

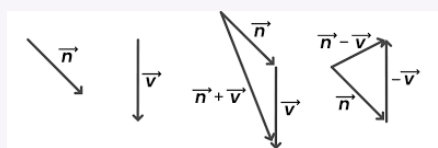
Newton's Laws of Motion

First Law: Objects have inertia, i.e. a stationary object remains stationary, or a moving object keeps on moving at the same speed in the same direction, if there is no net force acting on it

Second Law: Acceleration of an object is directly proportional to and in the same direction as the net force on it, and inversely proportional to its mass.
 $F_{net} = ma$

Third Law: When object A exerts a force on object B, B exerts a force of the same magnitude in the opposite direction on A.
 $F_{on A by B} = -F_{on B by A}$

Vector Addition



SLM Constant Acceleration Equations

Uses: Equation

$v u a t$ $v = u + at$

$v u t s$ $s = 1/2 (u + v) t$

$u a t s$ $s = ut + 1/2 at^2$

$v a t s$ $s = vt - 1/2 at^2$

$v u a s$ $v^2 = u^2 + 2as$

Interpreting Motion Graphs

	d - t	v - t	a - t
Direct	d at any t	v at any t	a at any t
Reading	t at any d	t at any v	t at any a
Gradient	instantaneous velocity at any point v_{avg} between any two points	instantaneous acceleration a_{avg}	-

Area under graph

- change in position
- change in velocity

Einstein's Special Relativity

Postulate One
The Principle of Relativity

the laws of physics are the same in all inertial frames of reference (not just mechanics)

there is no 'preferred' or 'correct' frames of reference

Postulate Two
The Constancy of the Speed of Light

the speed of light is constant for all observers

this implies a universal speed limit

this has implications of simultaneity of events

Time Dilation

$$t = t_0 \gamma$$

$$\gamma = 1 / \sqrt{1 - v^2/c^2}$$

t_0 is proper time, t is dilated time (larger than proper time), γ is the Lorentz Factor

Length Contraction

$$L = L_0 / \gamma = L_0 \sqrt{1 - v^2/c^2}$$

L_0 is proper length, L is contracted length (small than proper length), and γ is still Lorentz factor

Relativistic Energy

Einstein concluded that it takes energy to make mass, and energy is released if mass disappears. Energy released from nuclear fusion and fission is based on a difference in mass.

$$m = \text{relativistic mass} \quad \text{and} \quad m_0 = \text{rest mass} \quad m = m_0 \gamma$$

$$E_{tot} = mc^2 \quad \text{and} \quad E_{rest} = m_0 c^2$$

- $E_{tot} = E_k + E_{rest}$
- $E_k = E_{tot} - E_{rest}$
- $E_k = mc^2 - m_0 c^2 = m_0 \gamma c^2 - m_0 c^2 = (\gamma - 1) m_0 c^2$

Note 1: As an object approaches c , the mass becomes infinitely large. This would require an infinite force to increase the velocity of an object past the speed of light (ie. it's not possible)

Note 2: In the VCAA formula sheet, 'm' represents the rest mass

Magnetic Flux and Induced EMF

$$\Phi_B = \mathbf{B} \cdot \mathbf{A} = BA \cos \theta$$

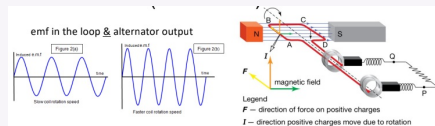
Induced emf (Faraday's Law of Induction)

$$\epsilon = \frac{-\Delta \Phi_B}{\Delta t} \quad \epsilon = \frac{-N \Delta \Phi_B}{\Delta t} \text{ for more than one loop}$$

Note that the flux needs to be changing over time (either the field strength or the area) to induce an emf

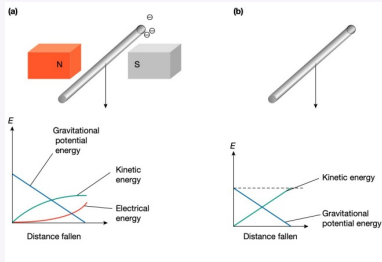
The negative sign refers to the direction of the induced emf

AC Generators (Alternators)



- AC Generators (Alternators) use slip rings
- Carbon brushes contact the slip rings
- Using the RH slap rule to determine current direction
- Using the RH grip rule to determine current direction

Induced EMF and Energy



Lenz's Law

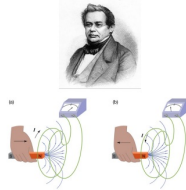
Lenz's Law: The magnetic field associated with the induced emf (and current) is **opposite** in direction to the change in flux

1. What is the direction and change in flux that is happening?

2. What is the direction of the induced field that will oppose the change in flux (or restore the original conditions)?

3. What is the current direction to match the induced field?

RH-Grip rule (fingers through the loop)



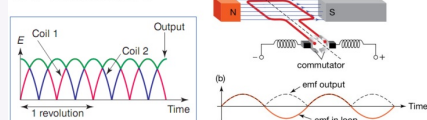
Transformer Equations

Across step-up and step-down transformers $V_1 / V_2 = N_1 / N_2$
 $I_2 = I_1 / I_2$

Where voltage and no. of turns are proportional to each other and current is inversely proportional.

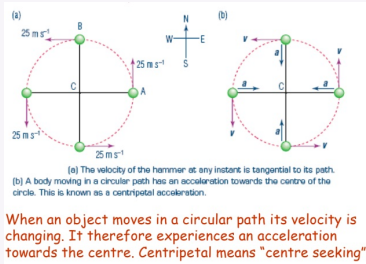
DC Generators

DC Generators



- DC Generators use a **split ring commutator**
- emf in the loop still has an alternating current
- emf output current goes from zero to a maximum but the current is always in the same direction (due to the split ring commutator)
- emf output can be smoothed by adding more loops (& more splits in the commutator)

Circular Motion



Centripetal Acceleration

1. Draw diagram showing all forces
2. If required, resolve forces into components
3. There is always a net force towards centre of circular path

Useful equations:

$$F_{\text{net}} = mv^2 / r$$

$$v = 2\pi r / T$$

$$a = v^2 / r = 4\pi^2 r / T^2 = 4\pi^2 f^2 r$$

Energy

Conservation of Energy

in an isolated system, energy is transformed from one form to another, can neither be created nor destroyed

$$E_k = 1/2mv^2$$

$$E_g = mg\Delta h$$

Hooke's Law

force exerted by spring is directly proportional, but opposite in direction, to the spring's extension or compression

$$F_s = -kx$$

Strain Potential Energy

$$E_s = 1/2k\Delta x^2$$

Gravity

Newton's

Law of

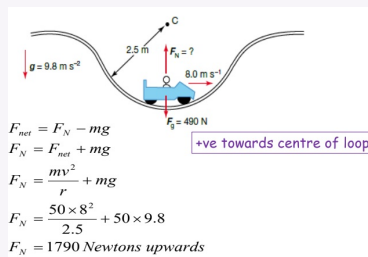
Universal

Gravit-

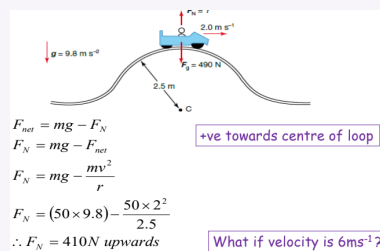
ation

Gravitation is a force of attraction that acts between any two bodies. The gravitational force between two bodies is given by:
 $F = GMm/r^2 = mg$

Motion at Bottom of Loop



Motion at Top of loop



By WhooshBoosh

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Gravity (cont)

Gravitational Fields Vector field, a physical quantity with value at each point in space, existing in any region with gravitational effect
 $g = f/M = GM/r^2$ ($N\ kg^{-1}$) = $a(m\ s^{-1})$

Free Falling Objects influenced only by gravity
 net force given by: $\Sigma F = mg$
 $a = \Sigma F/g = mg/g = g$

Kepler's Law $R^3/T^2 = GM/4\pi^2$

Gravity (cont)

Work done objects moving through constant gravitational field
 $E_g = mg\Delta h$
 total energy of object moving through gravitational field is constant, even though relative amounts of kinetic and gravitational potential energy may change
 area under gravitational field-distance graph gives energy change per kilo of mass

Electricity

Electric Fields vector fields occurring around charged objects
 fields exert a non-contact force, may be attractive or repulsive

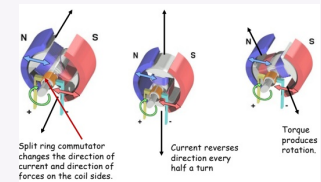
Force on Charged Particle $F = qE$

Electricity (cont)

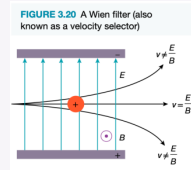
Coulomb's Law The electric force between two charges (q_1, q_2) is proportional to the product of the charges and inversely proportional to the square of the distance between them.

Point Charges $F = kq_1q_2/r^2$
 where a positive value of force represents repulsion
 $E = kQ/r^2$ ($N\ C^{-1}$)

DC Motors (Split Ring Commutators)

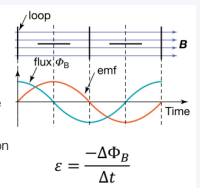


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Changing the flux by rotating a loop

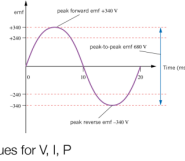
- Generating a current from a magnet moving in & out of a coil is not efficient.
- Another way is to rotate a loop of wire within a magnetic field
- Maximum flux when the loop is perpendicular to the magnetic field
- Zero flux when the loop is parallel to the magnetic field
- Maximum emf occurs when the rate of change in flux is greatest (at the inflection point)
- $emf \propto$ wire cutting across field lines



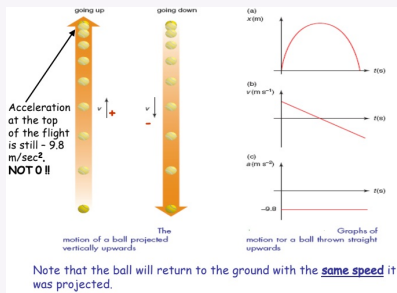
Root Mean Square Voltage

The steady (DC) voltage that produces the same power in a resistor as an alternating voltage (AC)

- RMS Voltage, $V_{RMS} = \frac{V_{peak}}{\sqrt{2}}$
- RMS Current, $I_{RMS} = \frac{I_{peak}}{\sqrt{2}}$
- RMS Power, $P_{RMS} = V_{RMS} \times I_{RMS} = \frac{1}{2} V_p I_p$
- Peak Power, $P_p = V_p \times I_p = 2V_{RMS} I_{RMS}$
- Note: Unless specified, assume RMS values for V, I, P



Projectile Motion



Momentum

"mass in motion" $p = mv$

is a vector $F_{net} = \Delta p / \Delta t$

A net force on an object will cause a change in momentum (Impulse)

Conservation of Momentum

If two objects collide in an isolated system, momentum will be conserved

initial momentum = final momentum

$$\sum p_{initial} = \sum p_{final}$$

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

$$\text{OR } \sum p_{final} - \sum p_{initial} = \Delta p = 0$$

Impulse

$$\text{Impulse} = F_{net} \Delta t = m \Delta v = \Delta p$$

is a vector

units are either $N s^{-1}$ OR $kg m s^{-1}$

using this equation between two states gives us the average F_{net}

is area under force-time graph

Collisions

An isolated event (no external forces and momentum is conserved) involving 2 or more objects

Elastic Collision
momentum and energy is conserved

Usually interact (often strongly) for a short period of time

Inelastic Collision
momentum is conserved but energy is not (lost to usually heat and sound)

Equal and opposite impulses are exerted on each other

Work

Work(scalar) is the energy transferred to an object or transformed by the application of a force

Work is done by a force on an object when it causes a displacement of an object in the direction of the force

$$W = Fs$$

$$W = Fs \cos \theta^*$$

Work done on an object:

$$W = F_{net} s$$

If the energy doesn't change, or force is perpendicular to displacement, no work is done on object

Work (cont)

is area under force-displacement graph

Magnets

Magnetic Fields vector fields, denser the lines means stronger the fields
field lines go from north to south pole and never touch
magnets are always dipole, can never be monopole

Earth as a Magnet The Earth is one large magnet – believed to be due to convection currents of molten metals in the outer core
True geographic north pole is actually magnetic south pole

Induced EMF in a Moving Conductor

- Recall a charge moving in a magnetic field:

$$F = qvB, \quad \text{and also } W = Fd$$

- If l is the length of the conductor over which the electrons travel, combining equations and equating to work per unit charge:

$$\epsilon = \frac{Bqlv}{q} = l v B \text{ (J/C or Volts)}$$

Linear Particle Accelerators

- We only consider the acceleration of particles in **uniform** electric and magnetic fields
- Electron gun: electrons are 'fired' from a hot **cathode** (negative charge) to an **anode** (positive charge)
- Electrons continue through a hole in the anode
- In a uniform electric field, recall:

$$F = qE \quad E = \frac{V}{d} \quad W = qEd \quad W = qV$$

- Work is also the change in kinetic energy of the particle

$$\frac{1}{2} m v^2 = qV$$

This is often referred to as the electron-gun equation.



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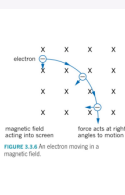
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Charged Particles in a Magnetic Field

- A charged particle enters a magnetic field
- $F = qvB$ for a charged particle in a magnetic field
- The force is always at right angles to the direction of travel, causing centripetal acceleration (but magnitude of velocity constant), hence equations for uniform circular motion can be used
- Show that: $qvB = \frac{mv^2}{r}$ or $r = \frac{mv}{qB}$
- The charge must be travelling perpendicular to the magnetic field and remain within the field for circular motion to occur
- How to determine the direction of motion?



Generating Voltage

We know electric currents can produce magnetic fields

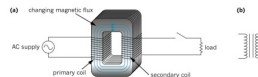
The separation of charges in the falling rod is an induced electromotive force or induced voltage (or potential difference)

The object needs to keep moving, or the magnetic field needs to be changing for charges to remain separated (to maintain an induced voltage)

Electromotive force (emf), is a source voltage

Transformers

- A transformer works on the principle of a **changing magnetic flux to induce an emf**
- Coils can be interwoven or connected by a soft iron core

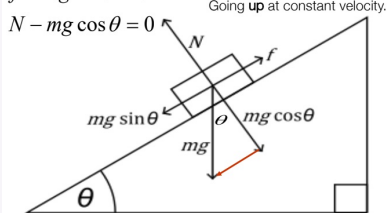


- Transformers need an AC supply in order to create a changing magnetic flux
- What would happen with a DC supply?

Inclined Plane

$$f - mg \sin \theta = 0$$

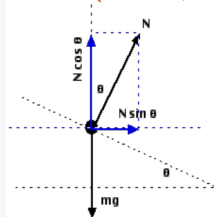
$$N - mg \cos \theta = 0$$



Remember: constant velocity means $F_{net} = 0$

Banked Turn Design Speed

(Assumes no friction required)



$$F_{net} = N \sin \theta$$

$$mg - N \cos \theta = 0$$

$$\Rightarrow N = \frac{mg}{\cos \theta}$$

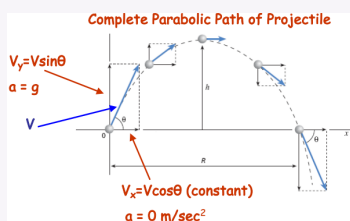
$$\therefore F_{net} = \frac{mg \sin \theta}{\cos \theta}$$

$$\Rightarrow F_{net} = mg \tan \theta$$

$$\text{so } \frac{mv^2}{r} = mg \tan \theta$$

$$\therefore v = \sqrt{rg \tan \theta}$$

Projectile Motion



An object projected with a velocity V at an angle θ , has both vertical and horizontal components to that initial velocity V .

Projectile Range Formula

$$R = \frac{v^2 \sin(2\theta)}{g}$$

assuming symmetric motion

