measure the weight of the truck using the spring scale.

Results: Vertical height H = ______________ cm

Weight of truck = ______________ N

	30^0	40^0	50^0	60^0	70^0	80°
Distance S (cm)						
Force required (N)						

Analysis:

1. What relationship to you find between the force and the distance S ?

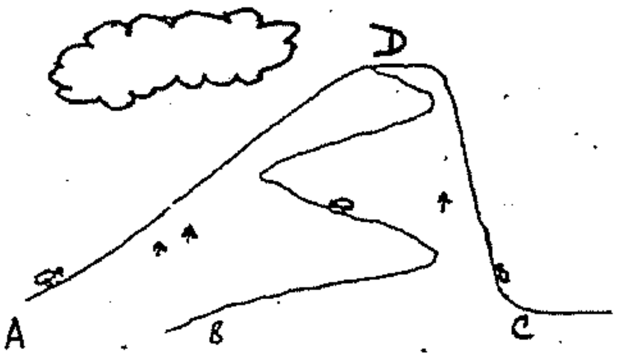
2. One characteristic of an inverse proportionality is that the product of the quantities should be constant. Complete the table below to find if this holds for force and distance values.

	30^0	40^0	50^0	60^0	70^0	80^0	90^0
force x distance (N. cm)							

3. Which values did you multiply for the 90^0 column?

4. How many Joules of work does it take to move the truck up the ramp? (See Hewitt, pages 101 - 103)

Going Further:



A hill has three paths up its sides to a flat summit area, D, as shown. The three path lengths AD, BD, and CD are all different, but the vertical height is the same. Not including the energy used to overcome the internal friction of a car, which path requires the most energy (gasoline) for a car driving up it? Explain your answer.

Review

Use $g = 9.80$ N/kg

1. Calculate the work done by a 47 N force pushing a pencil 0.26 m.
2. Calculate the work done by a 47 N force pushing a 0.025 kg pencil 0.25 m against a force of friction of 23 N.
3. Calculate the work done by a 2.4 N force pushing a 400 g sandwich across a table 0.75 m wide.
4. How far can mother push a 20.0 kg baby carriage, using a force of 62 N, if she can only do 2920 J of work?
5. How much work is it to lift a 20 kg sack of potatoes vertically 6.5 m?
6. If a small motor does 520 J of work to move a toy car 260 m, what force does it exert?
7. A girl pushes her little brother on his sled with a force of 300 N for 750 m. How much work is this if the force of friction acting on the sled is (a) 200 N, and (b) 300 N?
8. A 75.0 kg man pushes on a 500 000 t wall for 250 s but it does not move. How much work does he do on the wall?
9. A boy on a bicycle drags a wagon full of newspapers at 0.80 m/s for 30 min using a force of 40 N. How much work has the boy done?
10. What is the gravitational potential energy of a 61.2 kg person standing on the roof of a 10-storey building relative to each of the following levels (each storey is 2.50 m high)?
    (a) the 10th floor
    (b) the sixth floor
    (c) the first floor
11. A 10 000 kg airplane lands, descending a vertical distance of 10 km while travelling 100 km measured along the ground. What is the plane's loss of potential energy?
12. A coconut falls out of a tree 12.0 m above the ground and hits a bystander 3.00 m tall on top of the head. It bounces back up 1.50 m before falling to the ground. If the mass of the coconut is 2.00 kg, calculate the potential energy of the coconut relative to the ground at each of the following times.
    (a) while it is still in the tree
    (b) when it hits the bystander on the head
    (c) when it bounces up to its maximum height
    (d) when it lands on the ground
    (e) when it rolls into a groundhog hole and falls 2.50 m to the bottom of the hole
13. Calculate the kinetic energy of a 45 g golfball travelling at:
    (a) 20 m/s (b) 40 m/s (c) 60 m/s
14. When the speed of an object doubles, does its kinetic energy double? Explain your answer.
15. How fast must a 1000 kg car be moving to have a kinetic energy of:
    (a) 2.0×10^3 J (b) 2.0×10^5 J (c) 1.0 kW·h
16. How high would you have to lift a 1000 kg car to give it a potential energy of: (a) 2.0×10^3 J (b) 2.00×10^5 J (c) 1.00 kW·h
17. A 50 kg bicyclist on a 10 kg bicycle speeds up from 5.0 m/s to 10 m/s.
    (a) What was the total kinetic energy before accelerating?

(b) What was the total kinetic energy after accelerating?
(c) How much work was done to increase the kinetic energy of the bicyclist?
(d) Is it more work to speed up from 0 to 5.0 m/s than from 5.0 to 10.0 m/s?

18. At the moment when a shotputter releases a 5.00 kg shot, the shot is 3.00 m above the ground and travelling at 15.0 m/s. It reaches a maximum height of 8.00 m above the ground and then falls to the ground. If air resistance is negligible,
(a) What was the potential energy of the shot as it left the hand, relative to the ground?
(b) What was the kinetic energy of the shot as it left the hand?
(c) What was the total energy of the shot as it left the hand?
(d) What was the total energy of the shot as it reached its maximum height?
(e) What was the potential energy of the shot at its maximum height?
(f) What was the kinetic energy of the shot at its maximum height?
(g) What was the kinetic energy of the shot just as it struck the ground?

19. A power mower does 9.00×10^5 J of work in 0.500 h. What power does it develop?

20. How long would it take a 500 W electric motor to do 1.50×10^5 J of work?

21. How much work can a 22 kW car engine do in 60 s if it is 100% efficient?

22. A force of 5.0 N moves a 6.0 kg object along a rough floor at a constant speed of 2.5 m/s.
(a) How much work is done in 25 s?
(b) What power is being used?
(c) What force of friction is acting on the object?

23. How much electrical energy (in kilowatt hours) would a 60.0 W light bulb use in 60.0 d if left on steadily.

24. A 6.0 kg metal ball moving at 4.0 m/s hits a 6.0 kg ball of putty at rest and sticks to it. The two go on at 2.0 m/s.
(a) What is the kinetic energy of the metal ball before it hits?
(b) What is the kinetic energy of the metal ball after it hits?
(c) What is the kinetic energy of the putty ball after being hit?
(d) How much energy does the metal ball lose in the collision?
(e) How much kinetic energy does the putty ball gain in the collision?
(f) What happened to the rest of the energy?

25. A 3.0 kg metal ball, at rest, is hit by a 1.0 kg metal ball moving at 4.0 m/s. The 3.0 kg ball moves forwards at 2.0 m/s and the 1.0 kg ball bounces back at 2.0 m/s.
(a) What is the total kinetic energy before the collision?
(b) What is the total kinetic energy after the collision?
(c) How much energy is transferred from the small ball to the large ball?

26. Two balls with the same mass, one of wood and the other a ping-pong ball partly filled with sand, are rolled along a desk. The wooden ball rolls along nicely, but the ping-pong ball stops in a few centimetres. What happened to its kinetic energy? Was the kinetic energy changed to heat energy by the force of friction between the ball and the desk? Explain your answer.

Chapter 12 Measuring Heat

1. HEAT CAPACITY

Heat Capacity is the amount of heat required to increase the temperature of a substance by 1°C. (It is also the amount of heat released by a substance when it cools by 1°C.) 1 Kg of substance

Different substances have different heat capacities. For example, when you bite into a hot piece of apple pie, the filling is usually hotter than the crust even though they were heated the same amount. The filling has the ability to retain its thermal energy longer, so it remains hot longer.

2. SPECIFIC HEAT CAPACITY

Specific heat capacity is the heat capacity of 1 kilogram of a specific substance. In other words, we say that "the specific heat capacity of a substance is the amount of heat energy transferred when the temperature of 1.0 kg of the substance changes by 1°C".

The symbol used for specific heat capacity is "c " and the unit is J / (kg °C). J/kg K

See Table 12.1, p. 248 of your text for the specific heat capacity values for some common substances.

3. THE HIGH SPECIFIC HEAT CAPACITY OF WATER

You may have noticed in Table 12.1 that water has a higher specific heat capacity than most other substances. Because water has such a high specific heat capacity, a small amount of water can absorb a fairly large amount of heat energy without undergoing a large temperature change. This property makes water a useful coolant in radiators and engines. Also, this property means that water takes a long time to cool. This is why areas of land near lakes and oceans have more moderate seasonal climates (it keeps the land cooler in summer and warmer in winter).

4. CALCULATING SPECIFIC HEAT CAPACITY

As stated above, the unit for specific heat capacity is J/ kg °C. It gives a clue about how to calculate c:

specific heat capacity = energy/(mass x temperature change)

Therefore, the formula is: $c = E/(m\Delta T)$ E = energy (J)

where c = specific heat capacity (J/kg °C)
m = mass (kg)
ΔT= <u>change</u> in temperature (°C) or K

<u>Sample Problem</u>: An immersion heater is used to warm 500g of a liquid from 35°C to 55°C. If 2.0×10^4 J of energy are given to the liquid, determine the specific heat capacity and suggest the identity of the liquid (using Table 12.1).

<u>Solution</u>:
$c = E/(m\Delta T) = 20\,000 J/\{(0.5 \text{ kg}) (55°C - 35°C)\}$

$= 20\,000 J /\{(0.5 \text{ kg}) (20°C)\}$

$= 20\,000 J/10 \text{ kg °C} = 2000 \text{ J} / (\text{kg °C})$

Therefore the liquid is vegetable oil.

5. SOLVING FOR THE OTHER VARIABLES

The equation can be rearranged to solve for the other variables.

Solving for specific heat capacity: $c = E/(m\Delta T)$

Solving for energy: $E = mc\Delta T$

Solving for mass: $m = E/(c\Delta T)$

Solving for ΔT: $\Delta T = E/(mc)$

<u>Sample Problem</u>:

<u>Calculate the amount of heat needed</u> to warm 2.0 kg of ethyl alcohol from 32°C to 62°C. (Refer to Table 12.1 for the specific heat capacity of ethyl alcohol.)

ΔT

<u>Solution</u>: E = ?, m = 2.0 kg, c = 2500J/kg°C
2450 K
ΔT= 62-32 = 30°C

$E = mc\underline{\Delta T}$ = (2.0 kg) (2500J/kg°~~C~~K) (30°~~C~~K) = 150 000J

32°C 305K
<u>62°C</u> <u>335K</u>
<u>30</u> <u>30</u>

<u>Sample Problem</u>:

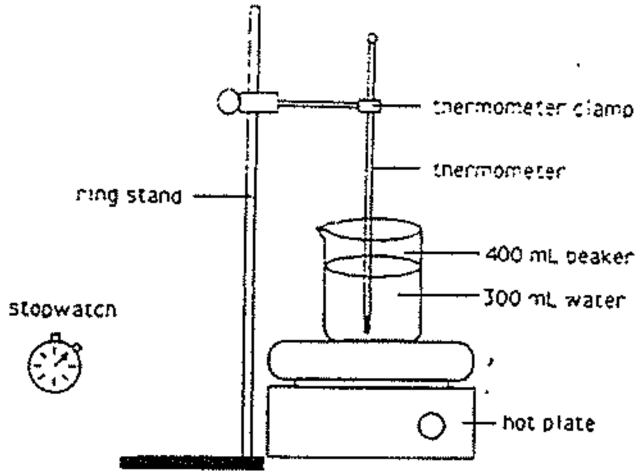
<u>What mass of copper</u> will change temperature from 25°C to 65°C when heated with 6.24×10^4 J of energy? (Refer to Table 12.1)

<u>Solution</u>: $E = 6.24\times 10^4$J, m =?, c = 390J/kg°C, ΔT = 65- 25=40°C

$m = E \ /(c\Delta T)$
= 62400J/{(390 J/kg°C) (40°C)}
= 62400J/15600 J/kg = 4kg of copper

INVESTIGATION: THE POWER OF A HOT PLATE

Purpose. To measure the power of a hot plate indirectly, by measuring the heat transferred to a known mass of water in a measured time.



+ tongs

Procedure:

1. Measure out 300 mL of water into a 400 mL beaker, using a graduated cylinder. Since water has a density of 1 g/mL, this will give you 300 g, or 0.300 kg of water.

2. Arrange the thermometer so that it is not touching the bottom of the beaker.

3. Let the hot plate warm up for a minute or two, then start your stopwatch and record the temperature of the water as precisely as you can. Record the temperature of the water every half minute for 10 minutes. Stop the experiment if the water comes to a boil, and use only you data for temperatures less than the boiling temperature.

Data:

Mass of Water: _____ g

Temperature (°C)							
Time (s)	0	30	60	90	120	150	....

4. Plot a graph with temperature on the Y-axis and time on the X-axis.

5. Find the slope of your graph, which is $\Delta T/\Delta t$. Units will be °C/s.

6. Since the energy transferred to the water from the hot plate is $E = mc\Delta T$, then the power of the hot plate would be

$$P = \frac{E}{\Delta t} = \frac{mc\Delta T}{\Delta t} = mc\left(\frac{\Delta T}{\Delta t}\right)$$

use m + c from next page to calculate P (power) in $\frac{J}{s}$ (wat of hot plate.

Calculate the power of your hot plate, using m = 0.300 kg and c = 4200 J/kg/°C.

7. Find a cooled hot plate, and read the label on the hot plate to see what the manufacturer's power rating is for the hot plate. -555 watts for 0-6 setting plates

-625 watts for 0-10 setting plates

Discussion Questions:

1. What was your calculated power for the hot plate?

2. Calculate the percent difference between your calculated power and the manufacturer's power rating, as follows:

$$\% \text{ Difference} = \frac{(\text{Manufacturer's Power Rating} - \text{Calc. Power Rating})}{\text{Manufacturer's Power Rating}} \times 100\% = ?$$

3. Assuming your calculations were correct, and the manufacturer's rating was also correct, what is the ratio of the power you calculated (heat absorbed by the water per second) to the hot plate's rated power (heat given off by the hot plate per second)? This ratio is the efficiency of the hot plate. Convert it to a percent by multiplying the decimal fraction by 100.

$$\text{Efficiency} = \frac{\text{Calc. Power rating}}{\text{Man. power rating}} \times 100\% = ?$$

4. Why is the efficiency less than 100 %?

TEST REVIEW QUESTIONS

CHAPTER 10 : Work & Power

Review Problems p. 214

17. (a) 5.5×10^3 J
    (b) no work
    (c) 5.5×10^3 J
    (d) no
    (e) 2.2 kW

18. (a) 9×10^3 J
    (b) 3 kW

Practice Problems p. 203

9. 1.15×10^3 W
10 (a) 6.0×10^2 J
    (b) 5.9×10^3 J
    (c) 3.3 W
11. 1.3×10^5 N

CHAPTER 11 : Energy & Conservation

Practice Problems p. 222

2. (a) 1.96×10^3 J
   (b) 1.96×10^3 J
   (c) 2.6×10^3 N

Practice Problems p. 224

5. at edge : 4×10^4 J ; at bottom: -4×10^4 J
6 (a) 1.96×10^5 J
   (b) -9.80×10^4 J
7. (a) 3200 J
   (b) 3200 J
   (c) directly from W done by person;
      indirectly from the chemical E stored
      in person's body

Practice Problems p. 234

13. (a) 4.3 m/s
    (b) 290 J
    (c) 2.3 J
    (d) 290 J
    (e) 99%
14. 1×10^2 m/s
15. 6.7×10^{-2} m/s

Review Questions p. 238

8. (a) 2×10^8 J
   (b) 2×10^8 J
   (c) 2×10^8 J
   (d) 100 m/s
12. 2.1×10^3 J
13. 1.3×10^2 J
16. 20.0 m

17. 17 J
20. (a) 5×10^3 J
    (b) 5×10^3 J
    (c) 5×10^3 J
21. (a) 2×10^4 J
    (b) 2×10^4 J
    (c) 50 m/s

23. (a) 400 J
    (b) 20 m/s
24. (a) 3 m/s
    (b) 2×10^2 J
25. 4.1 m/s

ENERGY REVIEW PROBLEM SET

Use g = 9.80 N/kg

1) How far can a mother push a 20.0 kg baby carriage, using a force of 62 N, if she can only do 2920 J of work?

2) A boy on a bicycle drags a wagon full of newspapers at 0.80 m/s for 30 min using a force of 40.0 N. How much work has the boy done?

3) What is the kinetic energy of a 45 g golfball travelling at:

a. 20 m/s b. 40 m/s c. 60 m/s

4) A 50. kg bicyclist on a 10 kg bicycle speeds up from 5.0 m/s to 10 m/s.

- a. What was the total kinetic energy before accelerating?
- b. What was the total kinetic energy after accelerating?
- c. How much work was done to increase the kinetic energy of the cyclist?
- d. Is it more work to speed up from 0 to 5.0 m/s than from 5.0 to 10.0 m/s?

5) How long would it take a 500 W electric motor to do 1.50 x 105 J of work?

6) A 3.0 kg metal ball, at rest, is hit by a 1.0 kg metal ball moving at 4.0 m/s. The 3.0 kg ball moves forwards at 2.0 m/s and the 1.0 kg ball bounces back at 2.0 m/s

- a. What is the total kinetic energy before the collision?
- b. What is the total kinetic energy after the collision?
- c. How much energy is transferred from the small ball to the large ball?

7) How much heat is needed to rias the temperature of 50 g of lead by 4.0 °C. (c = 130 J/kgC)

8) Suppose that your car has a mass of 1000. kg and is made completely of steel. What temperature change would 1.0 kWh of heat energy produce in it? (c = 480 J/kgC)

9) What is the specific heat capacity of a material if 2000. J of heat energy can raise the temperature of 10. g of it by 140°C?

10) A 10,000 kg airplant lands, descending a vertical distance of 10 km while travelling 100 km measured along the ground. What is the plane's loss of potential energy?