Capacitors

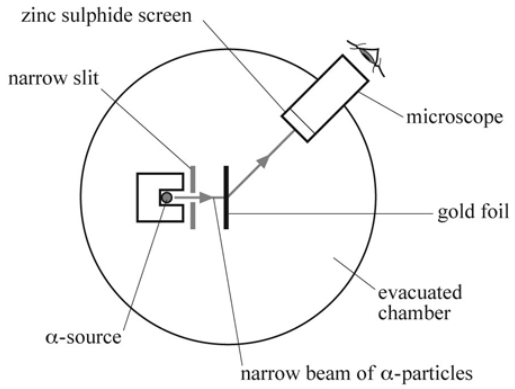
(m) **Describe the uses of capacitors for the storage of energy in applications such as flash photography, lasers used in nuclear fusion and as back-up power supplies for computers**

- When capacitor is charging, work is done by the battery to move charge on to the capacitor
- Energy is transferred from the power supply and is stored as electrical potential energy in the capacitor
- Camera flash:
    - Capacitor takes a few seconds to charge when connected to the battery
    - Energy is discharged very quickly
    - Flash-bulb gives short intense flash
- Computer back-up power supply:
    - Maintains operation of the clock and calendar while mains supply is disconnected
    - Energy is discharged very slowly

Nuclear Physics

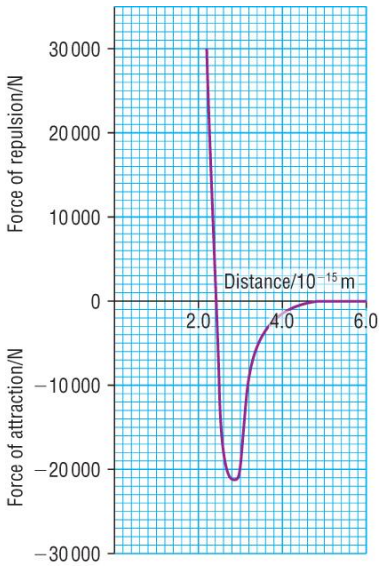
5.3.1

(a) **Describe qualitatively the α-particle scattering experiment and the evidence this provides for the existence, charge and small size of the nucleus**



- Vast majority passed through with little or no deviation from original path
- Very few deflected through angle greater the 90^o
- Small number deviated through angle of more than 10^o
- Conclusions:
    - Majority of the mass of an atom is concentrated in a very small volume at centre of atom. (most alpha particles would therefore pass through foil undeviated)
    - Nucleus is positively charged, alpha particles experience a repulsive force causing them to deviate
    - Alpha particles that pass very close to nucleus will experience large enough force to deviate them through angle larger than 90^o
    - Very few were deviated through large angle, so nucleus is very small and atom is mainly empty space
    - Atoms are neutral, so must contain negative particles

(d) Describe the properties of the strong nuclear force



- Attractive force between adjacent nucleons
- Becomes repulsive at very-short distances, otherwise nucleons would collapse in on themselves
- Does not act beyond distances of a few femtometres,(only within nucleus)
- Independent of charge
- Greater than electrostatic force between protons

5.3.2

(g) **Describe how there is a weak interaction between quarks and that this is responsible for β decay**

- Relatively weak force, much less strong than the strong nuclear force
- Very small range - 10^{-17} m
- Acts on leptons and hadrons
- Strong force could only explain alpha decay but not beta
- Weak interaction is responsible for β decay

5.3.3

(a) **Describe the spontaneous and random nature of radioactive decay of unstable nuclei**

- Random nature: It is impossible to predict when any particular nucleus will decay
- Spontaneous: No known cause of emission

(b) **Describe the nature, penetration and range of alpha particles, beta particles and gamma rays**

- Alpha:
  - Nature: Helium Nucleus
  - Range: few cm of air
- Beta:
  - Nature: electron

    - Range: about 30-40cm of air
- Gamma:
    - Nature: short wavelength electromagnetic radiation
    - Range: several km of air

(h) **Compare and contrast decay of radioactive nuclei and decay of charge on a capacitor in C-R circuit**

- Similarities:
    - The number of active nuclei and charge both decay exponentially with time/ have a constant ratio property for a given interval of time.
    - Decay equations are in the form $N = N_0e^{-\lambda t}$ and $Q = Q_0e^{-\frac{t}{CR}}$
- Differences
    - With charge, you can predict *exactly* the charge left after a certain time.
    - The decay of radioactive nuclei is random and spontaneous.
    - Curve of decay of nuclei is irregular, whereas discharge curve is smooth

(-i) **Describe the use of radioactive isotopes in smoke alarms**

- Americium-241 is an alpha emitter
- Alpha particles pass between two electrodes in an ionisation chamber open to air in the room
- Ionisation of air produces small, constant current between electrodes
- If air contains higher concentration of smoke, smoke particles absorb alpha particles
- So current is reduced, and audible alarm is triggered

(j) **Describe the technique of radioactive dating (i.e carbon dating)**

- Living organisms take up ^{14}C via CO_2
- When they die, ^{14}C is no longer taken in
- The ^{14}C decays but ^{12}C does not
- Ratio of ^{12}C: ^{14}C falls as time passes and this can be used to estimate how long ago a organism died
- Technique cannot be used for:
    - Meteorites and other materials found elsewhere in solar system due to no living organisms being present (No carbon)
    - Samples more than 100 000 years old; low count rate
    - Samples less than a 100 years old; too little difference in count rate

5.3.4

(e) & (f) **Describe the process of induced nuclear fission & describe and explain the process of nuclear chain reaction**

- Slow neutrons are fired at U-235 nucleus which absorbs it
- Nucleus becomes very unstable and quickly disintegrates into two smaller nuclei and a few neutrons
- If these neutrons are absorbed by other U-235 nuclei, these too may become unstable and undergo fission, thereby releasing more neutrons
- This is a chain reaction which is accelerating

(g) **Describe the basic construction of a fission reactor and explain the role of the fuel rods, control rods and the moderator**

- Fuel rods are the source of energy
- Moderator (graphite): Slows down neutron but does not absorb them, slow neutrons are more readily absorbed by U-235 nucleus
- Control rods (boron):
    - Absorbs neutrons
    - Used to control rate of fission reaction
    - Rods are lowered in to reactor to derease rate or raised to increase rate
- Coolant:
    - Gas or liquid
    - Removes heat from fuel rods and transfers it to water which produces high pressure steam to drive turbines

(h) **Describe the use of nuclear fission as an energy source**

- Turbines at power station transform thermal energy into electrical energy
- Generator supplies the electrical energy to the national grid

(-i) **Describe the peaceful and destructive uses of nuclear fission**

- Peaceful:
    - Generation of electrical power for industrial and domestic use
    - Prepare radioactive nuclide not naturally found, for use as tracers or treatment
- Destructive:
    - Fission bomb used to destroy cities

(j) **Describe the environmental effects of nuclear waste**

- Fission bombs in atmosphere cause nuclear fallout
- Movement of air causes circulation of radioactive material

- Eventually falls on the ground, settling on crops and vegetation
- So enters food chain, alpha and beta emitters can cause damage to interior organs

(k) **Describe the process of nuclear fusion**

- H nuclei fused together to form helium
- Helium is more stable ∴ energy is released (binding energy)

(l) **Describe the conditions in the core of the stars that make fusion possible**

- Temperatures of 10^9K and Extreme pressures
- Positive nuclei repel each other
- At higher temperatures nuclei move faster, ∴ greater kinetic energy
- Nuclei will have enough energy to overcome coulomb force and combine with each other due to the strong nuclear force
- High pressures cause nuclei to come closer together increasing the chance of combining