SUPER PHYSICS

H2 Definition Checklist

1.	Systematic error	An error which causes measurements to be either, always larger than the true value, or always smaller than the true value.
2.	How to reduce systematic error?	Cannot be reduced by taking the average of repeated measurements but can be eliminated by checking the instrument in which the error is suspected, against a known reliable instrument.
3.	Accuracy	Refers to the degree of agreement between the result of a measurement and the true value of the quantity.
4.	Random error	An error which causes measurements to be sometimes larger than the true value and sometimes smaller than the true value.
5.	How to reduce random error?	Can be reduced by taking the average of repeated readings.
6.	Precision	Refers to the degree of agreement [scatter, spread] of repeated measurements of the same quantity. Is a measure of the magnitude of the random errors present; high precision implies a small random error.
7.	Base units	Base units are units by which all other units are expressed.
8.	Derived units	Derived units are expressed as a product and/or quotient of the base units.
9.	Scalar & Vectors	A scalar quantity is a quantity which has only magnitude but no direction. A vector quantity has both magnitude and direction.
10.	Distance	Distance travelled is the total length covered irrespective of the direction of motion.
11.	Speed	Speed is defined as the rate of change of distance travelled.
12.	Explain why it is incorrect to define speed as distance per second	Distance is a physical quantity while second is a unit. The physical quantity speed should be defined in terms of quantities, and not a mixture of a quantity and a unit. The correct definition for speed is the distance travelled per unit time.
13.	Displacement	Displacement is defined as the distance moved in a specific direction.
14.	Velocity	Velocity is defined as the rate of change of displacement.
15.	Acceleration	Acceleration is defined as the rate of change of velocity.
16.	2 conditions for equations of motion	1) motion in a straight line 2) magnitude of the acceleration is constant

17.	Equation of motion (1) $v = u + a t$	derived from definition of acceleration: $a = (v - u) / t$
18.	Equation of motion (2) $s = ½ (u+v)t^2$	derived from the area under the v-t graph
19.	Equation of motion (3) $(v^2 = u^2 + 2as)$	derived from equations (1) and (2)
20.	Equation of motion (4) $s = ut + ½ at^2$	derived from equations (1) and (2)
21.	Field of force	A region of space within which a force is experienced.
22.	Gravitation field	A region of space in which a mass experiences an attractive force due to the effect of another mass.
23.	Electric field	A region of space where an electric charge experiences an (attractive or repulsive) force due to the effect of another charge.
24.	Magnetic field	A region of space in which a moving electric charge or a current-carrying conductor experiences a force (that is perpendicular to the magnetic field).
25.	Hooke's law	If the limit of proportionality is not exceeded, the extension is directly proportional to the force/ load applied.
26.	2 conditions for static equilibrium	1) The resultant force acting is zero. {translational equilibrium} 2) The resultant moment about any point equals zero. {rotational equilibrium}
27.	3 forces in equilibrium	If a mass is acted upon by 3 forces only and is in equilibrium, then the lines of action of the 3 forces must pass through a common point.
28.	Principle of moments	For a body to be in rotational equilibrium, the sum of all the anticlockwise moments about any point must be equal to the sum of all the clockwise moments about that same point.
29.	Moment of a force	The product of the force and the perpendicular distance of its line of action from the pivot/ axis of rotation.
30.	Torque of a couple	The product of one of the forces of the couple and the perpendicular distance between the lines of action of the forces.
31.	Couple	A Couple is a pair of equal and opposite forces, whose lines of action do not coincide. (Hence it tends to produce rotation only.
32.	Define centre of gravity	Centre of gravity of an object is defined as that single point through which the entire weight of the object may be considered to act.

33.	Derive Pressure	By Newton's Laws, the net force acting on the column of fluid is zero because the column is stationary (it is part of a uniform incompressible fluid which is also stationary). Thus, the fluid force *F* acting on the bottom surface is equal to the weight of the column of fluid, mg → $F = mg$ Since the fluid force $F = pA$ and mass of fluid $m = \rho Ah$ (Recall that density ρ is mass m per unit volume V, hence $m = \rho V = \rho Ah$) Hence, $pA = \rho Ahg$ $\rightarrow p = \rho hg$
34.	Upthrust	An upward force exerted by a fluid on a submerged or floating object due to the difference in pressure between the upper and lower surfaces of the object. It is also equal in magnitude and opposite in direction to the weight of the fluid displaced by the object.
35.	Flotation Principle	When an object floats, the upthrust acting on it must be equal in magnitude and opposite in direction to the weight of the object since it is in vertical equilibrium.
36.	Newton's first law	Every object continues in a state of rest or constant speed in a straight line unless a net (external) force acts on it.
37.	Newton's second law	The rate of change of momentum of a body is (directly) proportional to the net force acting on the body, and the (rate of) change of momentum takes place in the direction of the force.
38.	Newton's third law	When body X exerts a force on body Y, object Y exerts a force of the same type that is equal in magnitude and opposite in direction on object X.
39.	Action-reaction pairs	Always act on different objects, hence they cannot cancel each other out. They are of the same type of force.
40.	Linear momentum	Linear momentum of a body is defined as the product of its mass and velocity.
41.	Impulse of a force	Impulse of a force is defined as the product of the force and the time during which it acts.
42.	Principle of conservation of linear momentum	When objects of a system interact, their total momentum before and after interaction are equal if no net external force acts on the system,
43.	Mass	Mass is a measure of the inertia a body (which is the property of a body which resists change in motion).
44.	Weight	Weight is the force experienced by a mass in a gravitational field.
45.	Apparent weightlessness	A body is said to be experiencing apparent weightlessness if the resultant force acting on it is its weight (mg) and its acceleration, a, is equal to g.
46.	Work done by a constant force	Work done by a constant force is defined as the product of the force and displacement in the direction of the force.

47.	Define energy	Energy is the ability to do work. It exists in many possible forms: Mechanical (i.e. Kinetic, potential energies), Chemical, Sound, Thermal, Internal, Radiation (photon), Nuclear energies.
48.	Potential energy (PE)	PE is defined as the stored energy available to do work.
49.	Principle of conservation of energy	Total energy of an isolated system remains constant; energy may be transferred from one form to another, but never created nor destroyed.
50.	Gravitational Potential Energy (GPE)	GPE is the potential energy possessed by a mass due to its position {or height or distance} in the field of another mass
51.	Elastic potential energy (EPE)	EPE of a system is due to its deformation {or stretching or compression}.
52.	Derive $KE = ½ mv^2$	We can infer the formula for kinetic energy from the amount of work that is done by an external force to bring a body from rest to its state of motion. → $KE = F s$ By Newton's second law: → $KE = (ma)s$ Using the equations of motion for uniform acceleration: $KE = ma (ut + ½ at^2) = ma (½at^2) = ½ma^2t^2$ Sub $a = (v-u)/t$ and let u = 0 → $KE = ½ mv^2$
53.	Derive $GPE = mgh$	Mathematically, we can form an equation as follows, Increase in GPE = Work done by force exerted on box by person, → $W = F_{ext}\ h = mgh$ (Since there is no acceleration at equilibrium) Hence, Increase in G.P.E. = mgh
54.	Power	Power is defined as the work done per unit time.
55.	Derive $P = Fv$	Consider a force F that acts on a body for a small time interval Δt. The body moves a small displacement Δx in the direction of the force. Work done by the force F during Δt, → $\Delta W = F \Delta x$ Power delivered by that force F during the time interval → $P = \Delta W / \Delta t = (F \Delta x) / \Delta t = F(\Delta x/\Delta t) = Fv$ Where v is the instantaneous velocity of the body.
56.	Angular displacement	Angular displacement of a body is the angle in radians through which a point revolves around a centre.
57.	Define 1 radian	1 radian is the angle (subtended) at the centre of a circle by an arc equal to the radius of the circle.
58.	Angular velocity	ω is defined as the rate of change of angular displacement.
59.	Linear/tangential velocity	Tangential velocity is the instantaneous velocity at any point in its circular path.
60.	Centripetal force	Centripetal force refers to the resultant of all the forces that act on a system in circular motion.

61.	Explain why a person in a satellite orbiting earth experiences “weightlessness” although the gravitation field strength at that height is not zero	Since the person and the satellite would both have the same acceleration; hence the normal reaction on the person is zero. {To elaborate: the sensation of weight is due to the normal reaction exerted on the object. When the person & the floor of the satellite have the same acceleration, the contact force between them is zero, hence the normal reaction is zero. This is the state of “weightlessness”.}
62.	Why is velocity constant for an object in horizontal circular motion?	For uniform circular motion, there is no work done by the centripetal force since the direction of the force is always perpendicular to the direction of displacement. Hence, KE of the object remains constant.
63.	Use newton’s laws to explain why an object moving with constant speed in a circle experiences a resultant force towards the centre of the circle.	Since object experiences a constant change in direction of motion, by N1L, there must be a resultant force on it. • Given that the tangential speed remains constant by N2L, there must not be any component of force in the tangential direction. • Hence resultant force must act perpendicular to the velocity, in the radial direction, towards the centre of the circle.
64.	Geostationary satellites	Geostationary satellites are always above a certain point on the Earth as the Earth rotates about its axis.
65.	Requirements for geostationary orbit	1) have a period = period of Earth’s rotation {24 hours} 2) rotate from west to east 3) be at a fixed height from the Earth’s surface (r = 4.23 × 107 m) 4) have only one orbital speed 5) lie in equatorial plane of Earth
66.	Newton’s Law of gravitation	Newton’s Law of gravitation states that the gravitational force of attraction between two point masses is proportional to the product of their masses & inversely proportional to the square of their separation.
67.	Gravitational field strength	Gravitational field strength at a point is defined as the gravitational force per unit mass at that point.
68.	Explain why apparent weight at equator is more than at the poles	Resultant of the gravitational force and the normal reaction $N_{equator}$, provides the centripetal force to keep the body in a circular motion.
69.	Explain why acceleration of free fall near Earth’s surface is constant	Since a small change in height on Earth’s surface << Radius of earth , change in g is negligible.

70.	Gravitational potential	Gravitational potential at a point is defined as the work done (by an external force) in bringing unit mass from infinity to that point (without changing its KE).
71.	Explain why gravitational potential values are always negative	• Potential of any point at infinity is zero. • As the gravitational force is attractive, the force exerted by the external agent is opposite in direction to the displacement of the body (in bringing unit mass from infinity to any point in the field), hence work done is negative • The potential, which is the work done per unit mass, are always negative.
72.	Gravitational potential energy	Gravitational potential energy U of any mass m at a point in the gravitational field of another mass M, is the work done in bringing that mass m {NOT: "unit mass", or "a mass"} from infinity to that point.
73.	Explain why a satellite does not move in the direction of the gravitational force	The gravitational force exerted by the Earth on the satellite is JUST sufficient to cause the centripetal acceleration.
74.	Explain why satellites, as they gradually lose energy due to small resistive forces, may burn up in the Earth's atmosphere	K.E. increases, but P.E. decreases, and the sum decreases due to dissipation against friction.
75.	Displacement	Displacement is the distance of the oscillating mass from its equilibrium position in a particular direction.
76.	Amplitude	Amplitude is the maximum displacement from the equilibrium position.
77.	Period	Period T, is the time taken for one complete oscillation.
78.	Frequency	Frequency f, is the number of oscillations per unit time,
79.	Angular frequency	Angular frequency ω, is defined by $\omega = 2\pi f$
80.	Phase	Phase is an angle in radians (rad) which gives a measure of the fraction of a cycle that has been completed by an oscillating particle or by a wave. {One cycle corresponds to 2π rad.}
81.	Phase difference	Phase difference is the separation between 2 wave particles, measured along the direction of wave motion; Or the time difference between two waves or two particles in a wave.

82.	Simple harmonic motion	• Simple harmonic motion is an oscillatory motion in which the acceleration [or restoring force] is • Always proportional to, and • opposite in direction to the displacement from a certain fixed point / equilibrium position {MUST define where displacement is from}
83.	Damping	Damping refers to the loss of energy from an oscillating system to the environment, caused by a dissipative force acting in opposite direction of motion of the system, eg friction, viscous force.
84.	Light damping	The system oscillates about the equilibrium position with decreasing amplitude over a period of time.
85.	Critical damping	The system does not oscillate & damping is just adequate such that the system returns to its equilibrium position in the shortest possible time. {Need to describe practical examples, eg, in analogue ammeters}
86.	Heavy damping	The damping is so great that the displaced object never oscillates but returns to its equilibrium position very slowly.
87.	Free oscillation	An oscillating system is said to be undergoing free oscillations if: Its oscillatory motion is not subjected to an external periodic driving force. Hence the system oscillates at its natural frequency.
88.	Forced oscillation	An oscillating system is said to undergo forced oscillations if: It is subjected to an input of energy from an external periodic driving force. As a result, the frequency of the forced or driven oscillations will be at the frequency of the driving force [called the driving frequency] i.e. no longer at its own natural frequency.
89.	Resonance	A phenomenon whereby the amplitude of a system undergoing forced oscillations is at a maximum. It occurs when the frequency of the periodic driving force is equal to the natural frequency of the system.
90.	Effects of damping on system undergoing forced oscillation	1) resonant frequency decreases 2) sharpness of resonance [resonant peak] decreases 3) amplitude of forced oscillations decreases
91.	Progressive wave	A progressive wave is the movement of a disturbance from a source which transfers energy from the source to places around it by means of vibrations/oscillations.
92.	Transverse wave	It is a wave in which the oscillations of the wave particles {NOT: movement/motion} are perpendicular to the direction of the propagation of the wave.
93.	Longitudinal wave	It is a wave in which the oscillations of the wave particles are parallel to the direction of the propagation of the wave.
94.	Wavelength	Wavelength is the distance between 2 consecutive points on a wave which are in phase.

95.	Wave speed	Wave speed refers to the speed of propagation of the energy
96.	Phase	Phase is the angle which gives a measure of the fraction of a cycle that has been completed by an oscillating particle or by a wave. {One cycle corresponds to 2π rad.}
97.	Phase difference	Phase difference (ϕ) is a measure of how much one wave is out of step with another wave or how much one particle in a wave is out of step with another particle in the same wave.
98.	Intensity of a wave	Intensity of a wave is defined as the rate of energy flow per unit cross-sectional area perpendicular to the direction of wave propagation.
99.	Polarization	Polarisation is a process by which the oscillations of the wave are confined to only one direction, in the plane normal to the direction of energy transfer.
100.	Polarized wave	A polarised wave is one whose oscillations are confined to only one direction, in the plane normal to the direction of energy transfer (propagation of the wave).
101.	Malus' law	Intensity I of light transmitted by the analyser is directly proportional to the square of the cosine of angle between the transmission axes of the analyser and the polarizer.
102.	Diffraction	Diffraction refers to the spreading {not: bending} of waves when they pass through an opening [gap], or round an obstacle into the "shadow" region.
103.	Condition for diffraction to occur	For significant diffraction to occur, the size of the gap should be approximately equal to the wavelength of the wave
104.	Principle of superposition	When two or more waves of the same type meet/superpose {NOT: superimpose} at a point, the resultant displacement {NOT: amplitude} of the waves is equal to the vector sum of their individual displacements at that point.
105.	Coherence	Two waves are coherent if they have a constant phase difference (not just zero phase difference) between them (with respect to time).
106.	Interference	Interference refers to the superposition of coherent waves which results in a change in the overall intensity.
107.	Constructive interference	This occurs when waves from two (or more) coherent sources arrive at a point in phase (i.e. zero phase difference), producing a resultant wave with amplitude that is the sum of the amplitudes of the individual waves.
108.	Destructive interference	This occurs when waves from two (or more) coherent sources arrive at a point in anti-phase (i.e. phase difference of π radians), producing a resultant wave of minimum amplitude and intensity.
109.	Conditions to produce a well-defined interference pattern	1) Coherent, 2) Have about the same amplitude (equal is best), 3) Meet / superpose 4) Be polarised in the same direction, or unpolarised (only for transverse waves)

110.	Rayleigh criterion	Rayleigh criterion states that 2 images are said to be just resolved if the central maximum of one image falls on the first minimum in the diffraction pattern of the other.
111.	Stationary (standing) wave	is one • whose waveform/wave profile does not advance /move, • where there is no net transport of energy, and • where the positions of antinodes and nodes do not change.
112.	How do stationary waves form	A stationary wave is formed when two progressive waves of the same frequency, amplitude and speed, travelling in opposite directions are superposed.
113.	Node	A node is a region of destructive superposition where the waves always meet out of phase by π radians. Hence displacement here is permanently zero {or minimum}
114.	Antinode	An Antinode is a region of constructive superposition where the waves always meet in phase. Hence a particle here vibrates with maximum amplitude.
115.	Sound waves: change in pressure at nodes and antinodes	• At nodes: maximum pressure change occurs because every node changes from a point of compression to become a point of rarefaction half a period later. • At antinodes: there is no variation in pressure.
116.	Thermal equilibrium	Two objects are said to be in thermal equilibrium, if there is no net flow of heat between them.
117.	Absolute scale of temperature	The absolute scale of temperature is a theoretical scale that is independent of the properties of any particular substance.
118.	Absolute zero	Absolute zero: Temperature at which all substances have a minimum internal energy {NOT: zero internal energy}.
119.	Define Avogadro constant	It is the number of particles (atoms or molecules) in one mole of substance. NA = 6.02×10^{23} mol^{-1}.
120.	Define one mole	The mole is the amount of substance that contains the same number of particles as the number of atoms in 0.012 kg (or 12g) of carbon-12.
121.	Ideal gas	An ideal gas is one that obeys the equation $pV = nRT$ for all values of pressure, volume and temperature.
122.	What is a state?	'State' refers to the thermodynamic properties of pressure, volume, temperature and number of molecules.
123.	Explain how molecular movement causes pressure by a gas	As the gas molecules collide with the walls of a container, as shown on the left of the figure, the molecules impart momentum to the walls, producing a force perpendicular to the wall. The sum of the forces of all the molecules striking the wall divided by the area of the wall is defined to be the pressure.

124.	Derive $p = Nm<c^2>/3V$	1) Consider an ideal gas consisting of N identical molecules housed in a cubical container. N is large and the molecules move randomly. The length of each side of the container is L. 2) Since the molecules move randomly, they do not have any preferred direction of travel along the 3 axes – x, y and z. So we only expect one third of the N molecules to be moving along each axis. 3) Consider a one dimensional case along the x-axis. One gas molecule of mass *m* approaches the shaded wall with velocity *c*. It makes an elastic collision with the wall and leaves the wall with velocity *–c.* Thus, Change in its momentum, $\Delta p = (=mc) = mc = -2mc$ 4) After the collision, assume this molecule continues its motion uninterrupted. It will travel a distance *L* to the opposite wall and come back again to hit the first wall. The time it takes between successive collisions with the same wall, $\Delta t = 2L/c$ 5) By Newton's second law, the average force of the wall on the molecule is $\Delta p/\Delta t = -2mc/(2L/c) = - mc^2/L$ By Newton's third law, the average force of this molecule on wall, $F_1 = mc^2/L$ 6) Since there are N/3 molecules moving along this axis, using the mean square speed of the molecules gives us the average force on the shaded well: $F = mN <c^2> / 3L$ 7) Since the area of the wall is L^2 the pressure, $p = Nm<c^2>/3V$
125.	Basic assumptions for the kinetic theory of gas	• The gas consists of a very large number of molecules • The gas molecules are moving randomly • The collisions of the gas molecules with one another and with the walls of the container are perfectly elastic. • There are no intermolecular forces of attraction except during collision. • The volume of the gas molecules is negligible as compared to the volume of the container (volume of gas). • The duration of collision in negligible compared to the time interval between collisions
126.	Specific heat capacity	is defined as the amount of energy needed to produce unit temperature change for unit mass {NOT: 1 kg} of a substance, without causing a change in state,
127.	Specific latent heat of vaporization	Specific latent heat of vaporization is defined as the energy per unit mass required to change a substance from liquid phase to gaseous phase without a change of temperature.
128.	Specific latent heat of fusion	Specific latent heat of fusion is defined as the energy per unit mass required to change a substance from solid phase to liquid phase without a change of temperature.
129.	Internal energy	Internal Energy (U) of a substance is the sum of the kinetic energy of the molecules due to their random motion and the potential energy of the molecules (due to the intermolecular forces).

130.	Explain what "internal energy is determined by the state of the system" means?	Internal energy is determined by the values of N & T of the current state, i.e. it is independent of the path taken to reach its current state. Thus if a system undergoes a change from one state to another, its change in internal energy is the same, regardless of which path it has taken to get from A to B.
131.	First law of thermodynamics	First law of thermodynamics states that the increase in internal energy of a system is equal to the sum of the heat supplied to the system and the work done on the system.
132.	Why is specific latent heat of vaporization more than the specific latent heat of fusion for a given substance?	In vaporization, there is an expansion of the gas against the environment and thus significant work done on the environment. In melting, there is little change in volume. In vaporization, the intermolecular forces of attraction between molecules are completely broken and molecules are completely free. There is a huge increase in PE of the system. In melting, the increase in potential energy is not as much.
133.	Why when a liquid is boiling, thermal energy is being supplied, and yet, the temperature of the liquid does not change?	No change in average KE of the molecules. The energy supplied increases the potential energy among the particles of the system.
134.	Explain using the 1st law of thermodynamics, the specific heat capacity of an ideal gas measured at constant volume is different to the specific heat capacity when measured at constant pressure.	At constant volume, the system (by definition) is not able to do work on the surroundings because work involves a change in volume. All the heat you put in is spent raising the temperature (internal energy). At constant pressure, some of the energy you put in goes into raising the temperature (internal energy) and some of it goes into doing work by expanding the ideal gas. Thus, the temperature increase is smaller in the constant pressure case than in the constant volume case. This is equivalent to saying that the specific heat capacity at constant pressure is larger than the specific heat capacity at constant volume.
135.	Why cooling accompanies evaporation?	The molecules in the liquid have a range of KE. The ones with the most KE can overcome attraction with the other molecules, and overcome atmospheric pressure to escape from the surface, reducing the average KE per molecule of those remaining.
136.	Current	Electric current (I) is the rate of flow of charge.

137.	Drive $I = nAvq$	• Suppose there are n mobile charge carriers per unit volume. • If the charge carriers move with drift velocity v, the distance moved in time Δt is given by $\Delta x = v\Delta t$. • The charge carriers that flow out of the right shaded face of the shaded cylinder are the carriers that are within the volume of shaded section during the time Δt. • The total number of mobile charge carriers in that section would be given by $nA\Delta x$ and if each carrier is of charge q, then the total charge ΔQ in this section is given by ΔQ = number of charge carriers x charge per carrier = $(nA\Delta x)q = (nAv\Delta t)q$ • By dividing both sides with Δt, we see that the current in a conductor is given by: $I = nAvq$
138.	Emf (in terms of energy)	Emf is defined as the energy transferred per unit charge from other forms of energy into electrical energy by a source when charge is moved round a complete circuit.
139.	Potential difference (in terms of energy)	The potential difference between 2 points in a circuit is the energy converted from electrical energy to other forms of energy per unit electric charge moved between the 2 points
140.	Resistance	Resistance R of a circuit component is defined as the ratio of the potential difference across the component to the current flowing through it,
141.	Metallic ohmic resistor at constant temperature (sketch and explain)	Magnitude of vibration of lattice ions remains the same. Hence, rate of collision with lattice ions is constant. Thus, resistance is constant so ratio of V to I is constant.
142.	Semiconductor diode (sketch and explain)	Conducts well in one direction, but badly in other direction. An ideal diode has no resistance in forward-bias and infinite resistance in reverse-bias.
143.	Filament lamp (sketch and explain)	Resistance increases with increasing temperature (when I and V are larger) due to more frequent collisions between free electrons and lattice atoms which vibrate more vigorously at higher temperatures. There is no change in number of charge carriers.
144.	NTC Thermistor (sketch and explain)	Resistance decreases with increasing temperature due to large increase in number of charge carriers at high temperature (it is a semiconductor material). This effect overwhelms the increase in lattice vibrations.
145.	Resistivity	Resistivity ρ is defined as the resistance of a material of unit cross-sectional area and unit length.
146.	Characteristic of Light-dependent resistor	LDR is a semiconductor whose resistance decreases as light intensity falling on them increases.
147.	Characteristic of thermistor	Most thermistors have a negative temperature coefficient (NTC), hence resistance decreases with increasing temperature due to an increase in number of mobile charge carriers.

148.	Explain why using a potentiometer would be better than using a voltmeter across the source	To obtain an accurate value of the emf of a source, using a potentiometer would be better than using a voltmeter connected across the source. This is because a voltmeter has a finite resistance and draws some current which causes the voltage reading to be smaller than the emf (by an amount equal to the pd across the internal resistance of the emf source). {For a voltmeter to be ideal, it needs to have an infinite resistance.}
149.	Electric field	An electric field is a region of space where any charged particle in it experiences an electric force.
150.	Coulomb's law	Coulomb's law states that the (mutual) electric force between two point charges is proportional to the product of their charges & inversely proportional to the square of their separation.
151.	Electric field strength	E at a point is defined as the electric force per unit positive charge acting on a small positive (test) charge placed at that point.
152.	Why is electric field strength in a charged metal conductor zero?	Charge carriers (i.e. free electrons) of metal sphere are mobile and so they can distribute themselves to reach electrostatic equilibrium within conductor • Net force on charge carriers = 0; therefore $E = 0$ since $E = F/Q$
153.	Electric potential	Electric potential (V) at a point is defined as the work done per unit positive charge (by an external agent) in bringing a small test charge from infinity to that point (without a change in KE).
154.	Electric potential energy	Electric potential energy (U) of a charge (at a point) in an electric field is defined as the work done (by an external agent) in moving the charge from infinity to that point (without a change in KE).
155.	Equipotential surface	An Equipotential surface is a surface where the electric potential is constant.
156.	Explain why the equipotential lines are always perpendicular to the electric field lines	Movement along equipotential line requires no work done, hence this is only possible if no resultant force act on charge. Since force is directed in the direction of field lines , equipotential lines must always be perpendicular to field lines so that no component of force acts along acts along the equipotential lines
157.	Magnetic field	Magnetic Field: a region (of space) where a magnetic force is experienced by a current-carrying conductor {or moving charged particle or a permanent magnet}.
158.	Direction of a magnetic field line	The Direction of a magnetic field line defines the direction of the magnetic force on a north pole placed there.
159.	Magnetic flux density	Magnetic flux density is defined as the force acting per unit current in a wire of unit length placed at right-angles to the field.
160.	Fleming's left hand rule	Direction of the magnetic force is always perpendicular to the plane containing the current I and B

161.	How does a ferrous core change the field lines?	The magnetic domains in the soft iron causes the magnetic field to strengthen, so the number of field lines increase due to ferrous core.
162.	Describe circular motion for charged particle in B field	From FLHR, we conclude that the direction of F_B is always perpendicular to the direction of v. Hence the moving charge moves in a uniform circular path where centripetal force is provided by the magnetic force.
163.	Describe charged particle in velocity selector	A setup whereby an E-field and a B-field are perpendicular to each other such that they exert equal & opposite forces on a moving charge & hence causes no deflection of the particle.
164.	Magnetic flux	Magnetic flux is defined as the product of an area A and the component of the magnetic flux density B perpendicular to that area.
165.	Magnetic flux linkage	The product of the magnetic flux passing through a coil and the number of turns of the coil
166.	Electromagnetic induction	Electromagnetic induction refers to the phenomenon whereby an e.m.f. is induced when the magnetic flux linking a conductor changes.
167.	Faraday's law	The magnitude of e.m.f. induced in a coil is directly proportional to the rate of change of magnetic flux linking (or cutting) the coil.
168.	Lenz's law	The direction of the induced e.m.f. is such that it produces an effect to oppose the change which causes it; or, the direction of the induced e.m.f. is such that it gives rise to an induced current whose magnetic field opposes the change in flux.
169.	Explain how Lenz's law is an example of conservation of energy	As the external agent brings the magnet towards the coil, by Lenz's law, a current is induced in such a direction that the coil opposes, (i.e. repels) the approaching magnet. • Consequently, work has to be done by the external agent to overcome this opposition {the repulsive force}, and • It is this work done which is the source of the electrical energy
170.	Eddy currents	Eddy currents dissipate energy in a 'bulk piece' of metal as heat; and thus is a source of energy loss in the core of a transformer, electrical motors and generators. Laminating the piece of metal reduces eddy currents and thus, the energy loss (as heat).
171.	What is AC?	Alternating current occurs when charge carriers periodically reverse their direction of motion.
172.	RMS current of an A.C.	The magnitude of the steady direct current that produces the same average heating effect as the alternating current in a given resistor.
173.	Explain the use of a single diode for half-wave rectification	During the half-cycle when the diode is reverse biased, little or no current flows and the potential difference across R is zero. This is repeated for each cycle of AC input. The current flow is unidirectional and so is the potential difference across R. Although it fluctuates, it never changes direction.

174.	Explain why transformers require an A.C. supply to work	The primary voltage supply must be an alternating e.m.f. If not, the flux in the primary coil would not change (except for a short time immediately after the e.m.f. is first applied) and there would be no induced e.m.f. in the secondary coil.
175.	Photoelectric effect	Photoelectric effect refers to the emission of electrons from a metal surface when electromagnetic (EM) radiation of sufficiently high frequency is incident on it.
176.	4 major experimental observations from the photoelectric effect experiment	1) No electrons are emitted if the frequency of the EM radiation is below a minimum frequency {called the threshold frequency f_o}, regardless of the intensity of the radiation. 2) Photoelectric current is proportional to the intensity of radiation, for a fixed frequency (because the rate of emission of electrons $\propto$ rate of incidence of photons) 3) Max KE of photo-electrons depends only on the frequency and the work function, ϕ, of the metal used, not the intensity. {Note: Emitted electrons have a range of kinetic energy, ranging from zero to a certain maximum value} 4) Emission of electrons begins instantaneously {i.e. no (measurable) time lag between emission & illumination} even if the intensity is low. (1), (2) & (3) cannot be explained by Classical Wave Theory of Light; they provide evidence for the particulate {particle-like} nature of EM radiation.
177.	Failure of the classical wave theory to explain the photoelectric effect	• According to the "Particle Theory of Light", EM radiation consists of a stream of particles/ photons/ discrete energy packets, each of energy hf. • An electron is ejected when a single photon of sufficiently high frequency, transfers ALL its energy in a discrete packet to the electron. • According to equation, $hf - \phi = \frac{1}{2} m_e v^2$, if the energy of the photon hf < the minimum energy required for emission (ϕ), no emission can take place, no matter how intense the light may be. {Explains observation (1)} • This also explains why, (even at very low intensities), as long as $hf > \phi$, emission takes place without a time delay between illumination of the metal & ejection of electrons. {Explains observation(4)}
178.	Photon	A photon is a discrete packet {or quantum} of energy of an electromagnetic radiation with energy hf.
179.	Threshold frequency	Threshold frequency f_o is the minimum frequency of the EM radiation required to eject an electron from a metal surface.

180.	Work function	Work function ϕ of a metal is the minimum energy required to eject an electron from a metal surface. {This energy is necessary because the electrons are held back by the attractive forces of the positive nuclei in the metal.}
181.	Stopping potential	Stopping potential V_s is the minimum negative potential required to stop the fastest electron {& thus, ALL the electrons} from arriving at the collector plate.
182.	Why do photoelectrons have a range of KE?	Electrons below the surface lose some KE on their way to the surface if and when they collide with the metallic lattice. They do not ALL experience the same loss in KE during such collisions before they are emitted. Hence the KE of the emitted electrons has a range of values.
183.	Why does the current not continue to increase beyond its "saturation value" when the p.d. is increased?	For that given light intensity, all electrons ejected by the photons are already successfully attracted to the collector even for a low positive voltage applied {i.e. none has managed to "escape" through the sides of the photo cell}; thus increasing to a higher positive V value will not increase the current (which is proportional to the number of electrons collected per unit time.)
184.	What does the sloping section of the I-V graph for negative p.d. suggest?	It denotes the fact that the electrons are emitted with a range of KE.
185.	Explain why rate of emission of electrons is much smaller than the rate of incidence of photons	Not every photon would collide with & emit an electron; most are reflected by the metal or miss hitting any electron. On the way out to the metal surface, an electron may lose some kinetic energy to ions and other electrons it encounters along the way. This energy loss prevents it from overcoming the work function & so such electrons are absorbed by the metal.
186.	Wave-particle duality	Wave-particle duality refers to the idea that light and matter {such as electrons} have both wave & particle properties. Interference and diffraction provide evidence for the wave nature of E.M. radiation. In contrast, photoelectric effect provides evidence for the particulate nature of E.M. radiation. These evidences led to the concept of the wave-particle duality of light. Electron diffraction provides evidence that matter /particles have also a wave nature & thus, have a dual nature.
187.	Define energy levels	It refers to the possible energy values an electron can have without it radiating any energy.
188.	Ionization energy	Ionisation energy is the minimum energy required to remove an unexcited electron from the atom.
189.	What are the 2 ways to excite an atom?	1) a bombarding particle (typically, an electron): only if the bombarding electron has KE $\geq \Delta E$ (difference in energy levels) 2) absorption of an incident photon: can occur only if energy of photon is exactly equal to ΔE

190.	Emission line spectrum	The emission line spectrum is a series of discrete/separate bright lines of definite wavelength/frequency on a dark background. It is produced by electron transitions within an atom from higher to lower energy levels and emitting photons.
191.	Absorption line spectrum	The absorption line spectrum is a continuous bright spectrum crossed by "dark" lines (due to some 'missing' frequencies). It is produced when white light passes through a 'cool' gas. Atoms/electrons of the cool gas absorb photons of certain frequencies from the white light source, and get excited to a higher energy level which are then quickly re-emitted uniformly in all directions.
192.	Explain how existence of electron energy levels in atoms give rise to line spectra	• Energy levels are discrete. • During a downward transition, a photon is emitted. • Frequency of photon, $f = (E_i - E_f)/h$ • Since E_i & E_f can only have discrete values, the frequencies are also discrete and so a line {rather than a continuous} spectrum is produced.
193.	Significance of line spectra	• The fact that the lines are separated/ discrete is experimental evidence for the existence of discrete or "quantized" energy levels in the atoms. • Because all isolated atoms of any particular element have the same characteristic set of energy levels, each element produces a unique line spectrum which may be used to identify the element (source of the radiation).
194.	Origin of characteristic X-rays	• A high-energy electron colliding with a target metal atom may knock an electron out of an inner shell of the target metal (thus creating a vacancy). • Another electron (of target atom) from a higher energy state then drops down to fill the vacancy, thus emitting an X-ray with a specific wavelength, which is determined only by the difference in energy between the 2 energy levels.
195.	Origin of continuous X-ray spectrum (Braking radiation/Bremsstrahlung)	• Such x-rays are produced when fast electrons are suddenly decelerated upon colliding with atoms of the metal target. • The frequencies of emitted X-rays have a continuous range because the decelerations can occur in a nearly infinite number of different ways & hence the energies lost by electrons vary from one collision to another across a continuous range of values (hence spectrum).
196.	Minimum wavelength of continuous spectrum	When a bombarding electron loses all of its kinetic energy due to a single collision with the target metal, an X-ray photon of the highest energy (and therefore minimum wavelength) is produced.
197.	Heisenberg's uncertainty principle	If a measurement of the position of a particle (typically an electron) is made with uncertainty Δx and a simultaneous

		measurement of its momentum is made with uncertainty Δp, the product of these 2 uncertainties can never be smaller than h.
198.	Infer results from Rutherford's scattering experiment	Most of the α-particles which passed through the metal foil were deflected by very small angles, • A very small proportion was deflected by more than 90°, some of these approaching 180°. • From these observations, it can be deduced that: the nucleus occupies only a small proportion of the available space {i.e. the atom is mostly empty space} • & that it is positively charged since the positively-charged α-particles are repelled/deflected.
199.	Isotope	Atoms with the same proton number, but different number of neutrons in the nuclei.
200.	Nucleon	A particle within the nucleus; can be either a proton or a neutron.
201.	Nuclide	An atom with a particular number of protons and a particular number of neutrons.
202.	Nuclear stability	The higher the binding energy per nucleon, the more stable the nucleus is.
203.	Binding energy in nucleus	Energy that must be supplied to completely separate a nucleus into its individual particles; Or, the energy released {not: lost} when a nucleus is formed from its constituent nucleons.
204.	Explain by reference to the Binding energy per nucleon graph, how, in both nuclear fusion and fission, energy is released	• The products have higher B.E. per nucleon {due to shape of BE per nucleon vs nucleon number graph}; • Hence the products are more stable. This must mean that energy is released. (The source of the energy release is the mass "loss" during these processes.)
205.	Binding energy per nucleon number	B.E. per nucleon is a measure of the stability of the nucleus.
206.	Fusion	Process where 2 light nuclei are combined to produce a heavier nucleus.
207.	Fission	Process where a heavy nucleus disintegrates into 2 lighter nuclei with the release of energy.
208.	Radioactivity	Radioactivity is the spontaneous and random decay of an unstable nucleus, with the emission of an alpha or beta particle, and usually accompanied by the emission of a gamma ray photon.
209.	Spontaneous	The decay occurs without the need of an external trigger & is not affected by factors outside the nucleus such as temperature, pressure, etc. {must give at least 1 example}

210.	Random	It cannot be predicted when the next emission will occur even though the probability of decay per unit time of a nucleus is constant. {Evidence: the fluctuations in count-rate}				
211.		Notation	Charge	Mass	Nature	Penetrating Ability
	Nature of Alpha particles	${}^{4}_{2}He$ ${}^{4}_{2}\alpha$	+2e	4u	Particle	Can be stopped by a few cm of air or a thin sheet of paper.
	Nature of Beta particles	${}^{0}_{-1}e$	-e	$\frac{1}{2000}$ u	Particle	Can be stopped by a few mm of aluminium or ≈ 1 m of air.
	Nature of Gamma particles	${}^{0}_{0}\gamma$	0	0	EM	Can be stopped by a few cm of lead or 1 m of concrete.
212.	Activity	Activity is the rate at which the nuclei are disintegrating.				
213.	Decay constant	Decay constant is defined as the probability of decay of a nucleus per unit time, or, the fraction of the total no. of undecayed nuclei which will decay per unit time.				
214.	Half-life	Half-life is defined as the average time taken for half the number {not: mass or amount} of undecayed nuclei in the sample to disintegrate.				
215.	Ionizing radiation	Ionizing radiation with sufficient energy so that during an interaction with an atom, it can remove electron from the atom, causing it to be charged or ionized.				
216.	Background radiation	Background radiation refers to radiation from sources other than the source of interest.				
217.	Direct effect of ionizing radiation on cells	Radiation interacts directly with DNA molecules, or some other cellular component critical to the survival or the cell. DNA might be broken or have sections removed.				
218.	Indirect effect of ionizing radiation on cells	Radiation interacts with other molecules, e.g. water, producing ions and radicals which can then attack cells and DNA. They can also combine to form toxic substances like H_2O_2.				