Measurement and Mathematics

Estimation: $1 \mathrm{~kg}=2.2 \mathrm{lbs} \quad 1 \mathrm{apple}=1 \mathrm{~N} \quad 1$ quarter $=5 \mathrm{~g}=0.005 \mathrm{~kg}$ Order of magnitude: power of ten (thickness of paper $=10^{-4} \mathrm{~m}$ )

Fundamental Units: There are only 7 (see table). All other units are derived units.

Fundamental units

| Quantity | Units | Symbol |
| :---: | :---: | :---: |
| Length | meter | m |
| Mass | kilogram | kg |
| Time | second | s |
| Electric <br> current | ampere | A |
|  |  |  |
|  | e |  |
|  |  |  |

Factor-Label Conversions: " 1 goes with the prefix, exponent goes with the base."
Mean $=$ average
Range $=$ highest value - lowest value

$$
\% \text { error }=\frac{\mid \text { experimental }- \text { actual } \mid}{\text { actual }} \times 100
$$

Measured Uncertainties: use 1 sig fig and match decimal place of measurement eg. $2.0 \mathrm{~cm} \pm 0.1 \mathrm{~cm}$ (exception: extreme variability)
Calculated Uncertainties for multiple trials: use greatest residual of data and match decimal place of measurement

Accuracy: how close a measurement is to the accepted value (a measure of correctness)
Precision: agreement among a number of measurements made in the same way (a measure of exactness)
Systematic Error: all measurements off by same amount - non-zero y-intercept - can be eliminated - measure of accuracy
Random Uncertainty: unpredictable variations in data - the reason for error bars on graph - can be reduced by multiple trials but never eliminated - measure of precision

General Relationships:

Constant
$y=c$

Direct $y=m x$

Linear $y=m x+b$

Linear (Indirect)
$y=m x+b$

Inverse $y=c / x$
Inverse Quadratic $y=c / x^{2}$

Quadratic $y=c x^{2}$

Square Root $y=c \sqrt{x}$

| Scalars (magnitude only) | Vectors (magnitude and direction) - only 9! |
| :---: | :---: |
| Distance | Displacement |
| Speed | Velocity |
|  | Acceleration |
| Anything else! | Force (weight, normal force, etc.) |
|  | Momentum |
|  | Impulse |
|  | Fields (gravitational, electric, magnetic) |

$$
\begin{aligned}
& \sin \theta=\frac{o p p}{h y p} \\
& \cos \theta=\frac{a d j}{h y p} \\
& \tan \theta=\frac{o p p}{a d j}
\end{aligned}
$$

## Things You Should Know About Physics

## Mechanics

Equilibrium: no net force, no acceleration, constant velocity or at rest, forces form a closed figure

Concurrent vectors: placed tail-to-tail
Component vectors: must be head-to-tail to find resultant
Resultant force $=\mathrm{F}_{\text {net }}$ : head-to-head and tail-to-tail with components
Range of possible resultants:
Maximum = sum of vectors $\quad$ Minimum $=$ difference of vectors
Equilibrant: equal and opposite to resultant
Box on a Hill in Equilibrium: $m g \sin \theta=\mathrm{F}_{\mathrm{f}}$ or $\mathrm{F}_{\mathrm{A}}$ or $\mathrm{F}_{\mathrm{T}}$ and $\mathrm{mg} \cos \theta=\mathrm{F}_{\mathrm{N}}$
Mass (m): =inertia, amount of matter, constant from place to place, units: kg
Weight $\left(\mathrm{F}_{\mathrm{g}}\right):=$ force of gravity, changes from place to place, units: N Formula: $\mathrm{F}_{\mathrm{g}}=\mathrm{mg}$

Two names for little " $g$ ":


Triangle rule $\rightarrow$ sum of any 2 sides $\geq$ third side for forces to be in equilibrium

Inclined Plane

$\mathrm{F}_{\perp}=\mathrm{mg} \cos \theta$

1) acceleration due to gravity, units: $\mathrm{m} / \mathrm{s}^{2}$, formula: $\mathrm{g}=\mathrm{GM} / \mathrm{r}^{2}$
2) gravitational field strength, units: $N / k g$, formula: $g=F_{g} / m$



Newton's Third Law: Whenever A exerts force on B, B exerts equal/opposite force on A. (Action/reaction pairs: bat and ball, Earth and Moon, hammer and nail)

Forces are the same but the effects of the forces are not: $\mathrm{mA}=\mathrm{Ma}$

## Circular Motion



$$
\begin{aligned}
& v=\frac{d}{t}=\frac{\text { circumference }}{\text { period }}=\frac{2 \pi r}{T} \\
& a_{c}=\frac{v^{2}}{r} \quad F_{c}=m a_{c}=\frac{m v^{2}}{r}
\end{aligned}
$$

Things You Should Know About Physics


## Simple Harmonic Motion


Newton's Law of Universal Gravitation
$T=-\quad F_{g}=\frac{G m_{1} m_{2}}{r^{2}}$

1) Pendulum


$$
T=2 \pi \sqrt{\frac{L}{g}}
$$

$T=2 \pi \sqrt{\frac{M}{k}}$

# Things You Should Know About Physics 

## Electricity

Conductors (metals) have free electrons, insulators do not.
Objects become charged by losing or gaining electrons (not protons).
Elementary Charge: proton or electron
1 Coulomb of charge $=6.25 \times 10^{18}$ elementary charges
Charge of Electron: $q=-1 \mathrm{e} \quad$ OR $\quad \mathrm{q}=-1.60 \times 10^{-19} \mathrm{C}$
Mass of Electron: $\quad \mathrm{m}=9.11 \times 10^{-31} \mathrm{~kg}$
Charge of Proton: $\quad \mathrm{q}=+1 \mathrm{e} \quad$ OR $\quad \mathrm{q}=+1.60 \times 10^{-19} \mathrm{C}$

| Coulomb's Law <br> (electric force, <br> electrostatic force) |
| :---: |
| Electric Field <br> (units: N/C or $V / \mathrm{m}$ ) |

Mass of Proton: $\quad \mathrm{m}=1.67 \times 10^{-27} \mathrm{~kg}$
If two or more identical charged spheres touch, the final charge on each is the average charge (total charge /\# of spheres). The total charge is conserved.

A neutral object will be attracted (never repelled) by any charged object. If two objects attract, they could have opposite charges or one could be neutral. If two objects repel, they must have the same type of charge.

Charging by conduction: direct contact - electroscope gets same charge as rod Charging by induction: no direct contact - electroscope gets charge opposite of rod

Electric potential difference (voltage): work done per unit charge ( $\mathrm{V}=\mathrm{W} / \mathrm{q}$ )
Resistance of a wire: $R=\rho L / A$ where $A=\pi r^{2}$
Least resistance (best conductor): short, fat, cold
Most resistance (worst conductor): long, hot, skinny
Voltmeter: connect in parallel, infinite internal resistance
Ammeter: connect in series, zero internal resistance

## Series Circuit


$\frac{R_{1}}{R_{2}}=\frac{V_{1}}{V_{2}}=\frac{P_{1}}{P_{2}}$
Control: current
Resistance adds up (greater than greatest)
Adding extra resistor increases total resistance and decreases total current.

## Parallel Circuit



$$
\frac{R_{1}}{R_{2}}=\frac{I_{2}}{I_{1}}=\frac{P_{2}}{P_{1}}
$$

Control: voltage
Resistance adds down (less than least)
Adding extra resistor decreases total resistance and increases total current.


Lines go from + to -
Lines never cross.
Lines show direction of force on small positive test charge.
Field is most intense where field lines are most dense.


## Things You Should Know About Physics

## Resistance: $\mathrm{R}=\mathrm{V} / \mathrm{I}$

Ohmic Device: follows Ohm's law ( $\mathrm{V} \alpha \mathrm{I}$ at constant T ) = constant resistance $\square$
Slope $=1 / R \quad$ Slope $=R$


| Potential difference | V | Volt | $V=\mathrm{J} / \mathrm{C}$ |
| :---: | :---: | :---: | :---: |
| Current | I | Amps | $\mathrm{A}=\mathrm{C} / \mathrm{s}$ |
| Resistance | R | Ohms | $\Omega=\mathrm{V} / \mathrm{A}$ |
| Power | P | Watts | $\mathrm{W}=\mathrm{J} / \mathrm{s}$ |
| Charge | q | Coulombs | C |
| Energy | W | Joules | $\mathrm{J}=\mathrm{N} \cdot \mathrm{m}$ |

## Māgnētic Fiē̄d́s

From N to S , density = strength (intensity) Direction of lines = direction of compass needle


Two Principles of Electromagnetism:

1) An electric current (or moving charged particle) generates a magnetic field.
2) A changing/moving magnetic field induces an electric current (electromagnetic induction).

Mechanical Power: $\mathrm{P}=\mathrm{W} / \mathrm{t}=\mathrm{Fd} / \mathrm{t}=\mathrm{Fv}$
Electrical Power: $\mathrm{P}=\mathrm{VI}=\mathrm{I}^{2} \mathrm{R}=\mathrm{V}^{2} / \mathrm{R}$
1 electronvolt $(\mathrm{eV})=1.60 \times 10^{-19} \mathrm{~J}$
1 kilowatt hour $=(1000 \mathrm{~W})(1 \mathrm{hr})=3.6 \times 10^{6} \mathrm{~J}$
Three units of energy: joules, electronvolts, kilowatt hours


Transformer: 127,1[5( * (176


All transformers Ideal transformers

$$
\begin{array}{lc}
\mathbf{V}_{\mathbf{P}} / \mathbf{V}_{\mathbf{S}}= & \mathbf{P}_{\mathbf{P}}=\mathbf{P}_{\mathbf{S}} \\
\mathbf{N}_{\mathbf{P}} / \mathbf{N}_{\mathbf{S}} & \mathbf{V}_{\mathbf{P}} \mathbf{I}_{\mathbf{P}}=\mathbf{V}_{\mathbf{S}} \mathbf{I}_{\mathbf{S}} \\
\text { Step-up: } \mathrm{N}_{\mathrm{s}}>\mathrm{N}_{\mathrm{P}}, \mathrm{~V}_{\mathrm{s}}>\mathrm{V}_{\mathrm{P}}, \mathrm{I}_{\mathrm{S}}<\mathrm{I}_{\mathrm{P}} \\
\text { Step-down: } \mathrm{N}_{\mathrm{s}}<\mathrm{N}_{\mathrm{P}}, \mathrm{~V}_{\mathrm{s}}<\mathrm{V}_{\mathrm{P}}, \mathrm{I}_{\mathrm{S}}>\mathrm{I}_{\mathrm{P}}
\end{array}
$$

# Things You Should Know About Physics 

## Waves

Mechanical: needs medium Electromagnetic: no medium Transverse:
perpendicular $\begin{aligned} & \text { Longitudinal: } \\ & \text { parallel }\end{aligned}$

Radio Wave: electromagnetic wave - speed $=3.00 \times 10^{8} \mathrm{~m} / \mathrm{s}$

## Sound

Longitudinal, mechanical
Speed $=331 \mathrm{~m} / \mathrm{s}$ (STP) $340 \mathrm{~m} / \mathrm{s}$ (room temp)
Amplitude = loudness (volume)
Frequency $=$ pitch
Energy $\alpha$ amplitude
Speeds up when going from air to water Can't be polarized

## Light

Transverse, electromagnetic
Speed $=c=3.00 \times 10^{8} \mathrm{~m} / \mathrm{s}$ (vacuum)
Amplitude $\alpha$ brightness (intensity)
Frequency $\alpha$ energy ( $\mathrm{E}=\mathrm{hf}$ )
Slows down when going from air to water Can be polarized
Red: long wavelength, low frequency
Blue: short wavelength, high frequency

Period (T): seconds/cycle
Frequency (f): cycles/second Wave equation: $v=f \lambda$

$\lambda=$ Wavelength


Hard reflection: out of phase


Soft reflection: in phase


Constructive interference: in phase


Destructive interference: out of phase
Doppler Effect: apparent change in frequency due to relative motion

Constant
low
frequency, Decreasing amplitude


Constant high frequency, Increasing amplitude

## Doppler Shift for Light:

"blue shift" = object moving towards "red shift" = obiect moving awav

Standing Wave: Two identical waves traveling in opposite directions in the same medium interfere


Fundamental Wave:

lowest frequency $\left(\mathrm{f}_{1}\right), \quad \mathrm{f}_{3}=3 \mathrm{f}_{1} \quad \lambda_{3}=1 / 3 \lambda_{1}$ $\lambda_{1}=8.0 \mathrm{~m}$
Visible Light: 400 nm (violet) - 700 nm (red)

## Things You Should Know About Physics



# Things You Should Know About Physics 



Modern Physics


