Solving Physics Problems

Vectors

Characteristic: Displacement, velocity, acceleration, forces, momentum, impulse, electric field, magnetic field

Solution: Break each vector into x and y components
Add up x components
Add up y components
Magnitude of sum is given by $A = \sqrt{A_x^2 + A_y^2}$
Angle in right triangle formed by A, A_x, and A_y is given by $\theta = \tan^{-1}\left(\left|\frac{A_y}{A_x}\right|\right)$
State angle in conventional form

Warning: Be careful of signs. Be consistent.

Projectiles

Characteristic: Problem has an object moving through air

Solution: Break into x and y components
Use kinematic formulas
Use symmetry

Warning: If the object is in air, v is not zero!
Be careful of signs. Be consistent.
Object is a projectile only after leaving surface to just before landing

Newton's Second Law

Characteristic: Problem asks about forces or accelerations
Problem has an object moving in a circle (see **UCM**)

Solution: Draw one free body diagram (see **Forces**) for each object in problem
Ask yourself how the velocity is changing, or will change, to find a direction for the acceleration for each object
Choose axes such that one axis points in direction of the acceleration
Determine the x and y components of each force
Get an equation for the x components for each object using $\sum F_x = ma_x$
Get an equation for the y components for each object using $\sum F_y = ma_y$
If there is friction in the problem, write an equation for it using $f_k = \mu_k F_n$ and $f_s^{max} = \mu_s F_n$

Warning — The acceleration and the velocity of an object do not have to be in the same direction!
Be careful of signs. Be consistent.

Uniform Circular Motion

Characteristic — Problem has an object moving in a circle.

Solution — Follow **Newton's Second Law**
Acceleration of object is from object to centre of circle and $a_c = v^2/R$
Usually only interested in top of circle or bottom of circle - i.e. y direction
Is the object on the inside or the outside of the circle? This affects direction of Normal Force
Does the problem say anything about losing contact, i.e. $F_n = 0$
Does the problem say anything about the sense of weight or apparent weight (F_n).
May need to use $v = 2\pi R/T$

Warning — Do not confuse true weight, $W = mg$, with apparent weight F_n. True weight never changes.
Be careful of signs. Be consistent.

Satellites

Characteristic — Problem has an object (the satellite) orbiting a much more massive object

Solution — Use the satellite equations, $T^2 = \dfrac{4\pi^2 R^3}{GM_{central}}$ and $v = \sqrt{\dfrac{GM_{central}}{R}}$
May need to use $v = 2\pi R/T$

Warning — Are all the units SI (m, kg, s)? If not, change to SI.
R refers to the distance between the centres of the objects

Newton's Law of Gravitation

Characteristic — Problem has multiple objects in outer space (*Type A*)
Problem asks about acceleration due to gravity on another planet (*Type B*)

Solution — *Type A*
Use $F_{gravity} = \dfrac{Gm_1 m_2}{R^2}$ which is always attractive and a vector
Follow **Newton's Second Law**

Type B

Use $g(R) = \frac{GM_{planet}}{R^2_{planet}}$

Warning — Are all the units SI (m, kg, s)? If not, change to SI.
R refers to the distance between the centres of the objects

Work and Energy

Characteristic — Problem has an object changing height and/or speed
Problem asks about speed of the object
Problem asks about work or energy

Solution — Use $W_{nc} = \Delta K + \Delta U$ and/or $W = F_x\Delta x = F\Delta x\cos\phi$
Final and initial refer to the two locations of the object mentioned in the problem.
If the object has more than two locations you may need to write down several work-energy equations
If there is friction in the problem, W_{nc} is not zero. Follow **Newton's Second Law** to get an expression for f_k. $W_{nc} = W_f = -f_k\Delta x$.
Potential energy is *mgh*
Kinetic energy is $\frac{1}{2}mv^2$
Having determined W_f, and the kinetic and potential energy of the object at the final and initial locations, write down the equation for this problem

Warning — If the object is a projectile, solving the projectile problem may give more information
Forces that slow objects down do negative work
Kinetic friction always does negative work

Impulse and Collisions

Characteristic — Problem has an object colliding with an un-free body
Problem asks about average force
Problem asks for how long a collision lasts

Solution — Use $\boldsymbol{I} = m\boldsymbol{v}_f - m\boldsymbol{v}_i = \boldsymbol{F}_{average}\Delta t$

Warning — Be careful of signs. Be consistent. Dealing with vectors!

Momentum and Collisions

Characteristic — Problem has two free-moving objects colliding
Problem has an object exploding into two or more pieces
Problem mentions the words elastic or inelastic

Solution — There are three possible types of collisions
1D perfectly elastic collision (*Type A*)
1D totally inelastic collision (*Type B*)

2D totally inelastic collision (*Type C*)
Perfectly elastic means kinetic energy is conserved
Totally inelastic means that the objects stick together or explode apart
Momentum of an object is **p** = m**v**
Momentum is a vector quantity

Type A
Solve using $P_f = P_i$ and Conservation of Energy.
Since the motion is 1D, Conservation of Energy becomes $v_{1f} - v_{2f} = -(v_{1i} - v_{2i})$

Type B
Solve using $P_f = P_i$. Note v_f is the same both objects.

Type C
Solve using $P_{fx} = P_{ix}$ and $P_{fy} = P_{iy}$. Note - this is a vector problem! Carefully draw the vectors from a common origin.

Warning: Make sure that m_2 is the stationary target for the equations for a 1D elastic collision
Be careful of signs. Be consistent
In inelastic collisions, most of the energy energy is used to change the shape of the objects (deformation).
Momentum is only conserved in "free" collisions, ones in which the only significant forces are those between the objects colliding.

Coulomb's Law

Characteristic: Problem has multiple charged objects
Problem asks for force/acceleration of one charge

Solution: Use $\vec{F}_{Coulomb} = \frac{Kq_1q_2}{r^3}\vec{r}$ where r is the vector from one charge to the charge that you want to know the force
Remember like charges repel, opposite charges.
Follow **Newton's Second Law**
Vector problem

Warning: Are all the units SI (m, kg, s)? If not, change to SI.
R refers to the distance between the centres of the objects
If asked to calculate the force on multiple charges, calculate E first. See Electric Fields

Electric Fields

Characteristic: Problem has a single charged object in an external uniform electric field (*Type A*)
Problem asks for the electric field at a point due to an arrangement of charges (*Type B*)

Solution *Type A*

Use $\boldsymbol{F}=q\boldsymbol{E}$.

F and **E** are parallel if and only if q is positive.

F and **E** are antiparallel if and only if q is negative.

Type B

Use $\vec{E}_{Coulomb} = \frac{KQ}{r^3}\vec{r}$ where r is the vector from your charge to where you want to find the electric field.

Find $\vec{r}$ first in vector notation! Next find $r = |\vec{r}|$. Now evaluate $\vec{E}$.

Electric fields point away from positive charges

Electric fields point towards negative charges

Vector problem

Warning Are all the units SI (m, kg, s)? If not, change to SI.

R refers to the distance between the centres of the objects

Circuits

Characteristic Problem has a circuit or voltmeter or ammeter.

Solution Find all the nodes. Resistors in the same branch are in series. Two branches that share the same nodes are in parallel.

Use Ohm's Law, $V=IR$

Power is found by $P= IV$.

Resistors in Series	Resistors in Parallel
$R_s = R_1 + R_2 + \ldots$	$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$
R_s, R_1, R_2, …, have same I	R_p, R_1, R_2, …, have same V
R_s, R_1, R_2, …, have different V's	R_p, R_1, R_2, …, have different I's

Reduce circuit one piece at a time then work back up

Put answers in a table

Check each step so that voltages/currents add up

Ammeters connected to circuits in series

$(I_A - I_G)R_{shunt} = I_G R_{coil}$

Shunt and coil resistances are connected in parallel.

Need R_{shunt} to be very small

Voltmeters connected in parallel with circuit

$V_{voltmeter} = I_G(R_{coil} + R_{multiplier})$

Multiplier and coil are in series

Need $R_{multiplier}$ to be very large.

Warning	Ammeters and voltmeters have resistance, this affects any circuit they are in

Magnetic Field

Characteristic: Problem has a charge moving in a magnetic field (*Type A*)
Problem has a current carrying wire in a magnetic field (*Type B*)
Problem asks for the magnetic field at a point due to one or more wires (*Type C*)
Problem combines Type A or B with Type C

Solution

Type A

Force is given by $F = qvB\sin\phi$

Identify plane holding v and B, direction of force is perpendicular to **v** and to **B** and to the plane

Use Right Hand Rule for direction of force

Also for charged particles moving in a circle in a magnetic field $r = mv/qB$ and $W_{battery} = q\Delta V$

Type B

Force is given by $F = ILB\sin\phi$

Direction of force is perpendicular to **I** and to **B**

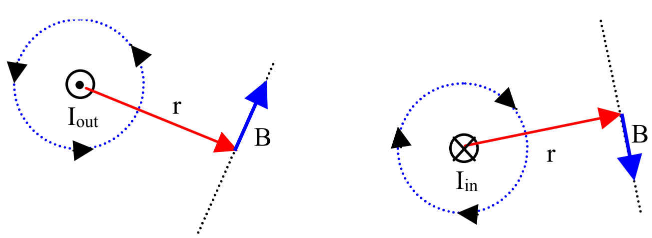
Use Right Hand Rule for direction of force

Type C

Magnetic Field given by $B = \frac{\mu_0 I}{2\pi R}$

B is tangential to circle of radius R about wire

Direction of B given by Right Hand Rule II



Combination

First follow Type C to determine $\mathbf{B}_{net}$ due to wires

Second - follow Type A or B

Warning:	Use conventional current direction when using RHR II
Magnetic field is a vector

Standing Waves

Characteristic: Problem has a vibrating string or air column
Problem asks about a vibrating long thin wire or rod or the like

Solution: For strings may need to use $v = \lambda f$ or $v = \sqrt{\frac{F_{Tenion}}{M/L}}$

If the string is fixed at both ends or air column is open at both ends

Use $f_n = n\left(\frac{v}{2L}\right), \quad n = 1,2,3,\ldots$

Use $\lambda_n = \frac{2L}{n}, \quad n = 1,2,3,\ldots$

If the string or air column has one open end and one fixed end

Use $f_n = n\left(\frac{v}{4L}\right), \quad n = 1,3,5,\ldots$

Use $\lambda_n = \frac{4L}{n}, \quad n = 1,3,5,\ldots$

Warning: Do not confuse the mass of the string, M, with the hanging mass that creates $F_{tension}$

Reflection, Refraction, and Lenses

Characteristic: Problem involves light
Problem asks about apparent depth
Problem mentions index of refraction
Problem mentions critical angle or total internal reflection
Problem asks about images formed by mirrors or lenses

Solution: Apparent Depth is given by $d_{apparent} = \left(\frac{n_{observer}}{n_{immersed}}\right) d_{actual}$

Refraction is governed by $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Total internal reflection occurs only for light in a denser medium reflecting off an interface with a less dense medium. Set $\theta_2 = 90°$ for $\theta_{critical}$.

Lenses and Mirrors are governed by $\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$

Warning: Be very careful with the sign convention for mirrors and lenses

Forces

Object has mass
- Near surface of planet, object has weight W = mg
- Far from planets, use Law of Gravity

Object is touching a surface
- There is a normal force for every surface touched
- Normal acts from surface through object perpendicular to surface of contact
- Normal force is the apparent weight (feeling of weight")
- Normal force is zero if and only if the object loses contact with surface

Object is on a rough surface
- There is a frictional force pointing along the surface
- If the object slides over surface, there is kinetic or sliding friction
- If the object does not slide relative to the surface, there is static friction
- Kinetic friction is always opposite to the motion of the object
- Static friction may point in either direction. The direction of the static friction is found by asking which way the object would move if a little more or a little less force was applied.
- Static friction opposes the potential motion

Strings or ropes are attached to object
- There is a tension force
- Ropes and strings can only pull
- Direction of tension is away from object along string

Charged object near one or more other charges
- There is the Coulomb force
- Coulomb's Law gives the magnitude of the force
- Direction given by opposites attract, like repel

Charged object in an external electric field
- There is an electric force $\mathbf{F} = q\mathbf{E}$
- **F** and **E** are parallel if and only if q is positive
- **F** and **E** are antiparallel if and only if q is negative

Moving charge in external magnetic field
- There is a magnetic force $F= qvB\sin\phi$
- **F** is perpendicular to both **v** and **B**
- Direction of **F** found using RHR
- The angle ϕ is the smallest angle formed by **v** and **B**

Current carrying wire in an external magnetic field
- There is a magnetic force $F= ILB\sin\phi$
- **F** is perpendicular to both **I** and **B**
- Direction of **F** found using RHR
- The angle ϕ is the smallest angle formed by **I** and **B**
- L is the length of the wire that is in the magnetic field