Appendix A - Glossary

- **Amplitude:** The maximum disturbance of an oscillating system in any one cycle.

- **Angular momentum:** A measure of how much an object is rotating or spinning. For a point particle rotating about an axis, it is the momentum of the particle multiplied by the perpendicular distance between the particle and the axis.

- **Anode:** A positively charged electrode.

- **Anthropic Principle:** The (philosophical) proposition that observations of the Universe must be compatible with the consciousness of the humans who conduct those observations.

- **Bell's Inequality:** The correlation between two measurements of the spin of a spin one-half particle separated by an angle θ is less than $1 - \theta/90$.

- **Binding Energy:** Energy required to liberate a particle from a bound state.

- **Blackbody:** A surface which absorbs all of the electromagnetic radiation incident upon it.

- **Boltzmann Constant:** A constant, denoted by k_B, which occurs often in thermodynamics. It is the volume (in cubic meters) occupied by one molecule of an ideal gas at a pressure of 1 Pascal (Newton per square meter) and a temperature of 1^0K (-272.16^0 C). It takes the value 1.38×10^{-23} meter^2 kg per sec^2 per ^0K . At a pressure of one atmosphere and a temperature of 0^0C a molecule of an ideal gas occupies a volume of $2.7k_B$ litres.

- **Cathode:** A negatively charged electrode.

- **Chandrasekhar limit:** The maximum density of a neutron star for which the degeneracy pressure is sufficient to prevent a neutron star from collapsing under its own gravity.

- **Classical probabilistic state:** A state of a system in which a given property is well-defined but not known because it has not yet been measured. The probability that a measurement will yield a given result is known.

- **Component:** The component of a vector in the x, y, or z-direction in the projection of the vector in that direction. It is equal to the magnitude of the vector multiplied by the cosine of the angle between the direction of the vector and that axis. The vector is uniquely defined by its three components

- **Correlated:** Two quantities are completely correlated if there is a one-to-one relation between them. For example, the radius of a circle and its circumference are completely correlated. When a particle at rest (zero momentum) decays into two particles the momenta of the two decay particles are equal and opposite owing to the conservation of momentum The two momenta are said to be completely correlated.

- **de Broglie wave Equation:** A particle with momentum p has an associated wave whose wavelength λ is given by

$$\lambda \;=\; \frac{h}{p}$$

- **Decoherence:** A process involving the interaction between a sub-microscopic system and a macroscopic environment by which a sub-microscopic system is transformed from being in a superposition of quantum states, into a classical probability distribution.

- **Degeneracy Pressure:** A system of forces of purely quantum origin which is a consequence of Pauli's exclusion principle and leads to the fact if two identical spin one-half particles have a high probability of being spatially close to each other, they then have a high probability to have very different momenta and therefore repel each other.

- **Degrees Kelvin (^{0}K) :** The temperature in degrees Kelvin is an absolute temperature, defined in terms of the laws of thermodynamics and not in any way dependent on the nature of the thermometer used to measure the temperature. 0^0K is the lowest possible temperature and is reached when all the atoms in the sample are in their ground (lowest energy) state. 0^0C is approximately 273.16^0K.

- **Diffraction:** The process by which two waves interfere with each other.

- **Electric field:** The electric field at some point $\mathbf{x}$, is the force on a unit charged particle at that point. Since force has a direction as well as magnitude the electric field at any point is a vector. An electric charge generates an electric field.

- **Electromagnetic radiation:** A wave of any wavelength in which the disturbance consists of an oscillating electric field and an oscillating magnetic field perpendicular to each other and also perpendicular to the direction of motion of the wave. Visible light is electromagnetic radiation with a wavelength between 390 nm and 700 nm.

- **Electron:** A negatively charged particle which moves around a nucleus in an atom.

- **Energy level:** One of the allowed energies of an atom or other quantum system.

- **Entangled State:** A state of two or more particles whose wavefunction cannot be expressed as the product of wavefunctions for the individual particles.$\frac{1}{2}$

- **Exclusion Principle:** A theorem due to Wolfgang Pauli that asserts that two identical spin-$\frac{1}{2}$ particles cannot be in the same quantum state.

- **Equilibrium:** A state of a system in which there are no net forces acting on any component of the system.

- **Frequency:** Frequency of an oscillating system is the number of cycles performed per second.

- **Geiger Counter:** A device for detecting radioactivity. The instrument clicks every time radioactive decay particle (α, β, or γ-ray) impinges on it.

- **Graphene:** An allotrope of carbon consisting of single layers of atoms in a hexagonal lattice.

- **Harmonic Motion:** Oscillation of a system about its equilibrium position with constant frequency.

- **Harmonic Oscillator:** A device which when displaced from equilibrium is subject to a restoring force proportional to the displacement. Such a device performs harmonic motion.

- **Helium atom:** An atom with a nucleus containing two protons and two electrons moving around it. Each electron is not only subject to a force which attracts it to the nucleus, and depends on the distance between the electron and the nucleus, but also a repulsive force due to the other electron, which depends on the distance between the electrons.

- **Hertz:** Unit of frequency equal to one cycle per second. It is abbreviated Hz.

- **Hydrogen atom:** An atom with a nucleus containing one proton and one electron moving around it. This is the simplest atom.

- **Impact parameter:** The perpendicular (shortest) distance between a target particle and the initial direction of a projectile particle that scatters off the target.

- **Infrared radiation:** Electromagnetic radiation whose wavelength is longer than any wavelength of visible light, i.e. greater than 700 nm.

- **Integer:** A whole number.

- **Interference:** The process in which the disturbance from two waves are added such that there are regions in which the total amplitude is enhanced (interference maxima) and regions in which it is depleted (interference minima).

- **Interference Pattern:** A series of light and dark fringes from the superposition of two or ore coherent waves.

- **Ion:** An atom which is electrically charged owing to the fact that it has more (for negative ions) or fewer (for positive ions) electrons than protons in the nucleus.

- **Joule:** Unit of energy equivalent to the work done when a force of one Newton is moved through one meter (in the direction of the force).

- **Kinetic energy:** Energy that a particle possesses due to its motion. For a particle of mass, m, moving with a speed, v, (much less than the speed of light) the kinetic energy is given by $\frac{1}{2}mv^2$.

- **Lattice:** A regular array of sites – usually in three dimensions. In a crystalline solid these sites mark the equilibrium position of the ions in the crystal.

- **Magnetic Dipole:** A magnetic system consisting of a magnetic north pole and a magnetic south pole. A closed loop of electric current generates a magnetic dipole.

- **Magnetic Field:** The magnetic field at some point, $\mathbf{x}$, is the force on a unit magnetic north pole at that point. Since force has a direction as well as magnitude the magnetic field at any point is a vector. An electric current generates a magnetic field.

- **Magnetic Moment:** The magnetic strength of a magnetic dipole determined by the torque which the dipole experiences when placed in a magnetic field of unit strength.

- **Micron (μm):** One millionth of a meter, or one thousandth of a millimetre. A human cell has a size of approximately one micron in each direction.

- **Momentum:** The momentum, $\mathbf{p}$, of a particle of mass m travelling with velocity $\mathbf{v}$, (much smaller than the speed of light) is given by

$$\mathbf{p} = m\mathbf{v}.$$

It is a vector quantity. All three components of total momentum are conserved in a collision between two particles.

- **Monochromatic Wave:** (also known as a harmonic wave) is a wave with a single wavelength (single frequency).

- **Nanometer (nm):** One billionth of a meter, or one millionth of a millimetre.

- **Neutron Star:** A star consisting only of neutrons which attract each other due to gravity, but have no electromagnetic repulsion. The gravitational attraction is balanced by the degeneracy pressure of the identical spin-$\frac{1}{2}$ neutrons. This degeneracy pressure is sufficient to prevent the collapse of the neutron star provided its density it below the Chandrasekhar limit.

- **Newton:** Unit of force equal to the force which when applied to a mass of one kilogram produces an acceleration of one meter per second per second.

- **Nucleus:** Positively charged core of an atom, consisting of positively charged protons and neutral (uncharged) neutrons. The number of protons is equal to the number of electrons in a neutral atom.

- **Photoelectric Effect:** Phenomenon in which metals emit an electric current when radiated with electromagnetic radiation (e.g. light) above a certain frequency.

- **Photon:** A particle or "quantum" of light.

- **Planck's Constant:** The energy of a single photon divided by its frequency. It is denoted by h and takes the value 6.63×10^{-34} Joules seconds. The symbol $\hbar$ is often used in Quantum Physics - this is Planck's constant divided by 2π.

- **Polarization:** The direction of the electric field of an electromagnetic wave.

- **Potential energy:** The energy that a particle possesses by virtue of its position in a force field.

- **Probability:** The probability of a system having the value x_i for some quantity, X is $P(x_i)$, if when the measurement of X is performed on N identical systems, the average number of times, $N(x_i)$ that the value of X is found to be x_i is given by

$$N(x_i) = NP(x_i),$$

Where "average" means averaged over a very large number of repetitions. For example the probability of a tossed coin coming down "heads up" is $\frac{1}{2}$ means that if the coin is tossed 100 times then on average we expect it to come down heads 50 times. This will not always be exactly correct - it could be a little more or a little fewer than 50 times. However, if this is repeated a sufficient number of times the average gets closer and closer to 50.

- **Probability Density:** A system has a probability density $P(x)$ if the probability of a given quantity being in the interval between x and $x+dx$ (where dx is a small interval of the quantity x) is $P(x)dx$.

- **Quantum:** A discrete quantity (i.e. a "packet") of energy, or of an oscillating system.

- **Quantum Numbers:** A set of integer numbers used to label the allowed discrete values of the physical properties of a system of particles in a given quantum state.

- **Quantum State:** A state of a system defined by the values of the properties of the system which can be exactly determined simultaneously, such as energy and momentum for a free particle (but not position and momentum whose values cannot, according to Heisenberg's uncertainty relation, be simultaneously determined.)

- **Quantum Tunnelling:** Process in which a particle with a given energy E can tunnel through a potential barrier whose maximum potential is larger than E. Classically this would be forbidden by conservation of energy and the particle would always be reflected at the boundary of the barrier. But in Quantum Physics the wave is attenuated but not eliminated by the potential barrier and so there remains a non-zero probability to find the particle on the other side of the barrier.

- **Radioactivity:** Process by which one type of nucleus converts into a different type by the spontaneous emission of an α-particle, β-particle or a γ-ray.

- **Repulsive force:** A force acting between two particles which increases the distance between the particles.

- **Resolving power:** The resolving power of an optical device is the minimum separation or angular separation of two objects that can be distinguished by the device.

- **Rydberg Constant:** This is a constant, R_H, which gives the wavelength, λ_{nm}, of the light emitted or absorbed when a hydrogen atom makes a transition between energy levels denoted by (principal) quantum numbers n and m

$$\frac{1}{\lambda_{nm}} = R_H \left| \frac{1}{n^2} - \frac{1}{m^2} \right|$$

It has a value of 10973731 per meter.

- **Schrödinger Equation:** A differential equation describing a particle or system of particles moving under the influence of a field of forces, whose solution is the wavefunction for that particle or system of particles.

- **Semiconductor:** A material which conducts electricity but with a very high resistance. An example is silicon which has a resistivity of 2300 Ohm-meters, compared with copper which is a conductor with a resistivity of 1.7×10^{-8} Ohm-meters.

- **Spectral Lines:** Wavelengths of the spectrum of an atom.

- **Spectrum:** Frequencies of light (or other electromagnetic) radiation emitted or absorbed by a given atom when an electron makes a transition from one energy level to another.

- **Spin down:** A particle whose component of spin in a given direction is $-\frac{1}{2}\hbar$.

- **Spin up:** A particle whose component of spin in a given direction is $+\frac{1}{2}\hbar$.

- **Standing Wave:** A wave whose shape does not change with time but oscillates about its equilibrium position.

- **State:** see quantum state

- **Superposition:** A superposition of waves is the wave formed by adding the disturbances of many (possibly infinite number of) waves with different wavelengths (frequencies). A particle or system of particles whose wavefunction is a superposition of quantum states does not possess well-defined values for the physical quantities that label the quantum states.

- **Transistor:** A component (such as an amplifier) used in electronic devices. It consists of several (at least three) layers of semiconductor of different type with electrodes attached to each layer.

- **Travelling wave:** A wave in which a point with a fixed disturbance travels with time in the direction of the wave motion.

- **Ultraviolet radiation:** Electromagnetic radiation with a wavelength shorter than the wavelength of any visible light – i.e. shorter than 390 nm.

- **Uncertainty Principle:** Werner Heisenberg's relation between the uncertainty, Δx, in the position of a particle and the uncertainty, Δp, in its momentum.

$$\Delta x \, \Delta p \; > \; \frac{1}{2}\hbar.$$

- **Vector:** A quantity which has direction as well as magnitude. Examples are position (measured relative to a chosen origin), velocity, acceleration, force, momentum, electric field, magnetic field.

- **Volt:** A measure of potential difference. When a unit electric charge (1 coulomb) moves between two points whose potential difference is one volt, it gains or loses one Joule of potential energy.

- **Wave disturbance:** The disturbance from equilibrium of a quantity which defines the wave.

- **Wavefront:** At any one time the wavefront of a wave is a surface of points with equal disturbance.

- **Wavefunction:** A mathematical function of space and time, but also possibly of a spin coordinate, which defines a de Broglie (matter) wave.

- **Wavefunction Collapse:** A process by which the wavefunction of a system which does not have well-defined values for certain measurable quantities is transformed into the wavefunction describing a system in which the quantities have definite value.

- **Wavelength:** The distance (measured in the direction of propagation of the wave) between two adjacent points with the same disturbance.

- **Wavenumber:** The inverse of wavelength.

- **Wavepacket:** A wave disturbance which exists only over a finite range and consists of a superposition of waves with different wavelengths (different frequencies).

- **Work function:** The energy required to liberate an electron from its binding in a metal.

- **X-rays:** Electromagnetic radiation with a wavelength about one thousand times shorter than any visible light. X-rays have higher penetration than visible light, and can penetrate human flesh.

- **Young's Slits:** An experiment in which one observes the interference between light emerging from two narrow slits.

- **α-particle:** A particle emitted in certain types of radioactive decay (α-decay). It is the nucleus of He^4, consisting of two protons and two neutrons.

- **β-particle:** An electron emitted in certain types of radioactive decay (β-decay)

- γ-**ray:** Electromagnetic radiation with a wavelength even shorter than those of X-rays. They are also emitted during radioactive decay, when a nucleus makes a transition from an excited energy level to a lower energy level.