Vectors

Definitions

Vector – Value with magnitude & direction
Must have arrows when drawn

Scalar – Value with magnitude only

Resultant – The sum of two or more vectors

Equilibrant – equal and opposite in magnitude to resultant

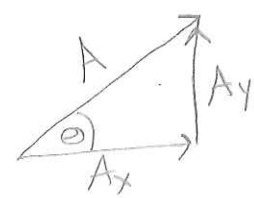
Magnitude – Size of a vector value

Useful Equations

$A_x = A\cos\theta$ $\quad A = \frac{A_x}{\cos\theta}$ $\quad \theta = \cos^{-1}\frac{A_x}{A}$

$A_y = A\sin\theta$ $\quad A = \frac{A_y}{\sin\theta}$ $\quad \theta = \sin^{-1}\frac{A_y}{A}$

$\theta = \tan^{-1}\frac{A_y}{A_x}$ $\quad A = \sqrt{A_x^2 + A_y^2}$



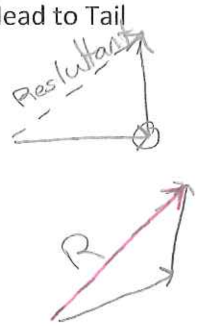
A_x = horizontal
A_y = vertical
A = hypotenuese
θ = between A_x & A

Examples of Vectors
- displacement, velocity, acceleration
Force momentum, impulse
Field strength

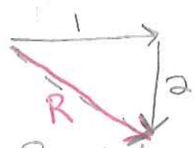
Examples of Scalars
-distance, speed, mass, time, energy, work, power, current, potential difference, wavelength, frequency, charge

"Graphical" Addition of Vectors

Head to Tail



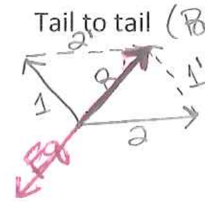
Parallel

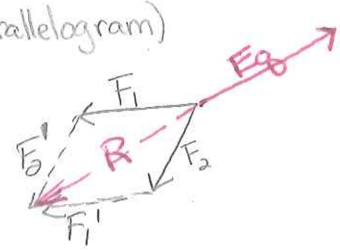


Perpendicular Vectors

Resultant from start of first to end of last

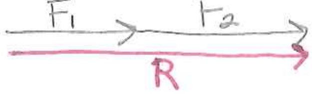
Tail to tail (Parallelogram)





Determining the Maximum of Minimum Resultant

The max resultant occurs when the difference between vectors is 0° (or the smallest angle) which means same direction



The min resultant occurs when the difference between vectors is 180° (or largest angle up to 180°) which means opposite direction

Graph Related Skills

Finding Slope

Slope = $\frac{\text{rise}}{\text{run}} = \frac{\Delta Y}{\Delta X}$

$m = \frac{\text{change in "y" variable}}{\text{change in "x" variable}}$

Significance of Slope

Match the graph expressed as $y/x = m$ to an equation from ref. table.

Ex; $\frac{E_{photon}}{f} = h$ $\quad d/t = V$

$a = \frac{\Delta V}{t}$ $\quad \frac{F_g}{m} = g$ $\quad \frac{V}{\lambda} = f$

$R = V/I$ $\quad V = W/q$ $\quad \frac{F_{net}}{a} = m$

Area under the graph

Multiply "y" · "x" and match to equation from ref. table

If shape of graph is rectangle use $A = y \cdot x$

If shape of graph is triangle use $A = \frac{1}{2} yx$

Ex: $\quad v = f\lambda$ $\quad$ constant Force

$PE_s = \frac{1}{2} F_s x$ $\quad W = Fd$

$W = \frac{1}{2} Fd$ For avg force

Graphical Relationships (Relationship types)

no relationship "y" is not influenced by a change in "x"

direct relationship – whatever happens to "x", happens to "y"
Ex: If "x" doubles "y" doubles
Equation: $y = mx$

direct square – whatever happens to "x", happens squared to "y"
Ex: "x" times 3 means "y" times 9
Equation $y = mx^2$

inverse – whatever happens to "x", the opp happens to "y"
$y = m/x$

inverse square – whatever happens to "x" the opp square happens to "y"
$y = m/x^2$

Rules for graphing and interpreting data

Scaling the axes

make sure all increments are equal for the same axis

Best Fit Line

use to average data

Leave some points above and some below

Slope from Best Fit

Pick points from best-fit not plotted points

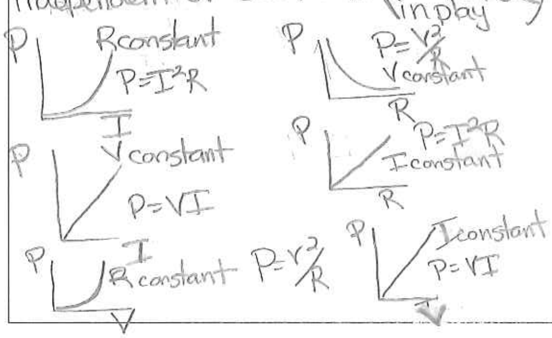
equation

$m = \frac{y_2 - y_1}{x_2 - x_1}$

Use caution with graphs of the following concepts or equations

Electrical Power

Determine which variable is dependent, independent or constant. (3rd variable in play)



Hooke's Law and Spring Elastic Energy

For springs the Force on the spring is not constant → it starts at 0 and increases at a constant rate so $\frac{F_s}{2}$

$W = \frac{1}{2} F_s x = PE_s$

$PE_s = \frac{1}{2} kx^2$

$W_{spring} = PE_s$

Assigning Units, Estimating Values and Rearranging Equations

Base "SI" units

Mass = kilograms

Length or position – meters

Time – seconds

Charge – coulombs

Derived Units

Force – Newtons = $kg\,m/s^2$

Work/Energy Joules = $kg\,m^2/s^2$ = Nm = VC

$W = PE = KE = PE_s$

$Fd = mgh = \frac{1}{2}mv^2 = \frac{1}{2}kx^2$

Power = Watts = J/s = $\frac{Nm}{s}$

$P = W/t$

Current – Amperes = C/s

$I = q/t$

Potential Difference – V = J/C

$V = W/q$

Resistance = Ohms

$R = V/I$

Frequency = Hertz = $1/s$

$f = 1/T$

Deriving alternate units from an equation

$v = f\lambda = (Hz)(m) = m/s$

$v = d/t = (m/s)$

$F = ma = (kg\,m/s^2)$

$p = mv = (kg\,m/s)$

$J = F_{net}t = (Ns = kg\,m/s^2 \cdot s)$

$k = \frac{F_s}{x} = (N/m)$

$W = Fd = (Nm)$

$PE = mgh = (kg(m/s^2)m)$

$P = W/t = (J/s)$

$P = VI = (VA)$

$I = q/t = (C/s)$

$W = (Vq = eV)$

$P = I^2R = (A^2\Omega)$

$V = W/q = (J/C)$

$P = VI = (J/C \cdot C/s = J/s)$

$v = f\lambda = (Hz \cdot m = m/s)$

$v = \lambda/T = (m/s)$

$E_{photon} = hf = (Js \cdot Hz = \frac{Js}{s} = J)$

$E = F_e/q = (N/C)$

DO NOT MEMORIZE – Practice Skill

Scientific Notation and the Metric system

$420\,nm = 4.2\times10^2\times10^{-9}m = 4.2\times10^{-7}m$

$1.6\times10^{-5}A = 1.6\times10^1\times10^{-6}A = 16\mu A$

$1.6\times10^{-2}\times10^{-3}A = .016mA$

$6.4\times10^{-7}m = 6.4\times10^2\times10^{-9}m = 640\,nm$

Rearranging Equations

Determine which variable the equation should be written "in-terms-of"

– isolate by multiplying, dividing etc

Ex = solve for t in $d = v_it + \frac{1}{2}at^2$

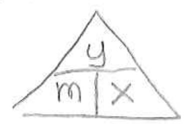
when d ... & $a = g$ & $v_i = 0$

$t = \sqrt{\frac{2d}{g}}$

solve for t when $v = d/t$ $t = d/v$

How to make a "triangle"

Start from equation in format of $y = mx$



Ex = $d = vt$

$F_{net} = ma$

Estimating Values for mass, weight, height/length, time

Put all values in terms of the most reasonable metric unit and eliminate #'s that don't make sense.

Keep in mind the following metric–English equivalents

1 kg = 2.2 lbs

1 ft = 30 cm

Use metric prefix chart on PRT

$1\,kg = 1\times10^3 g = 1000g$

$1\,mm = 1\times10^{-3}m = .001m$

$25\,cm = 25\times10^{-2}m = 2.5\times10^{-1}m$

$3.5\times10^{-1}\mu m = 3.5\times10^{-5}m$

KINEMATICS GRAPHS

Vocabulary:

Distance
Scalar – length without direction
– change in position w/o direction

Displacement
Vector – length with direction
– change in position with direction

Velocity – rate of change in position with direction $v = d/t$

Speed – rate of change in position without direction

Acceleration – rate of change in velocity
change in speed or direction

Equilibrium – $F_{net} = 0$ $a = 0$
not speeding up or slowing down

Net Force – The unbalanced force
"The amount a force wins by"

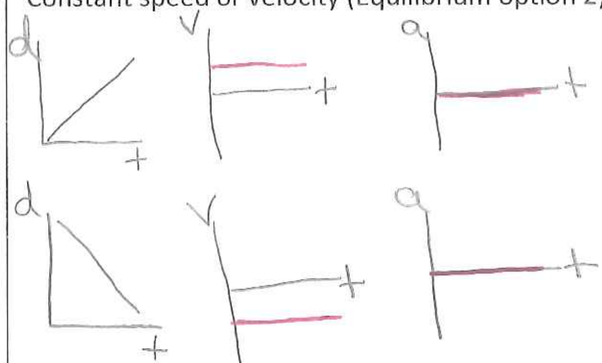
Constant unbalanced force
Constant F_{net} = constant acc

Objects at rest (Equilibrium option 1)

object at rest, stays at rest

No Net force, No "a"

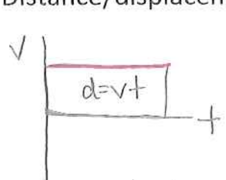
Constant speed or velocity (Equilibrium option 2)



No net force – object in motion remains in motion – no "a"

– NOT SPEEDING UP or SLOWING DOWN

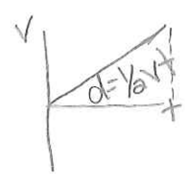
Distance/displacement from a v vs. t graph



constant v.

d is the area of v vs t

$d = vt$

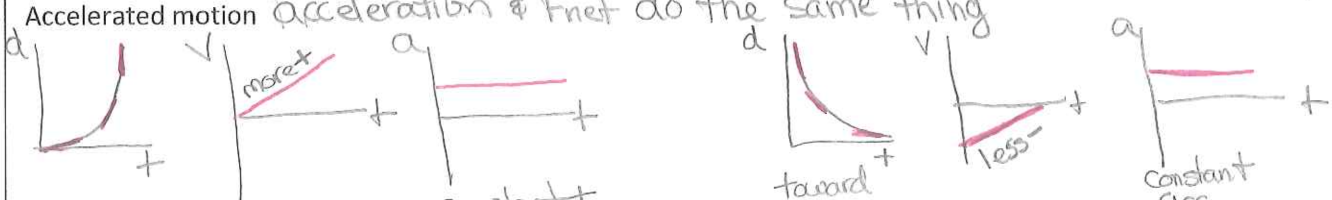


inc v

$\bar{v} = \frac{v_i + v_f}{2}$

$d = \bar{v}t$

Accelerated motion acceleration & Fnet do the same thing

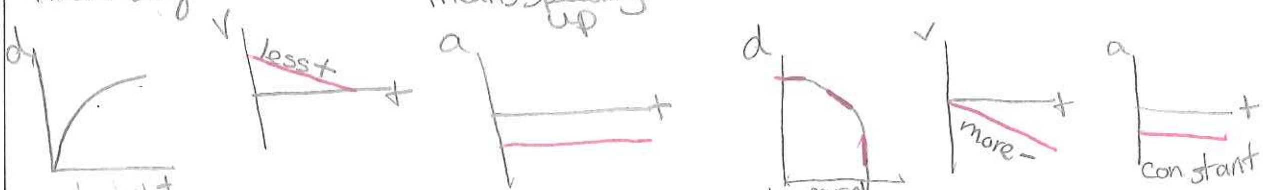


away +
increasing

constant + acceleration means speeding up

toward slowing

constant acc



away +
decreasing

toward speeding up

constant acc

Accelerated Motion

Acceleration
Change in velocity
speed or direction
$a = \frac{\Delta v}{t}$
$a_c = \frac{v^2}{r}$

Average speed/velocity
$\bar{v} = \frac{v_i + v_f}{2}$

Initial Velocity
v_i

Final Velocity
v_f

Distance/Displacement
d

Equilibrium
$F_{net} = 0 \quad a = 0$

Non-Equilibrium
F_{net} is present
F_{net} constant; a is constant

Net Force
$F_{net} = ma$

Centripetal Acceleration
$a_c = \frac{v^2}{r}$

Kinematics equations:

When acceleration equals zero use the equation

$v = d/t \qquad d = vt \qquad t = d/v$

When acceleration (net force) is present use these equations:

$v_f = v_i + at$ | $v_f = at \quad \Delta v = at$

$v_f^2 = v_i^2 + 2ad$ | if $v_i = 0$ | $v_f = \sqrt{2ad}$

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

OR if possible find average v using equation

$\bar{v} = \frac{v_i + v_f}{2}$

And use the equation

$d = \bar{v}t$

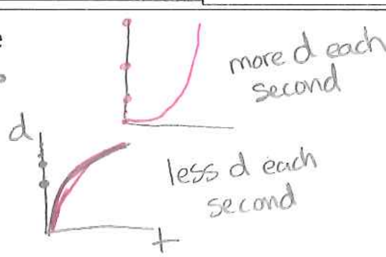
Acceleration can also be found using Newton's 2nd Law

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

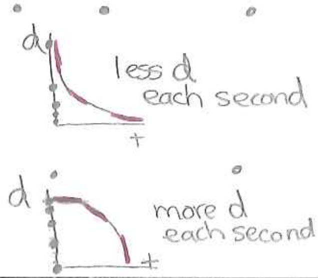
$F_{net} = m\frac{\Delta v}{t}$

Dot diagram or Ticker tape

t=0
t=0



t=0



t=0

Short cuts for v_i=0

$d = \frac{1}{2}at^2 \qquad t = \sqrt{\frac{2d}{a}}$

$v_f = at \qquad v_f = \sqrt{2ad}$

"Head Problem" Method

v_i	v_f	$\bar{v}$	d	a	t

Free Fall and other Projectiles

Vocabulary

Acceleration due to gravity
9.8 m/s² Earth

$g = \frac{F_g}{m}$

Gravitational Field Strength
9.8 N/kg

Force due to gravity
– Weight

Free Fall
- $a = g$ no air resistance

Projectile
The only force is gravity F_g

Horizontal Component
remains constant

Vertical Component
V_{iy} equal but opp to V_{fy}
$V_y = 0$ at top

Initial Horizontal Velocity
$V_{ix} = V_i \cos\theta$

Initial Vertical Velocity
$V_{iy} = V_i \sin\theta$

Vertical Acceleration
$a_y = g = 9.8\,m/s^2$ downward

Range
horizontal displacement
$d_x = V_x t$ — t determined using vertical axis

Launch Angle
$\theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)$ 45° max range

Max height/high pt
$V_{iy} = 0$ ½ total time

Rules for all projectiles

- The net force is Weight – F_g so $a = g = 9.81\,m/s^2$ downward (vertical axis only)

$a_x = 0$ $a_y = g$

x at equilibrium y experiencing net force

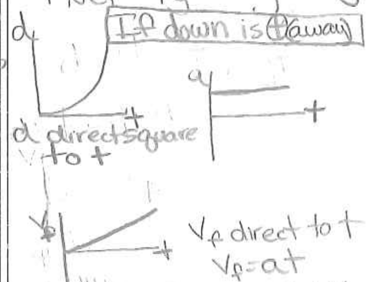
Objects dropped from rest ($v_{iy}=0$) (downward can be assigned +)

V_i and a agree

Flip if g is negative (toward)

$F_{Net} = F_g = mg$ $g = 9.8\,m/s^2$ $d = \frac{1}{2}at^2$ $t = \sqrt{\frac{2d}{g}}$ $V_f = gt$

If down is ⊕ (away)



V_f direct to t
$V_f = at$
d is area of v vs t $d = \frac{1}{2}(V_f t)$

V_i	V_f (at)	$\bar{V}$	d (½at²)	a	t
0	10 m/s	5 m/s	5 m	10 m/s²	1 s
0	20 m/s	10 m/s	20 m	10 m/s²	2 s
0	30 m/s	15 m/s	45 m	10 m/s²	3 s
0	40 m/s	20 m/s	80 m	10 m/s²	4 s
0	50 m/s	25 m/s	125 m	10 m/s²	5 s

For .1 s to .5 s change to cm

BENCHMARKS USING 10 m/s²

Objects launched upward (down must be assigned -)

"V_i" and "a" are different directions so sign required
$a_y = -9.81\,m/s^2$

time up = time down → time up or down
$V_f = V_i + at$ $0 = V_i + at$
$t = \frac{\Delta V}{a}$

V_{iy} equal and opposite V_{fy}

V_y at top = 0

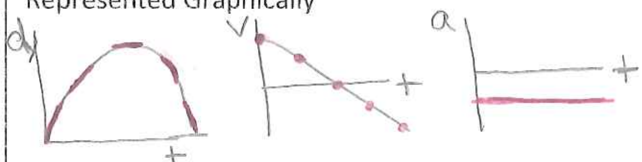
total vertical d ($d_y = 0$)

total time
$t = \frac{2V_{iy}}{a}$

V_f or V_i $V_f = \sqrt{2gh}$

$d = \frac{1}{2}at^2$ (use falling side) up = down

Represented Graphically



Horizontal Projectiles

y axis
$F_{Net} = F_g = mg$

x equilibrium
$F_{netx} = 0$
$a = 0$

vertical
Follow rules for dropped objects

horizontal

V_x	d_x	t

vertical

V_{iy}	V_{fy}	$\bar{V}_y$	d_y	a_y	t
0					

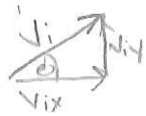
time is the same for both axes

$d = \frac{1}{2}at^2$ if $t(\times 2)$ $d(\times 4)$
$t(\times 3)$ $d(\times 9)$

$t = \sqrt{\frac{2d}{a}}$ if $d(\times 2)$ $t(\sqrt{2})$
$d(\times 3)$ $t(\sqrt{3})$
$d(\times 4)$ $t\sqrt{4}$ or $2t$
$d(\times 5)$ $t\sqrt{5}$
$d(\times 9)$ $t\sqrt{9}$ or $3t$

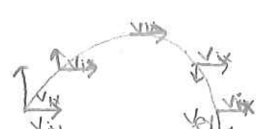
Projectiles at an angle.

Combine x axis at equilibrium ($v = d/t$)
with object launched upward
need to break V_i into horizontal & vertical components



$V_{ix} = V_i \cos\theta$
$V_{iy} = V_i \sin\theta$

max range = d_x = 45° or (angle closest to 45°)
- equal difference from 45° is same landing spot
- max height equals greatest time in air highest angle



V_x constant V_y changes

Newton's Laws and Dynamics

First Law

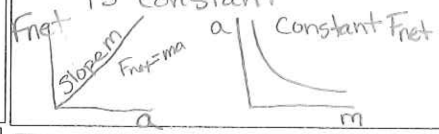
Law of Inertia
(Inertia is mass)
at rest, stay at rest
in motion, stay in motion
unless an unbalance (F_{net}) is present.
ie Velocity (speed or direction) only changes if a net force is present

Second Law

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

Whatever F_{net} does acceleration does

If F_{net} is constant "a" is constant



Third Law

For every force there exists an equal and opposite force
(Newton's 3rd Law force pairs)

Pairs act on each object

Vocabulary

Inertia — mass

Equilibrium — $F_{net} = 0$
$a = 0$

Net Force / Unbalanced Force — cause acceleration: speed up, slow down, change direction

Applied Force F_A

Horizontal Component of Force
$F_{Ax} = F_A \cos\theta$

Vertical Component of Force
$F_{Ay} = F_A \sin\theta$

Parallel component of weight
$F_{g\parallel} = F_g \sin\theta = mg\sin\theta$

Perpendicular component of weight
$F_{g\perp} = F_N = mg\cos\theta$

Resultant
sum of 2 or more vectors

Equilibrant
equal but opposite of Resultant

Action Reaction Pair
Equal but opp force

Weight
$F_g = mg$ — F_{net} on a projectile

Normal Force
$F_N = F_g$ level surface — $F_N = F_{g\perp}$ on incline

Frictional Force
$F_f = \mu F_N$ opposes motion

When $F_{net}=0$ — Equilibrium

Set Forces from an axis equal to zero if v is 0 or constant

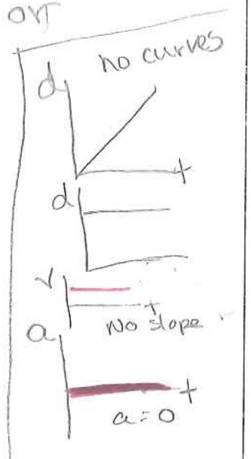
If $F_{net} = 0$ $a = 0$

object remains at rest or constant velocity

Friction scenario
$F_{net} = F_A + F_f$ $0 = F_A + F_f$ $F_A = -F_f$

Lift scenario
$F_{net} = F_A + F_g$ $0 = F_A + F_g$ $F_A = -F_g$

Other Examples
$F_{net\,x} = F_{Ax} + F_f$ $F_{net\parallel} = F_{g\parallel} + F_A$
$F_{net\perp} = F_{g\perp} + F_N$



When F_{net} is present (always constant)

- If F_{net} is present acceleration is present
- Whatever F_{net} does acceleration does
- Set Force Vectors for an axis equal to ma and solve for unknowns

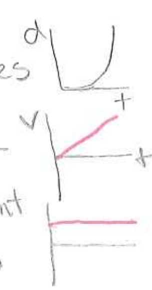
Examples
$F_{net} = F_A + F_f$ $ma = F_A + F_f$

Lift problem
$F_{net} = F_A + F_g$ $ma = F_A + F_g$ $ma = F_A + mg$ (must pay attention to direction (sign))

$F_{net\parallel} = F_{g\parallel}$ $ma = mg\sin\theta$
$a = g\sin\theta$

Elevator Problem
Normal Force (upward) is the apparent weight
- accelerating upward $F_N > F_g$
- accelerating down $F_N < F_g$
- constant speed or rest $F_N = F_g$

graphs
d vs t — curves
v vs t — slope
a vs t — constant non zero



Other Force Equations

Frictional Force, Centripetal Force, Force on a Spring and Forces on and incline ($F_{g\parallel}$ and $F_{gperpendicular}$)

Vocabulary:

Coefficient of Friction

$\mu = \frac{F_f}{F_N}$ on Front of PRT

Kinetic Friction
moving

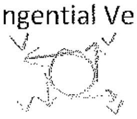
$\mu_s > \mu_k$

Static Friction
at rest

Centripetal Acceleration
When direction is changing
a_c toward center $a_c = v^2/r$

Centripetal Force
Force to center $F_c = ma_c$
$F_c = mv^2/r$

Tangential Velocity



Elongation of a spring
x (m)

Spring Constant
$k = \frac{F_s}{x}$ (N/m)

Spring Force
$F_s = kx$ For vertical
$F_s = F_g$
$kx = mg$

Parallel component of weight
$F_{g\parallel} = F_g \sin\theta$
$mg \sin\theta$

Perpendicular Component of weight
$F_{g\perp} = F_N = F_g \cos\theta$

Normal Force Perpendicular to surface
$F_N = F_g$ on level surface
$F_N = F_{g\perp}$ on incline $= mg\cos\theta$

Angle of incline
level = 0°
vertical = 90°

Frictional Force – Always opposes motion or net force

$F_{Net} = F_{AX} + F_f$ or $F_{Net} = F_A + F_f$

$F_f = \mu F_N$

Only Factors to influence F_f are presence of motion ($\mu_s > \mu_k$), magnitude of normal force

Static → push at rest
Kinetic → keep

Centripetal Force

Net force which causes circular path

$F_c = ma_c$ $a_c = v^2/r$ $\boxed{F_c = mv^2/r}$

$v = \frac{\text{Circumference}}{T} = \frac{2\pi r}{t \text{ of 1 rev}}$

F_c & a_c toward center
Velocity tangent

F_c is always caused by another agent
For a car on a curve
$F_c = F_f$
For a planet in orbit
$F_c = F_g$
For an object on a string
$F_c = F_T$

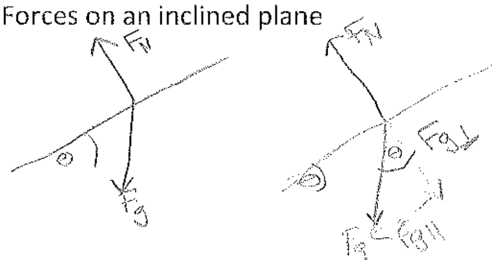
Spring Force

$F_s = kx$ k is spring constant x is stretch

in vertical
F_s is weight so $F_g = mg$ → $F_s = F_g$, $kx = mg$

One of the only forces that is not constant
as F_s increases x increases

Forces on an inclined plane



$F_g = \sqrt{F_{g\perp}^2 + F_{g\parallel}^2}$

$\theta = \tan^{-1}\left(\frac{F_{g\parallel}}{F_{g\perp}}\right)$

$F_{g\perp} = F_g \cos\theta = mg\cos\theta$

$F_{g\parallel} = F_g \sin\theta = mg\sin\theta$

⊥ in equilibrium $F_N = F_{g\perp}$
∥ axis depends on other forces

For frictionless
$F_{Net} = F_{g\parallel} = mg\sin\theta$
$ma = mg\sin\theta$ $a = g\sin\theta$

For equilibrium with friction
$F_{Net} = F_{g\parallel} + F_f$
$-F_f = F_{g\parallel}$ $F_f = mg\sin\theta$

(Pay attention to starting in kg or N)

Momentum and Impulse
Conservation of momentum

Momentum p ($kg\ m/s$)

$p = mv$

Conserved Quantity

Inertia

- Mass
- resistance to change in condition

Impulse J $\Delta p = J$

$J = Ft$

Force (Average Force)

Newton's 3rd Law

Conservation of Momentum

$p_{before} = p_{after}$

Elastic Collision

stay separate

Inelastic collision

Join

Separation/Explosion

separate from rest

Rate of change of momentum

$\frac{\Delta p}{t} = F$

Change in momentum

recoil

Helpful Hints Momentum and Impulse are Vectors

On the day of the test when given the ok add the following to PRT

$J = F_{net}t = \Delta p = m\Delta v$ and $Ft = m\Delta v$ $F = \frac{\Delta p}{t}$

Relationship between Momentum and Impulse

Any change in momentum is caused by an impulse (Force acting for a time)

$F_{net} = ma$ mean $F_{net} = \frac{m\Delta v}{t} = \frac{\Delta p}{t}$

Force and time have an inverse relationship for a constant Δp.

If two objects with the same v_i are brought to rest, they experience the same Δp & J. The net force will be different

F_T or $F_\uparrow T$ (concept behind airbag)

Conservation of momentum in collision $p_{before} = p_{after}$ (on PRT)

Elastic objects remain separate

$p_1 + p_2 = p_1' + p_2'$

□ + □ = □ + □

$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$

(If velocity is zero p is zero & can be eliminated from equation)

momentum is a vector so direction must be taken into account

Inelastic objects initially separate, join together

$p_1 + p_2 = p_{1+2}$

$m_1v_1 + m_2v_2 = (m_1+m_2)v'$

[1] + [2] = [ ]

usually larger mass so final v is less

Separation/Explosion objects initially together separate (at rest) usually

[1 2] = [1] + [2]

$p_{1+2} = p_1 + p_2$

$0 = m_1v_1 + m_2v_2$

Recoil

$m_1v_1 = -m_2v_2$

$p = mv$ for each object

Equations are scenario dependent

Work, Energy, Power
Conservation of Energy

VOCABULARY

Work = Energy (Joules)
$W = Fd = \Delta E$

Energy (J)
KE, PE, PE_s or Q

Power – Rate of energy or work
$P = W/t$

Work against Gravity
$W = F_g d = mgh = PE$

Work on a frictionless surface
$W = F_{net} \times d = mad = KE$

Work on a spring
$W = \frac{1}{2} F_s x = \frac{1}{2} kx^2 = PE_s$

Work against friction
$W = F_f d = Q$

Potential energy
Energy associated with vertical position

Kinetic energy
Energy associated with motion

Elastic (Spring) Potential Energy
Energy stored in a spring PE_s

Internal Energy
Energy related to friction

Spring constant
$K = F_s / x = N/m$

Total (Mechanical) Energy

Change in Energy

Conservation of Energy

Relationship between Work, Energy and Power

Work done is equal to energy gained
$W = Fd = \Delta E$ measured in Joules or Nm or $kg\frac{m^2}{s^2}$
F_{vector} must agree with direction of d if force applied at angle
Power is the rate of Work or Energy
$P = W/t = \frac{\Delta E}{t} = \frac{Fd}{t} = Fv$ measured in Watts

Work Energy Theorem

Work on a horizontal frictionless surface = KE
$W = F_{net} d = mad = \frac{1}{2}mv^2$ ($v_f^2 = 2ad$ so $ad = \frac{1}{2}v_f^2$)
Work against gravity = ΔPE Constant force so Fd
$W = F_g d = mgh$
Work on a spring = ΔPE_s (remember Force ↑ with stretch so you need avg force with springs)
$W = \frac{F_s}{2} x = \frac{1}{2}kx^2$
Work against friction = Q
$W = F_f d = Q$ also equals difference between ideal & real

Conservation of Energy (remember bar graphs)

Unless other work is done Total mechanical energy is constant throughout problem (KE+PE)

E_T top = E_T Bottom $E_T = KE + PE$ (Frictionless)

$E_T = KE + PE + Q$ (Friction/Heat)

	PE + KE	E_T
Top		
Mid		
Bottom		

Any loss in PE becomes KE

without friction E_T remains constant

KEY to problem solving is finding point where all energy is a single form ex: $PE = E_T$ at top
$KE = E_T$ a bottom

Negative Work, Energy lost to friction, Internal energy

When friction or resistance is present use $E_T = PE + KE + Q$
$Q = E_T - (PE + KE)$

Negative Work takes away from total mechanical energy

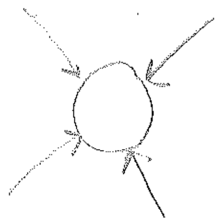
- Internal energy becomes heat.

Gravitational, Electric and Magnetic Fields

Gravitational Fields

Uniform Field (Surface of Planet)

$F_g = mg \quad g = \frac{F_g}{m}\ (N/kg)$



always attractive

$F_g = mg$

Force between Masses

$F_g = \frac{G m_1 m_2}{r^2} \quad G = 6.67\times10^{-11}\ N\,m^2/kg^2$

Whatever happens to r; opp² to F_g

Whatever happens to F_g; √opp to r

Ex if r ×3 F_g ÷9
if F_g ÷9 r×√9 ×3
if r×2 F_g ÷4
if F_g×2 r÷√2

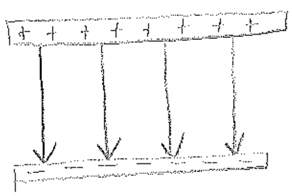
$m_{electron} = 9.11\times10^{-31}\,kg$
$m_{proton} = 1.67\times10^{-27}\,kg$

Electric Fields

Uniform Field (Parallel Plates)

$F_e = Eq$

$E = \frac{F_e}{q}\ (N/C)$



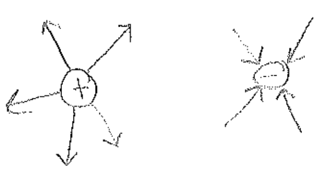
Force between Charges

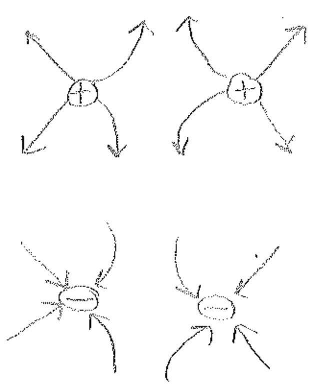
$F_e = \frac{k q_1 q_2}{r^2} \quad k = 8.99\times10^{9}\ N\,m^2/C^2$

$q_{electron} = 1.6\times10^{-19}\,C$

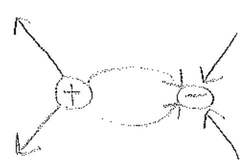
F_e = direct to q
F_e = inverse square to r
r = inverse square root to F_e
r×2 means F_e÷4
F_e×2 means r÷√2

Fields around charges



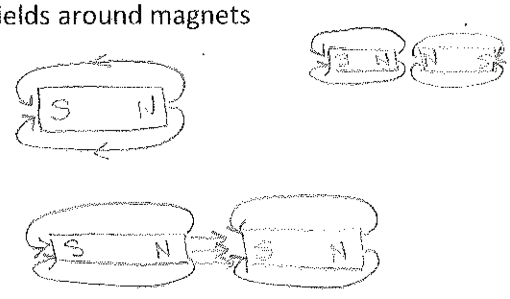


Work done against field increases potential energy



lines with arrows away from ⊕ toward ⊖

Fields around magnets



The origin of a magnetic field is the oscillation (acceleration) of a charge

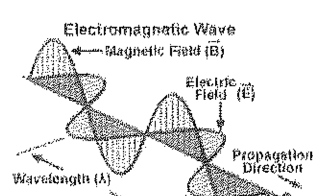


Figure 1

Electric charge → electric field

moving electric charge → electric & magnetic field

accelerating charge → photon → EM wave

Charge and Movement of Electrons

Proton
$q = 1e = 1.6\times10^{-19}C$

Neutron
$q = 0e$

Electron
$q = -1e = -1.6\times10^{-19}C$

Sub-atomic
part of the atom

Elementary Particle
smallest possible stable particle

Elementary Charge
smallest possible stable charge

Electromagnetic force
Force between charged particles
opp charges attract
like charges repel

Strong Force
Force between quarks

Conductor
materials which allow electrons to flow easily

Insulator
materials which prevent electrons from flowing easily

Conduction
movement of electrons by contact

Induction
temporary imbalance of electrons due to repulsion

Electroscope
Device used to observe charge

Converting between elementary charge and coulombs

$1e = 1.6\times10^{-19}C$

multiply into $\times 1.6\times10^{-19}$
divide out $\div 1.6\times10^{-19}C$

Ex: $22e \times \frac{1.6\times10^{-19}C}{1e} = 3.52\times10^{-18}C$

$8\times10^{-17}C \times \frac{1e}{1.6\times10^{-19}C} = \frac{8\times10^{-17}e}{1.6\times10^{-19}} = 500e$

Possible charge on an object

elementary charge must be a whole # of e
- Cannot have a partial elementary charge
- Can have a partial coulomb as long as it doesn't split on "e"

→ Divide charge in coulombs by $1.6\times10^{-19}C$ and make sure it is a whole #.

Loss or gain of electrons ONLY Electrons are transferred

If electrons are lost, the charge on an object becomes less negative or more +

If electrons are gained, the charge on an object becomes more negative or less +

- Charge is conserved - The net charge remains constant
  If one object loses the other object gains

Conductor vs. Insulator

Charge moves easily in a conductor by contact.

Charge spreads out over the conductor
the charge on each object is found by $\frac{\text{total charge}}{\#\text{ of objects}}$

Charge moves in an insulator but only over a short distance (polarized)

Charged objects attract opposite AND Neutral

Electric Field, Electrical Energy (work), Potential Difference, Current and Resistance

Electrical energy

$W = Vq$ = (Joules) = VC

eV

1 eV = 1.6×10^{-19} J

Electric field strength

$E = \frac{F_e}{q}$: (N/C)

Work = Electrical Energy

$W = Vq$ = (VC = eV = J)

Potential Difference

$V = W/q$ = (J/C) or (V)

Current

$I = q/t$ (C/s = Ampere)

Resistance Ω

$R = \frac{\rho L}{A}$

$R = V/I$

Ohm's Law

$R = V/I$ $V = IR$

$I = V/R$

Power Law

$P = W/t = VI = I^2R = V^2/R$ = (W = J/s)

Electric Field Strength

$E = \frac{F_e}{q}$ = (N/C)

Electric Field is uniform between plates

Electric Field weakens with the square of distance from a point source

Work on a charge (work by the field or against the field)

If like charges are pushed together (against field) or if opposite charges are pulled apart work is done.

If like charges are allowed to repel (move with field) or opposite charges are pulled together the field is doing the work

Potential Energy (qEd) becomes kinetic energy

Current

$I = q/t$

If charge is given in electrons convert to Coulombs (multiply by 1.6×10^{-19})

Ampere = C/s

Power Rate of Energy

$P = W/t = VI = I^2R = V^2/R$

Measured in Watts = J/s

For graphs of power you must identify dependent, independent variable and the 3rd thing held constant.

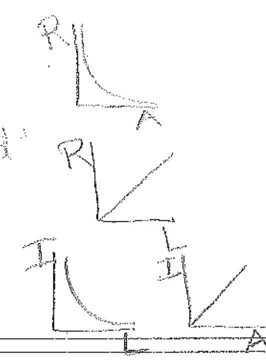
Resistance in a wire

$R = \frac{\rho L}{A} = \frac{\rho L}{\pi r^2}$ $I = \frac{V}{R}$ so $I = \frac{VA}{\rho L}$

Low Resistance → "Short, Fat, Cold, Gold"

If temp↑ Resistance↑ not in an equation

ρ of nichrome = 150×10^{-8} Ω m



Ohm's Law

$V = IR$

If a question says "Obeys Ohm's Law" it means Resistance is constant.

Ohm's Law applies to each component and the entire circuit

Electric Circuits

Ammeters symbol (A)
measures current
Set-up in-line (series) with a component to be measured. Set up after final branch for total current

Voltmeters (V)
Voltmeters measure potential difference; set-up in parallel.

Wires
- Conducting path for current
- Resistance in wires is zero in a circuit.

Series Circuits

Single Path for current to flow

Current equal throughout
$I_T = I_1 = I_2 = I_3$

Voltage split
$V_T = V_1 + V_2 + V_3$

Resistance Sums
$R_{eq} = R_1 + R_2 + R_3$

VIRP Charts (Series)

Ohm's Law applies to each row

	V	I	R	P
R_1				
R_2				
R_3				
R_{eq}				

Parallel Circuits

Alternate paths for current to flow
Current split between paths
$I_T = I_1 + I_2 + I_3$

Potential Difference equal in each branch
$V_T = V_1 = V_2 = V_3$

R_{eq}: Inverse of sum of inverses

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

The addition of another resistor reduces R_{eq} & increase total current

VIRP (Parallel)

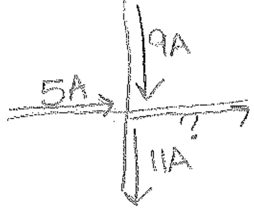
	V	I	R	P
R_1				
R_2				
R_3				
R_{eq}				

The addition of a resistor does not impact existing resistors
- Lowers R_{eq} but increases I

Junction Rule and other miscellaneous circuit

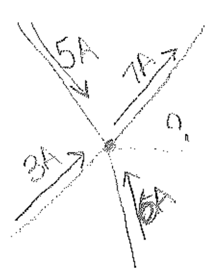
The current that enters a junction of wires must exit the junction

Ex:



IN	OUT
5A	11A
9A	? 3A

(14A)



IN	OUT
5A	7A
3A	
6A	? 7A

(14A)

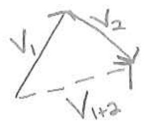
Constructive interference
0° or 360° 1λ

Questions involving Angles

destructive Interference
or node
180° – ½λ

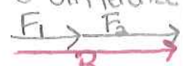
Adding Vectors

Head to Tail



Parallel Vectors

0° difference



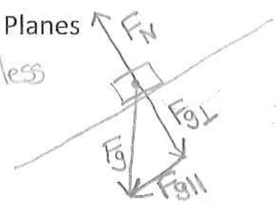
max R

Tail to Tail

180° difference

Inclined Planes

Frictionless



$F_N = F_{g\perp}$ $F_{net} = 0$

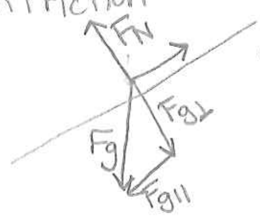
$F_{Net} = F_{g\parallel}$

$ma = mg\sin\theta$

$a = g\sin\theta$

Normal is perpendicular to surface

With Friction



$F_{Net} = F_{g\parallel} + F_f$

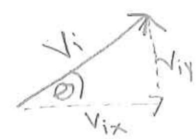
(Be careful with sign)

Projectiles at Angles

Max Range (d_x)

Greatest d_x is 45°
or angle closest to 45°

Angles equal distance from 45°
will result in same d_x
ie; 40° & 50° (Δ5°)
30° & 60° (Δ15°)
35° & 55° (Δ10°)



$V_{ix} = V_i\cos\theta$ (constant v)

$V_{iy} = V_i\sin\theta$ ($a = g = 9.8\,m/s^2$)

$t = \frac{2v_{iy}}{g}$

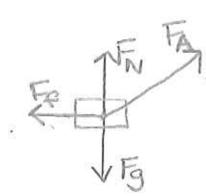
Max Time of flight

Greatest time of flight
is the highest angle
greatest V_{iy} highest θ

$\theta = \sin^{-1}\left(\frac{A_y}{A}\right)$ $\theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)$

Forces applied at an angle (horizontal surface)

If at equilibrium $F_{Net} = 0$
If accelerating $F_{Net} = ma$



$F_{net\,x} = F_{Ax} + F_f$

$F_{net\,y} = F_{Ay} + F_N + F_g$

$F_{Ax} = F_A\cos\theta$

$F_{Ay} = F_A\sin\theta$

$F_g = F_N$ on a level surface without other applied forces

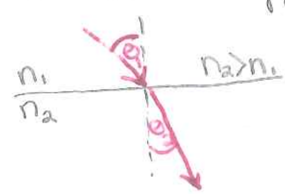
$F_g = F_N + F_{Ay}$ on a level surface with applied force

Reflection and Refraction

$\theta_i = \theta_r$ Law of reflection
angles measured from Normal line

$n_1\sin\theta_1 = n_2\sin\theta_2$
Snell's Law

refraction



ray crosses from Q2 to Q4
can't bounce off normal

Converting between Units

Converting between elementary charge and charge in coulombs

$1e = 1.6\times10^{-19}C$

elementary charge → Coulomb's
multiply by $\frac{1.6\times10^{-19}C}{1e}$

You can't have a fraction of an e

Coulombs → elementary charge divide by $1.6\times10^{-19}C$

$6.4C \times \frac{1e}{1.6\times10^{-19}C} = 4\times10^{19}e$

Converting between energy in joules and energy in electronvolts

$1eV = 1.6\times10^{-19}J$

1 electron volt is the energy required to move 1 elementary charge through a potential difference of 1V

$W = qV$
$= CV =$ Joule
or eV

You can have a fraction of an eV (since you can have a fraction of a V)

into J $\times \frac{1.6\times10^{-19}J}{1eV}$

out of J $\times \frac{1eV}{1.6\times10^{-19}J}$

Converting between mass and energy

Universal (atomic) mass units to energy

If mass is in u $\times 9.31\times10^{2}MeV$
($E=mc^2$ already done)

Ex: $0.036u \times \frac{9.31\times10^{2}MeV}{1u} = 33.5MeV$

$1MeV = 1\times10^{6}eV$

$1MeV \times \frac{1\times10^{6}eV}{1MeV} \times \frac{1.6\times10^{-19}J}{1eV} = 1.6\times10^{-13}J$

mass in kg to energy

mass in kg to energy in J use

$E = mc^2$

If it relates to movement of electrons in hydrogen & mercury convert Joules to eV's

Converting between mass in kg and pounds (not on Regents but helpful for estimation)

$1kg = 2.2lbs$

$1oz = 28.35g$

$1in = 2.54cm$

$1mi = 1.609km$

$1km = .621mi$

$\frac{65mi}{hr} \times \frac{1609m}{1mi} \times \frac{1hr}{3600s} = 29m/s$

$65 mi/hr = 29 m/s$

$10m/s \times \frac{1mi}{1609m} \times \frac{3600s}{1hr} = 22.3 mi/hr$

"Tricky" but simple questions

A plane flying with a horizontal velocity of 80 m/s drops a 3kg box from a height of 1000m. What is the horizontal velocity of the box just before it hits the ground?

Horizontal Velocity does not change

80 m/s

An astronaut with a mass of 80kgtravels from Earth, to a point 4 Earth radii away from the center of the Earth, what is the mass of the astronaut at this location?

Mass does not change with gravitational field

Lightbulb A and B are connected in series to a 20V source of potential difference. If the current through lightbulb A is 2amperes, what is the current through lightbulb B?

Current remains constant in series

What is the max and min resultant?

0° between vectors means same direction
→ Max Resultant

180° between vectors mean opposite direction
→ Min Resultant

Any question involving vectors and change in direction

Pay attention to direction
→ assign (+) & (−)

east positive x west negative x

north positive y south negative y

Miscellaneous

- Newton's 3rd Law - If two objects push on eachother The forces are equal (forces act on each object in different diagrams)
  Forces are equal acceleration depends on mass
- Rate of energy equals Power (measured in Watts)
- Inertia is mass