AS Physics – Revision Notes
Unit 1 – Mechanics And Radioactivity

Units And Dimensions
1. A quantity is a physical property that can be measured. A unit is a measure of the quantity.
2. Base units are used to derive all other units – called derived units. The main base quantities and units are:
   a. Length   m
   b. Mass   kg
   c. Time   s
   d. Temperature   K
   e. Electric current   A
   f. Amount of substance   mol
3. Each of the base quantities has a dimension, shown in square brackets. These are [L], [M], [T] and [I] for length, mass, time and current respectively.
4. Homogeneity is the principle that both sides of an equation should have the same units and dimensions – otherwise the equation cannot be physically correct.
5. Prefixes are used in front of units to signify a factor of a power of 10 in the answer:
   a. Giga   G 10^9
   b. Mega   M 10^6
   c. Kilo   k 10^3
   d. Milli   m 10^{-3}
   e. Micro   μ 10^{-6}
   f. Nano   n 10^{-9}
   g. Pica   p 10^{-12}
   h. Femto   f 10^{-15}

Mechanics
1. For constant velocity:

$$v = \frac{s}{t}$$

2. For constant acceleration (kinematic equations):

$$v = u + at$$
$$s = ut + \tfrac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

3. Velocities can be measure by:
   a. Using a stopwatch to measure the time for an object to travel a set distance.
   b. Using a ticker tape to place a series of dots on a strip of paper at a set frequency.
   c. Using light gates to measure the time for which a set length of card breaks an infra-red beam, and using data logging equipment to record this. Two light gates can be used to measure acceleration.
4. For displacement-time graphs, the differential represents the velocity.
5. For velocity-time graphs, the differential represents the acceleration, and the integral represents the displacement.
6. Velocities are vector quantities with both horizontal and vertical components. Taking an angle q from the horizontal and magnitude n, then:
   a. $v_h = n\cos q°$
   b. $v_v = n\sin q°$
7. For projectile motion, the following assumptions are made:
   a. There is a uniform acceleration due to gravity of g (i.e. –9.81 ms^{-2}).
   b. The acceleration is straight down (i.e. it only affects the vertical component of motion).
   c. There is no air resistance.
8. Only the vertical component is affected by gravity, so use the kinematic equations to calculate with this. For the horizontal component, the velocity will be constant, so simply use $s = ut$.
9. For one or more vector quantities acting on an object, the resultant vector is simply the sum of them all. This can be converted into a magnitude and direction:

$$v = \begin{bmatrix} v_h \\ v_v \end{bmatrix} \Rightarrow \text{magnitude}, n = \sqrt{v_h^2 + v_v^2} \Rightarrow \text{angle between } v \text{ and } v_h, q = \tan^{-1}\left(\frac{v_v}{v_h}\right)$$

10. Momentum is the product of mass and velocity:
$$p = mv$$

11. The law of the conservation of momentum says that the momentum before a collision will always be equal to the momentum after a collision (i.e. momentum is always conserved).

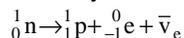12. Kinetic energy (KE) and gravitation potential energy (GPE) are calculated by:
$$KE = \tfrac{1}{2}mv^2$$
$$GPE = mgh$$

13. Collisions can be either elastic or inelastic:
    a. In elastic collisions, both momentum and kinetic energy are conserved.
    b. In inelastic collisions, the objects are deformed in some way. Momentum is conserved (it must be), but kinetic energy is not (some KE is converted into deforming the objects, and perhaps also into sound or heat).

14. Collisions can be modelled using an air-track:
    a. The air track is fed by an air pump to create a nearly frictionless surface.
    b. Two light gates are placed at intervals along the track.
    c. A puck is placed at each end of the track, with an elastic band (for elastic collisions), or a pin and blue-tak (for inelastic collisions). A card of set length is placed above each of them.
    d. They are set on a collision course – the light gates measure the velocities before, and then the velocities afterwards can be measured. By measuring the mass of the trolleys, momentum and kinetic energy can be calculated.

15. Newton's laws of motion:
    Law 1: A body will continue to exist at rest or in a state of continuous motion unless acted on by an external force.
    Law 2: The rate of change of momentum is directly proportional to the net force, and will take place in the direction of the net force – $F = ma$.
    Law 3: For every action there is an equal and opposite reaction.

16. In force calculations involving kinematics:
    a. Calculate the net (resultant) force, and resolve it.
    b. Calculate the acceleration with $F = ma$.
    c. Use the kinematic equations for calculations.

17. Weight = mass $\times$ gravitational field strength – $W = mg$.

18. When drawing force diagrams, always show the forces as arrows starting from where they originate. Weight will always originate at an object's centre of mass.

19. Work = force $\times$ distance moved in direction of force – $WD = Fd$.

20. Moment of a force about a pivot = force $\times$ perpendicular distance from pivot – $Moment = Fd$.

21. The principle of moments states that the sum of all the clockwise moments acting on a pivot must equal the sum of all the anticlockwise moments acting on the pivot for the system to be in dynamic equilibrium.

22. Impulse is a change in momentum – $Fdt = dmv$ or $Impulse = Ft$.

23. On a force-time graph, the area under the graph represents the impulse. For the same impulse, if the time for which the force is applied is short, then a large force must be applied, whereas if the time for which the force is applied is much longer, then a much smaller force will be applied.

Radioactivity

1. Radioactive decay is a spontaneous, random process.

2. Background radiation is present at all times, and is the same in all directions (1 or 2 counts per second). The main sources are:
    a. Radioactive decay of rocks in the Earth's crust.
    b. Cosmic radiation (from the Big Bang).
    c. Materials in buildings that produce radon gases.

3. Radiation can be detected using a Geiger counter, whereby radiation enters a Geiger-Müller tube, ionising the gas particles inside which are attracted across an electric field to give a pulse of current, that is translated into a 'click'.

4. Alpha radiation is in the form of α particles:
    a. These are high-speed helium nuclei – $^{4}_{2}\text{He}^{2+}$.

    b. They are very ionising, as they readily interact, but not have a very weak penetration. Therefore they are most dangerous when ingested.

    c. Alpha radiation is used in smoke detectors – a stream of α particles carry a current over a short space of air. In the presence of smoke this is blocked off, so the current stops and an alarm will sound.

    d. Alpha radiation can be stopped by a sheet of paper.

5. Beta radiation is in the form of β particles:

    a. These are high-speed electrons – $_{-1}^{0}e$.

    b. Beta radiation is produced in the decay of a neutron into a proton:

$$_{0}^{1}n \rightarrow _{1}^{1}p + _{-1}^{0}e + \overline{v}_e$$

    c. They are much less massive than α particles, and less ionising. Beta radiation is more penetrating however.

    d. Beta radiation is used in paper mills for thickness maintenance – a stream of β particles are passed through the paper and monitored. A change in the count of beta particles causes the rollers to move and make the paper thicker or thinner.

    e. Beta radiation can be stopped by a thin sheet of aluminium.

6. Gamma radiation is in the form of γ rays:

    a. These are high frequency electromagnetic waves – $_{0}^{0}g$.

    b. Gamma radiation is produced when the nucleus of an atom rearranges itself – normally after the release of an α or β particle, but metastable isotopes will emit only γ rays.

    c. They are weakly ionising, but extremely penetrating.

    d. Gamma radiation has uses in diagnostic medicine (as tracers).

    e. Gamma radiation can be reduced to 'safe' levels by several centimetres of lead.

7. The half-life of a radioisotope is the time taken for half of the atoms in a sample to decay into another isotope (i.e. the time taken for the activity to drop by half). Where λ is the decay constant:
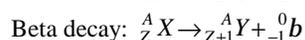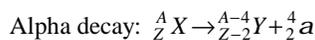
$$l T_{\frac{1}{2}} = \ln 2$$

8. For all radioactive emissions:

$$\frac{dN}{dt} = -lN$$

Hence $N = N_0 e^{-lt}$

9. One Becquerel (Bq) is equal to an activity of one disintegration per second.

10. Radioactive decays can be shown by nuclear equations, where X is the parent, and Y is the daughter:

$$\text{Alpha decay: } _{Z}^{A}X \rightarrow _{Z-2}^{A-4}Y + _{2}^{4}a$$

$$\text{Beta decay: } _{Z}^{A}X \rightarrow _{Z+1}^{A}Y + _{-1}^{0}b$$

11. Rutherford's gold foil experiment disproved Thomson's plum pudding model of the atom:

    a. Alpha particles were fired at a thin sheet of gold foil. A moveable alpha detector detected the frequency of particles at different positions.

    b. Most of the alpha particles went straight through, showing that the atom is mostly empty space.

    c. Some of the alpha particles were deflected, and a few even completely recoiled showing that there is a very concentrated positive charge in the nucleus of the atom.

12. An atom has a diameter of approximately 10^{-10}m, and that of the nucleus is approximately 10^{-14}m.

13. The pre-Rutherford concept of the atom was that of an r-slope – i.e. there would be many small deflections, and some would go straight through. The post-Rutherford concept on the other hand was that of a $\frac{1}{r}$ -slope – i.e. most would be undeflected, there would be some large deflections, and a few completely recoiling.

14. When electrons are fired at atomic nuclei, the collisions turn out to be inelastic. These are called deep inelastic collisions, and provide evidence for the existence of quarks.