

# The Definitive Physics Definition List

Engineers of Dubious Quality  
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September 12, 2016

## 1 Measurements

Express errors/uncertainties to 1 s.f. and write the measured value to the same decimal place as its error/uncertainty

Systematic Error	An error that occurs consistently more or consistently less than the actual reading.
Random Error	An error that occurs as a scattering (or spreading) of readings about the average or mean value of the measurements.
Precision	The <b>reproducibility</b> of a measurement. Repeated measurements which are very close to one another are precise measurements. Thus an experiment which has <b>small random errors</b> (i.e. small spread of readings) is said to have <b>high precision</b> .
Accuracy	The <b>agreement</b> between the measured value and the true or accepted value of a quantity. An experiment which has <b>small systematic errors</b> is said to have <b>high accuracy</b> . The <b>average value</b> is close to the true value.
Vector Quantity	A quantity that has a <b>magnitude and direction</b> .
Scalar Quantity	A quantity that has a <b>magnitude only</b> .

## 2 Kinematics

We define a coordinate system with defined reference positive directions and we assume constant acceleration.

Displacement	$\mathbf{s}$	The distance travelled in a stated direction from a reference point.
Velocity	$\mathbf{v} = \frac{d\mathbf{s}}{dt}$	The rate of change of displacement with respect to time.
Speed	$v =  \mathbf{v}  = \left  \frac{d\mathbf{s}}{dt} \right $	The rate of change of distance travelled with respect to time.
Acceleration	$\mathbf{a} = \frac{d\mathbf{v}}{dt} = \frac{d^2\mathbf{s}}{dt^2}$	The rate of change of velocity with respect to time.

### 3 Dynamics

#### 3.1 Newton's Laws of Motion

1 <sup>st</sup> Law	A body will continue in its <b>state of rest</b> , or <b>move</b> at <b>constant speed in a straight line</b> unless an <b>external resultant force</b> acts on it.
→ Inertia	The resistance to change in the state of motion of an object
→ Mass	A property of that determines the objects inertia.
2 <sup>nd</sup> Law	<p>The <b>rate of change of linear momentum</b> of a body is <b>directly proportional</b> to the resultant force acting on it, and its direction is in the <b>same direction</b> as this resultant force.</p> <p>The <b>force acting on an object</b> is defined as the <b>rate of change of linear momentum</b> of an object.</p> $\mathbf{F} \propto \frac{d\mathbf{p}}{dt}, F = m\mathbf{a} \text{ (if constant mass)}$
3 <sup>rd</sup> Law	<p>If body A exerts a force on body B, then body B will exert an <b>equal and opposite</b> force on body A.</p> <p><i>Note:</i> Action-Reaction Pairs act on different bodies and are of the same nature.</p>
Weight	The gravitational force acting on the object.
Weightlessness	There is no contact force acting on the object. <i>A body experiences apparent weightlessness when the resultant force acting on it is its weight, or it is undergoing freefall.</i>

### 3.2 Momentum

Linear Momentum	$\mathbf{p} = m\mathbf{v}$	The product of an object's mass and its velocity.
Impulse	$\mathbf{J} = \int_{t_1}^{t_2} \mathbf{F} dt = \mathbf{p}_f - \mathbf{p}_i$	The product of the average force acting on an object and the time interval that the force is being applied.
Principle of Conservation of Linear Momentum	The total momentum of the system is a constant when no external resultant force acts on it.	

## 4 Forces

Pressure due to Fluid	$\Delta P = h\rho g$	The force acting per unit area by the fluid on a body submerged at a depth in the fluid.
Upthrust	$U = m_f g = \rho V_{dis} g$	The <b>net force exerted by a fluid</b> on a body submerged in the fluid.
Principle of Floatation	$m g = U = \rho V_{dis} g$	This holds true for an object floating in equilibrium in a fluid.
Drag	$\mathbf{F}_D = k\mathbf{v}$ (Laminar Flow)	It is the force resisting an object <b>moving relative to a fluid</b> . It always <b>opposes</b> motion, and its magnitude is <b>dependent on the velocity</b> of the object.
Moment of a force (Torque)	$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$	Moment of a force about a point (the pivot) is the <b>product</b> of the magnitude of the force and the <b>perpendicular distance</b> of the <b>line of action</b> of the force to the point.
Couple	A couple always consists of 2 parallel forces which are equal in magnitude and opposite in direction (their lines of action do not coincide)	
Torque of a couple	The <b>product</b> of the <b>magnitude of one of the forces</b> of the couple and the <b>perpendicular distance between the forces</b> .	
Center of gravity of a body	It is the point at which the weight of the body appears to act.	

## 4.1 Equilibrium of Forces

For a rigid body to be in static equilibrium, 2 conditions must be satisfied:

### 1. Translational equilibrium

The **net external** force acting on the body is zero.

$$\sum F = 0$$

### 2. Rotational Equilibrium

The **net torque** on the body about ANY point is zero.

$$\sum \tau = 0$$

For a 3-forces system in static equilibrium, the 3 forces form a *closed vector triangle*. For 3 forces acting on an *extended body* in static equilibrium, the lines of action of the 3 forces *must intersect at a common point* unless the 3 forces are parallel.

## 5 Work, Energy, and Power

Principle of Conservation of Energy	Energy can be <b>converted</b> from one form to another, but it <b>cannot be created or destroyed</b> . The <b>total energy</b> of an <b>isolated</b> system is constant	
Work done by a Force	$W = \int_{x1}^{x2} \mathbf{F} \cdot d\mathbf{x}$	The product of the magnitude of the force $F$ and the displacement $s$ in the direction of the force.
Total Mechanical Energy	$\sum KE + \sum PE$	The total mechanical energy of a system is the sum of all types of kinetic energy and potential energy.
Kinetic Energy	$E_k = \frac{1}{2}mv^2$	Kinetic energy of a body is a measure of the energy possessed by the body by virtue of its motion.
Potential Energy	—	The amount of work that was done on a body to give it that position.  It is a measure of the energy possessed by the body by virtue of its position or the arrangement of the system that it is part of. [There are 3 types: Elastic, Gravitational and Electrical]
Power	$P = \frac{dW}{dt} = Fv$	Power is the rate at which work is done.  When a force acts on a body that is moving with velocity $v$ , in the direction of the force, it delivers power to the body at the rate given by $P = Fv$ .

## 6 Circular Motion

Always write “The \_\_\_\_\_ forces provide the centripetal force”.

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Angular Displacement	$\theta$	Angle swept from a reference point.
Angular Velocity	$\omega = \frac{d\theta}{dt} = \frac{2\pi}{T} = 2\pi f$	Rate of change of angular displacement with respect to time.
Period	$T = \frac{1}{f}$	Time taken for one complete revolution.
Linear/Tangential Speed	$v = \frac{2\pi r}{T} = r\omega$	(No need to know definition)

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### 6.1 Uniform Circular Motion

Conditions:  $\omega$  constant,  $r$  constant

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Uniform Circular Motion	It is the motion of an object travelling at constant (uniform) speed in a circular path.
Centripetal Acceleration/ Centripetal Force	The centripetal acceleration/force is directed <b>radially inward</b> towards the centre of the circular path. The direction of the centripetal acceleration/force is continuously changing.

$$\sum a = a_{net} = a_c = \frac{v^2}{r} = r\omega^2 = v\omega$$

No acceleration/force in the tangential direction.  $\Rightarrow$  No work done.

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## 7 Gravitation

The ‘G’s in the following left column stands for ‘Gravitation’, or ‘Gravitational’.

Newton's Law of G	$F_g = G \frac{m_1 m_2}{r^2}$	Gravitational force between 2 objects is <u>directly proportional</u> to the product of their masses, and <u>inversely proportional</u> to the square of the distances between them.
G Field Strength	$g = \frac{F_g}{m} = G \frac{M}{r^2}$	The GFS $g$ at a point in a gravitational field is the <u>gravitational force per unit mass</u> acting on a small mass placed at that point.
G Field	—	A region of space surrounding a body possessing mass, in which any other body that has mass will experience a force of attraction.
G Potential	$\phi = \frac{U}{m} = -G \frac{M}{r}$ $g = -\frac{d\phi}{dr}$	Work done per unit mass by an external force in bringing a small mass from infinity to that point in a gravitational field without a change in kinetic energy.
G Potential Energy	$U = -G \frac{m_1 m_2}{r}$ $F_g = -\frac{dU}{dr}$	Work done by an external force in bringing the mass from the mass from infinity to that point in a gravitational field without a change in kinetic energy.
Geostationary Orbit		Satellite in orbit is above a fixed point on Earth, and appears stationary to observer on Earth.

## 8 Oscillations

Simple Harmonic Motion	$a = -\omega^2 x$	A body <u>oscillating</u> with SHM has <u>acceleration</u> that is <u>directly proportional</u> to the <u>displacement from equilibrium</u> and is in a <u>direction opposite</u> to that of displacement from equilibrium.
Damped Oscillation	—	Oscillation in which the <u>amplitude</u> of the oscillations <u>decreases with time</u>
Resonance	—	Phenomenon where the <u>maximum amplitude</u> of an object driven to oscillate is achieved when the <u>driver frequency</u> is equal to the <u>natural frequency</u> .

## 9 Waves and Superposition

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Progressive Waves	Disturbance/Vibration which <b>propagates</b> , carrying <b>energy without physically transferring</b> the wave particle
→ Transverse Waves	Progressive wave in which particles or fields oscillate perpendicular to direction of wave propagation
→ Longitudinal Waves	Progressive wave in which particles oscillate parallel to direction of wave propagation
Intensity	Power per unit area $E \propto A^2 \Rightarrow I \propto A^2$
Polarisation	Restriction of a geometrical orientation such that the vibrations occur in a single plane
Principle of Superposition	When 2 or more waves of the <b>same type</b> superpose, the <b>displacement</b> of a <b>resultant wave at any point</b> is the <b>vector sum</b> of the displacements of the individual waves at that point at that instant.
Stationary/Standing Waves	Formed when 2 <b>similar</b> waves of <b>same speed, frequency and amplitude</b> travelling towards each other in <b>opposite</b> directions superpose.
Interference	The superposing of 2 or more waves to give a resultant wave whose displacement at every point at any time is give by the Principle of Superposition. ⇒ Conditions: (i) Same kind of waves; (ii) overlap
→ Observable Interference	<ul style="list-style-type: none"> <li>• Same type, overlap</li> <li>• Coherence</li> <li>• Roughly same Amplitude</li> <li>• Unpolarised or polarised in the same plane</li> </ul> <p><u>Constructive</u>: Oscillation at that point has max resultant amp and max int.  <u>Destructive</u>: Oscillation at that point has min resultant amp and min int.</p>
Diffraction	Spreading of waves into “ <b>geometrical</b> ” <b>shadow</b> after passing through an aperture or around an obstacle as a result of a <b>redistribution of energy</b> .

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## 10 Thermal Physics

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Temperature	$T$	Measure of the average kinetic energy the molecules in a system possess.
Heat	$Q$	Thermal energy that naturally flows from regions of higher to lower temperature.
Thermal Equilibrium		2 objects in thermal contact with no net exchange of heat.
Kelvin Scale		Absolute temperature scale independent of thermometric properties.
Absolute Zero	0K	All molecules possess minimal internal energy.
Specific Heat Capacity	$C$	Amount of thermal energy per unit mass to increase the temperature of the unit mass of substance by one unit of temperature.
Specific latent heat of fusion	$L_f$	Amount of <b>thermal energy per unit mass</b> to convert the substance from solid to liquid without any change in temperature.
Specific latent heat of vaporisation	$L_v$	Amount of <b>thermal energy per unit mass</b> to convert the substance from liquid to gas without any change in temperature.
Internal Energy	$U$	Sum of microscopic random kinetic energy and microscopic potential energy of molecules in system. For ideal gases: $U = \frac{3}{2} nRT$

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### 10.1 Laws of Thermodynamics

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- 0<sup>th</sup> If two systems are in thermal equilibrium with a third system, they are in thermal equilibrium with each other.
- 1<sup>st</sup> Increase in internal energy of system is sum of heat absorbed by system and work done on system.

$$\Delta U = Q + W_{on}$$


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We need not know the 3<sup>rd</sup> and 4<sup>th</sup> laws.



## 10.2 PV Graphs

We assume, for the following, that the arrow points towards the positive- $V$  direction.

Isobaric	Constant Pressure	$W_{on} < 0$ , $\Delta U > 0$
Isochoric	Constant Volume	$W_{on} = 0$ , $\Delta U > 0$
Isothermal	Constant Temperature	$W_{on} < 0$ , $\Delta U = 0$
Adiabatic	Thermally Insulated	$W_{on} < 0$ , $Q = 0$
Cyclic	Start and end at the same state	$\Delta U = 0$

## 11 Electric Fields

Electric Field	$E = \frac{Q}{4\pi\epsilon_0 r^2}$	<b>Electric force per unit charge</b> acting on small positive test charge at that point
Coulomb's Law	$F_E = \frac{ Q_1  Q_2 }{4\pi\epsilon_0 r^2}$	Magnitude of the electric force between 2 point charges is directly proportional to the product of the magnitude of their charges and inversely proportional to square of their distance $F_E = qE$
Electric Potential	$V = \frac{Q}{4\pi\epsilon_0 r}$	<b>Work done per unit charge</b> by external force to bring small positive test charge from infinity to that point in an electric field without change in kinetic energy
Electric Potential Energy	$U = \frac{Q_1 Q_2}{4\pi\epsilon_0 r}$	<b>Work done</b> by external force to bring small positive test charge from infinity to that point in an electric field without change in kinetic energy $U = qV$

## 12 Current of Electricity

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Potential Difference	The potential difference <b>between 2 points</b> in a circuit is the <b>electrical energy converted to non-electrical energy per unit electric charge</b> between the 2 points.
Current	Rate of flow of charge.  $I_{\text{instantaneous}} = \frac{dQ}{dt}$
Electromotive Force	EMF <b>of a source</b> is the amount of <b>non-electrical energy converted to electrical energy</b> per unit electric charge in driving a charge round a <b>complete circuit</b>
Resistance	<b>Ratio</b> of potential difference across device to the current flowing through it  $R = \frac{\rho L}{A}$
Charge	The charge passing through a given point is the product of current and time during which the current flows.  $Q = It$
Coulomb	1 C is the quantity of electric charge that pass a given point in a circuit when a steady current of 1 A passes through that point for 1 s.
Ohm	1 $\Omega$ is the resistance of a device through which a current of 1 A flows when a potential difference of 1 V exists across it.

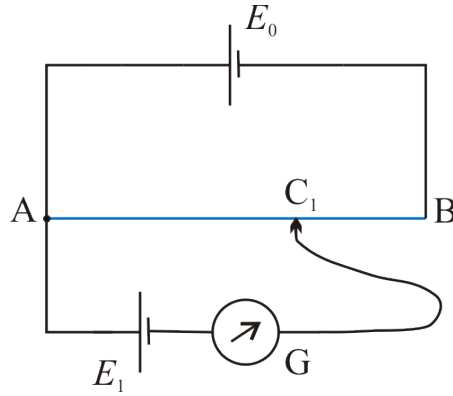
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### 13 DC Circuits

The potential divider rule is summarised by the equation:

$$V_{R1} = \frac{R_{R1}}{R_{\text{total}}} \times V_{\text{total}}$$

A potentiometer can be used to find the electromotive force of an unknown cell as well as its internal resistance. The simplest and most common potentiometer setup is shown in the following figure.



When the galvanometer shows zero deflection, i.e. no current passes through  $G$ , the emf of  $E_1$  can be found by:

$$V_{E_1} = \frac{L_{AC_1}}{L_{AB}} \times V_{E_0}$$

To find the internal resistance of  $E_1$ , a resistor of known resistance is added across  $E_1$ , and the position of  $C_1$  adjusted such that the galvanometer again shows no deflection. This effectively creates two separate circuits, one around  $E_0AB$  and one from  $E_1$  to the resistor. The terminal potential difference of  $E_1$  can be found using the same equation as above. Using this value, the previously found electromotive force of  $E_1$ , and the potential divider rule, the internal resistance can be found accordingly.

## 14 EM and EMI

### 14.1 Concepts

Magnetic Flux Density	$B$	The <b>force per unit length per unit current</b> acting on an <b>infinitely long</b> current carrying conductor placed perpendicular to the magnetic field. The SI unit is the tesla, T.
Tesla	T	The magnetic flux density of a magnetic field is said to be 1 T if the force acting per unit length on an infinitely long conductor carrying a current of 1 A and placed perpendicular to the magnetic field is $1 \text{ N m}^{-1}$ .
Magnetic Flux	$\varphi$	The magnetic flux through a surface is the product of the magnetic flux density <b>normal</b> to the surface and the area of the surface. The SI unit is the weber, Wb.
Weber	Wb	The weber is defined as the magnetic flux through a surface of $1 \text{ m}^2$ if a magnetic field of flux density 1 T exists perpendicular to the surface.
Flux Linkage	$\Phi$	The product of the magnetic flux through a coil and the number of turns of the coil. The SI unit is also the weber, Wb.
Lenz's Law		The polarity of the induced EMF is such that it tends to produce a current that creates a magnetic field so as to oppose the change in magnetic flux. It is a statement of the conservation of energy where the mechanical energy is converted to electrical energy. This law allows us to determine the polarity of the induced EMF and predict the direction of the induced current.

## 14.2 Equations

Force on Current Carrying Conductor	$F = BIL \sin \theta$
Force on Moving Charge	$F = BQv \sin \theta$
Torque in DC Motor	$\text{Torque} = NBIA \sin \theta$
Faraday's Law	$\varepsilon \propto \frac{d\Phi}{dt}$
Induced EMF in AC Generator	$\varepsilon = NBA\omega \sin(\omega t)$
Induced EMF in a Rod Cutting Flux	$\varepsilon = B_{\perp}Lv$
Induced EMF in a Faraday's Disc	$\varepsilon = BAf$

## 15 Alternating Current

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Alternating Current	Occurs when charge carriers periodically reverse their direction of motion.
Root-Mean-Square	<p>To find the RMS value for any AC graph:</p> <ol style="list-style-type: none"> <li>1. Square the <math>I/t</math> or <math>V/t</math> graph.</li> <li>2. Find area under graph in 1 period.</li> <li>3. Divide the area by 1 period.</li> <li>4. Square root the above result.</li> </ol> <p>If the graph is sinusoidal, the RMS value can be found by simply dividing the peak value by <math>\sqrt{2}</math>. The RMS value of an alternating current is the equivalent constant DC that will dissipate the same power in a given resistive load.</p>
AC to DC Conversion	Called rectification. Can be accomplished by placing a diode next to the AC source.
Non-Ideality in Transformers	<p>Caused by:</p> <ol style="list-style-type: none"> <li>1. Energy dissipated as heat due to resistance of windings in coils. Can be minimised by using thick coils.</li> <li>2. Alternating magnetic flux induces eddy currents in iron core and causes heating. Can be minimised by using a laminated core.</li> <li>3. Hysteresis loss whenever direction of magnetic flux is reversed causing some energy wastage. Can be minimised by using a soft iron core.</li> <li>4. Flux leakage if core is badly designed.</li> </ol>

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## 16 Quantum Physics

## 17 Lasers and Semiconductors

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Spontaneous Emission	Emission of photons through random de-excitation of excited atoms.
Stimulated Emission	Emission of photons from excited atoms as triggered by an incident photon with energy exactly equal to the difference between the excited state and the lower energy state. Emitted photon has exactly the same phase, energy, polarisation and direction of travel as incident photon.
Population Inversion	Condition where there are more atoms in the upper energy state/level than in the lower energy state/level.
Metastable State	Excited state with longer life-time than other excited states.
Conduction Band	Empty or partially filled band just above the valence band.
Valence Band	Highest <b>fully-filled</b> energy band at 0 K.
Metals	Metals have a partially filled conduction band at 0 K.
Insulators	Insulators have a fully-filled valence band and empty conduction band at 0K, and also a large bandgap. There are very few electrons in the conduction band even at room temperature due to the large bandgap.
Intrinsic Semiconductor	Intrinsic semiconductors have a full valence band and empty conduction band at 0K, but a smaller bandgap than that of insulators. An appreciable number of electrons are promoted to the conduction band at room temperature due to the smaller bandgap.

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## 18 Nuclear Physics

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Nucleon	A constituent of a nucleus, i.e. a proton or neutron.
Nuclide	A <b>species</b> of atom characterised by <b>constituent of nucleus</b> (no. of neutrons and protons).
Isotope	Atoms with the same number of protons but different number of neutrons.
Unified Atomic Mass Unit	1 u is defined as $\frac{1}{12}$ of the mass of a Carbon-12 atom.
Binding Energy of Nucleus/Atom	The energy required to <b>separate</b> the nucleus/atom into its <b>constituents</b> .
Binding Energy per Nucleon	The <b>average</b> energy required to remove a nucleon from its nucleus.
Radioactive Decay	A <b>spontaneous</b> and <b>random</b> process where an <b>unstable</b> nucleus changes into a different nuclide by emitting radiation. Spontaneous means that it is not triggered by external factors or influences, and random means that it is impossible to predict <b>which</b> nuclide will decay and <b>when</b> a <b>particular</b> nuclide will decay.
Activity	The rate of decay, or number of disintegrations per unit time. SI unit is $\text{s}^{-1}$ or the becquerel, Bq. $A = -\frac{dN}{dt} = \lambda N$
Decay Constant	<b>Probability per unit time</b> that a nucleus will decay. SI unit is $\text{s}^{-1}$ . $\lambda = \frac{A}{N}$
Half-Life	The <b>average</b> time taken for a number of <b>radioactive</b> nuclei to decay to <b>half</b> its original value. $t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

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Good luck! Don't panic, all is well.