

# Higher Physics

## Particles & Waves Unit

### Book 1 of 2

## St Andrew's Academy

Name: \_\_\_\_\_

This booklet has homework exercises, notes and space for completing worked examples on the Particles & Waves Unit and covers the following key areas:

1. Orders of magnitude
2. The standard model
3. Electric fields
4. Potential Difference
5. Deflection of Particles
6. Radioactive Decay
7. Decay Examples & Fission

## DATA SHEET

### COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	$c$	$3.00 \times 10^8 \text{ m s}^{-1}$	Planck's constant	$h$	$6.63 \times 10^{-34} \text{ J s}$
Magnitude of the charge on an electron	$e$	$1.60 \times 10^{-19} \text{ C}$	Mass of electron	$m_e$	$9.11 \times 10^{-31} \text{ kg}$
Universal Constant of Gravitation	$G$	$6.67 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$	Mass of neutron	$m_n$	$1.675 \times 10^{-27} \text{ kg}$
Gravitational acceleration on Earth	$g$	$9.8 \text{ m s}^{-2}$	Mass of proton	$m_p$	$1.673 \times 10^{-27} \text{ kg}$
Hubble's constant	$H_0$	$2.3 \times 10^{-18} \text{ s}^{-1}$			

### REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2.42	Water	1.33
Crown glass	1.50	Air	1.00

### SPECTRAL LINES

Element	Wavelength/nm	Colour	Element	Wavelength/nm	Colour
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet	Lasers		
	397	Ultraviolet	Element	Wavelength/nm	Colour
	389	Ultraviolet	Carbon dioxide	9550 } 10590 }	Infrared
Sodium	589	Yellow	Helium-neon	633	Red

### PROPERTIES OF SELECTED MATERIALS

Substance	Density/kg m <sup>-3</sup>	Melting Point/K	Boiling Point/K
Aluminium	$2.70 \times 10^3$	933	2623
Copper	$8.96 \times 10^3$	1357	2853
Ice	$9.20 \times 10^2$	273	...
Sea Water	$1.02 \times 10^3$	264	377
Water	$1.00 \times 10^3$	273	373
Air	1.29	...	...
Hydrogen	$9.0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of  $1.01 \times 10^5 \text{ Pa}$ .

## Relationships required for Physics Higher

$$d = \bar{v}t$$

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

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$s = \frac{1}{2}(u + v)t$$

$$W = mg$$

$$F = ma$$

$$E_w = Fd$$

$$E_p = mgh$$

$$E_k = \frac{1}{2}mv^2$$

$$p = \frac{E}{t}$$

$$p = mv$$

$$Ft = mv - mu$$

$$F = G \frac{m_1 m_2}{r^2}$$

$$t' = \frac{t}{\sqrt{1 - (v/c)^2}}$$

$$l' = l \sqrt{1 - (v/c)^2}$$

$$f_o = f_s \left( \frac{v}{v \pm v_s} \right)$$

$$z = \frac{\lambda_{\text{observed}} - \lambda_{\text{rest}}}{\lambda_{\text{rest}}}$$

$$z = \frac{v}{c}$$

$$v = H_0 d$$

$$W = QV$$

$$E = mc^2$$

$$E = hf$$

$$E_k = hf - hf_0$$

$$E_2 - E_1 = hf$$

$$T = \frac{1}{f}$$

$$v = f\lambda$$

$$d \sin \theta = m\lambda$$

$$n = \frac{\sin \theta_1}{\sin \theta_2}$$

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

$$\sin \theta_c = \frac{1}{n}$$

$$I = \frac{k}{d^2}$$

$$I = \frac{P}{A}$$

$$V_{\text{peak}} = \sqrt{2}V_{\text{rms}}$$

$$I_{\text{peak}} = \sqrt{2}I_{\text{rms}}$$

$$Q = It$$

$$V = IR$$

$$P = IV = I^2 R = \frac{V^2}{R}$$

$$R_T = R_1 + R_2 + \dots$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

$$E = V + Ir$$

$$V_1 = \left( \frac{R_1}{R_1 + R_2} \right) V_s$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

$$C = \frac{Q}{V}$$

$$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2} \frac{Q^2}{C}$$

$$\text{path difference} = m\lambda \quad \text{or} \quad \left(m + \frac{1}{2}\right)\lambda \quad \text{where } m = 0, 1, 2, \dots$$

$$\text{random uncertainty} = \frac{\text{max. value} - \text{min. value}}{\text{number of values}}$$

## Additional Relationships

### Circle

$$\text{circumference} = 2\pi r$$

$$\text{area} = \pi r^2$$

### Sphere

$$\text{area} = 4\pi r^2$$

$$\text{volume} = \frac{4}{3}\pi r^3$$

### Trigonometry

$$\sin \theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\cos \theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan \theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$\sin^2 \theta + \cos^2 \theta = 1$$

### Electron Arrangements of Elements

Group 1    Group 2  
(1)

1	H	1
2	He	2
3	Li	Be
4	Be	B
5	B	C
6	C	N
7	N	O
8	O	F
9	F	Ne
10	Ne	Na
11	Na	Mg
12	Mg	Al
13	Al	Si
14	Si	P
15	P	S
16	S	Cl
17	Cl	Ar
18	Ar	K
19	K	Ca
20	Ca	Sc
21	Sc	Ti
22	Ti	V
23	V	Cr
24	Cr	Mn
25	Mn	Fe
26	Fe	Co
27	Co	Ni
28	Ni	Cu
29	Cu	Zn
30	Zn	Ga
31	Ga	Ge
32	Ge	As
33	As	Sb
34	Sb	Te
35	Te	I
36	I	Xe
37	Xe	Rb
38	Rb	Sr
39	Sr	Y
40	Y	Zr
41	Zr	Nb
42	Nb	Mo
43	Mo	Tc
44	Tc	Ru
45	Ru	Rh
46	Rh	Pd
47	Pd	Ag
48	Ag	Cd
49	Cd	In
50	In	Sn
51	Sn	Pb
52	Pb	Bi
53	Bi	Po
54	Po	At
55	At	Rn
56	Rn	Fr
57	Fr	Ra
58	Ra	Ac
59	Ac	Th
60	Th	Pa
61	Pa	U
62	U	Np
63	Np	Pu
64	Pu	Am
65	Am	Cm
66	Cm	Bk
67	Bk	Cf
68	Cf	Es
69	Es	Fm
70	Fm	Md
71	Md	No
72	No	Lr
73	Lr	

Atomic number
Symbol
Electron arrangement
Name

#### Key

#### Transition Elements

21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn
2.8,18,9,2	2.8,18,16,9,2	2.8,18,16,10,2	2.8,18,16,12,1	2.8,18,16,13,1	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,14,2	2.8,18,16,14,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2
(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd
2.8,18,9,2	2.8,18,16,9,2	2.8,18,16,10,2	2.8,18,16,12,1	2.8,18,16,13,1	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,14,2	2.8,18,16,14,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2
57	La	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg
2.8,18,16,9,2	2.8,18,16,9,2	2.8,18,16,10,2	2.8,18,16,12,1	2.8,18,16,13,1	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,13,2	2.8,18,16,14,2	2.8,18,16,14,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2	2.8,18,16,15,2
89	Ac	104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt	110	Ds	111	Rg	112	Cn
2.8,18,32,18,9,2	2.8,18,32,18,9,2	2.8,18,32,32,10,2	2.8,18,32,32,11,2	2.8,18,32,32,11,2	2.8,18,32,32,12,2	2.8,18,32,32,12,2	2.8,18,32,32,13,2	2.8,18,32,32,13,2	2.8,18,32,32,14,2	2.8,18,32,32,14,2	2.8,18,32,32,15,2	2.8,18,32,32,15,2	2.8,18,32,32,17,1	2.8,18,32,32,17,1	2.8,18,32,32,18,1	2.8,18,32,32,18,1	2.8,18,32,32,18,1	2.8,18,32,32,18,2	2.8,18,32,32,18,2
Actinium	Rutherfordium	Dubnium	Seaborgium	Bohrium	Hassium	Mtnerium	Darmstadtium	Roentgenium	Copernicium	Flerovium	Livermorium	Niuhonium	Darmstadtium	Roentgenium	Copernicium	Flerovium	Livermorium	Niuhonium	Darmstadtium

5	B	6	C	7	N	8	O	9	F	10	Ne
2,3	2,3	2,4	2,5	2,5	2,6	2,6	2,7	2,7	2,8	2,8	2,8
(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
13	B	14	C	15	N	16	O	17	F	18	Ne
2,8,3	2,8,3	2,8,4	2,8,5	2,8,5	2,8,6	2,8,6	2,8,7	2,8,7	2,8,8	2,8,8	2,8,8
Aluminium	Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon	Sodium	Magnesium	Aluminium	Silicon	Phosphorus
31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr
2,8,18,3	2,8,18,18,3	2,8,18,4	2,8,18,5	2,8,18,5	2,8,18,6	2,8,18,6	2,8,18,7	2,8,18,7	2,8,18,8	2,8,18,8	2,8,18,8
Gallium	Germanium	Arsenic	Selenium	Bromine	Krypton	Rubidium	Strontium	Yttrium	Zirconium	Niobium	Molybdenum
49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe
2,8,18,18,3	2,8,18,18,4	2,8,18,18,4	2,8,18,18,5	2,8,18,18,5	2,8,18,18,6	2,8,18,18,6	2,8,18,18,7	2,8,18,18,7	2,8,18,18,8	2,8,18,18,8	2,8,18,18,8
Indium	Thallium	Lead	Bismuth	Polonium	Astatine	Radon	Francium	Radium	Actinium	Thorium	Protactinium
81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn
2,8,18,32,18,3	2,8,18,32,18,4	2,8,18,32,18,5	2,8,18,32,18,5	2,8,18,32,18,6	2,8,18,32,18,6	2,8,18,32,18,7	2,8,18,32,18,7	2,8,18,32,18,8	2,8,18,32,18,8	2,8,18,32,18,8	2,8,18,32,18,8
Thallium	Lead	Bismuth	Polonium	Astatine	Radon	Francium	Radium	Actinium	Thorium	Protactinium	Uranium

#### Lanthanides

57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu
2.8,18,18,9,2	2.8,18,18,9,2	2.8,18,21,8,2	2.8,18,21,8,2	2.8,18,22,8,2	2.8,18,22,8,2	2.8,18,23,8,2	2.8,18,23,8,2	2.8,18,23,8,2	2.8,18,24,8,2	2.8,18,24,8,2	2.8,18,25,8,2	2.8,18,25,8,2	2.8,18,25,8,2	2.8,18,27,8,2	2.8,18,27,8,2	2.8,18,28,8,2	2.8,18,29,8,2	2.8,18,30,8,2	2.8,18,30,8,2	2.8,18,31,8,2	2.8,18,31,8,2	2.8,18,31,8,2	2.8,18,32,8,2	2.8,18,32,8,2	2.8,18,32,8,2	2.8,18,32,8,2	2.8,18,32,9,2	2.8,18,32,9,2	
Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Hoium	Erbium	Thulium	Ytterbium	Lutetium	Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Hoium	Erbium	Thulium	Ytterbium	Lutetium
89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr
2.8,18,32,18,9,2	2.8,18,32,18,9,2	2.8,18,32,20,9,2	2.8,18,32,20,9,2	2.8,18,32,21,9,2	2.8,18,32,22,9,2	2.8,18,32,22,9,2	2.8,18,32,22,9,2	2.8,18,32,22,9,2	2.8,18,32,22,9,2	2.8,18,32,24,8,2	2.8,18,32,24,8,2	2.8,18,32,25,8,2	2.8,18,32,25,8,2	2.8,18,32,25,8,2	2.8,18,32,25,8,2	2.8,18,32,27,8,2	2.8,18,32,27,8,2	2.8,18,32,28,8,2	2.8,18,32,28,8,2	2.8,18,32,29,8,2	2.8,18,32,29,8,2	2.8,18,32,30,8,2	2.8,18,32,30,8,2	2.8,18,32,31,8,2	2.8,18,32,31,8,2	2.8,18,32,32,8,2	2.8,18,32,32,8,2	2.8,18,32,32,9,2	
Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Hoium	Erbium	Thulium	Ytterbium	Lutetium	

#### Actinides

# 1. Orders of magnitude

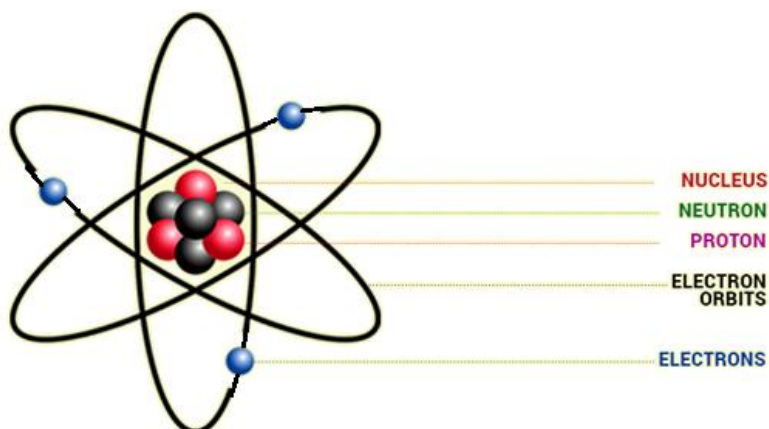
## Learning Outcomes:

- Describe the standard model of the atom
- The orders of magnitude – the range of orders of magnitude of length from the very small (sub-nuclear) to the very large (distance to furthest known celestial objects).

## The atom:

Ernest Rutherford carried out a series of experiments investigating the shape of the atom. Rutherford's conclusions:

- (a) The atom was mainly empty space.
- (b) At the centre of the atom there was a small, highly dense, positively charged nucleus.



This model of the atom is not to scale. If the atom was the size of a football stadium then the nucleus would be the size of a pea.

Where protons are positive, electrons are negative and neutrons have no charge.

The relative masses and charges of the proton, neutron and electron are:

Particle	Mass	Charge	Symbol
Proton	1	+1	${}^1_1\text{p}$
Neutron	1	0	${}^1_0\text{n}$
Electron	1/1840	-1	${}^0_{-1}\text{e}$

### Orders of magnitude:

It is important to understand the scale of sizes scientists have studied. In physics, we look at the very large and the very small. Examples of different objects and their sizes are listed below:

Smaller than a human, eg:

<b>Particle or object</b>	Neutrino	Proton	Hydrogen atom	Dust	Human being
<b>Order of magnitude</b>	$\sim 10^{-24}$ m	$10^{-15}$ m	$10^{-10}$ m	$10^{-4}$ m	$10^0$ m

Larger than a human, eg:

<b>Particle or object</b>	Earth	Sun	Solar system	Nearest star	Galaxy
<b>Order of magnitude</b>	$10^7$ m	$10^9$ m	$10^{13}$ m	$10^{17}$ m	$10^{21}$ m

- One order of magnitude is equal to a difference of 10 times.
- For example, if a distance is 1000 times longer than another (km compared to m), we say it is 3 orders of magnitude bigger ( $10 \times 10 \times 10$ ).

### Past Paper examples (multi-choice, paper 2 and open-ended):

#### Revised Higher 2012:

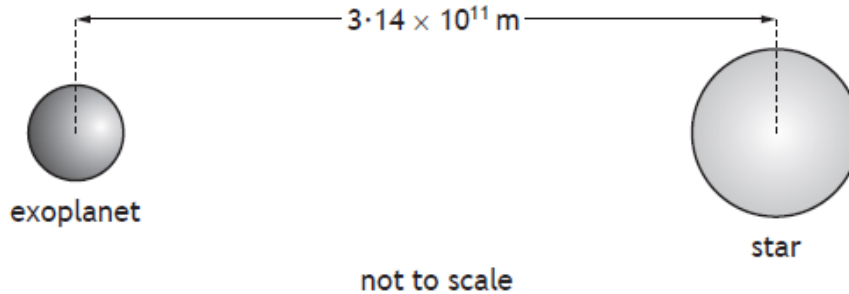
15. Which of the following lists the particles in order of size from smallest to largest?

- A helium nucleus; electron; proton
- B helium nucleus; proton; electron
- C proton; helium nucleus, electron
- D electron; helium nucleus, proton
- E electron; proton; helium nucleus

**CfE Higher 2017:**

5. Planets outside our solar system are called exoplanets.

An exoplanet of mass  $5.69 \times 10^{27}$  kg orbits a star of mass  $3.83 \times 10^{30}$  kg.



- (a) (i) Compare the mass of the star with the mass of the exoplanet in terms of orders of magnitude.

2

**Example - CfE Higher 2015:**

In the earlier part of this question you are asked to show the mass of the Higgs Boson.

- (i) Show that the mass of the Higgs boson is  $2.2 \times 10^{-25}$  kg.

This will be covered later. The next part of the question is an order of magnitude question and was answered very poorly by students during the exam.

- (ii) Compare the mass of the Higgs boson with the mass of a proton in terms of orders of magnitude.

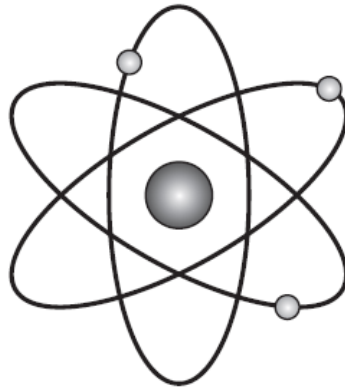
2



**2013 Revised Higher:**

*Marks*

27. A science textbook contains the following diagram of an atom.



Use your knowledge of physics to comment on this diagram.

**(3)**

## 2. The Standard Model:

### Learning Outcomes:

- The standard model of fundamental particles and interactions.
- Evidence for sub-nuclear particles and the existence of antimatter.
- Fermions, the matter particles, consist of quarks (six types) and leptons (electron, muon and tau together with their neutrinos).
- Hadrons are composite particles made of quarks.
- Baryons are made of three quarks, and mesons are made of two quarks.
- The force-mediating particles are bosons (photons, W- and Z-bosons, and gluons).
- Description of beta decay as the first evidence for the neutrino.

### What happens when we break everything (all matter) down?:

- Everything, all **matter**, is made up of **elements**
- Elements are made up of **atoms**
- Atoms have a central **nucleus**
- The nucleus has **protons** and **neutrons**
  
- Can we break protons and neutrons down any further?
- YES!

### What is the Standard Model of Fundamental Particles?

- Physicists have developed a theory called **The Standard Model** that explains what the world is and what holds it together.
- It is a simple and comprehensive theory that explains all the hundreds of particles and complex interactions with only:
  - **6 quarks**
  - **6 leptons** (*The best-known lepton is the electron. We will talk about leptons in just a few pages.*)
  - **Force carrier particles** (*like the photon. These are known as bosons and we will talk about these particles later.*)
- All the known matter particles are made up of quarks and leptons (**known as fermions**), and they interact with each other by exchanging force carrier particles.

### What is antimatter?:

- For every type of matter particle we've found, there also exists a corresponding **antimatter** particle, or **antiparticle**.
- Antiparticles look and behave just like their corresponding matter particles, except they have **opposite charges**.
- For instance, a proton is electrically positive whereas an antiproton is electrically negative.
  
- Many sub-atomic particles have been isolated and studied in the particle accelerators.
- Fermions have an antiparticle, which has the same mass but the opposite charge, eg.  
Particle: electron( $e$ )                      >      charge (-1)  
Anti-particle: positron( $\bar{e}$ )              >      charge (+1)

The group of anti-particles are known as anti-matter.

### Multi-choice questions:

#### 2013 Revised Higher:

10. Three students each make a statement about antiparticles.

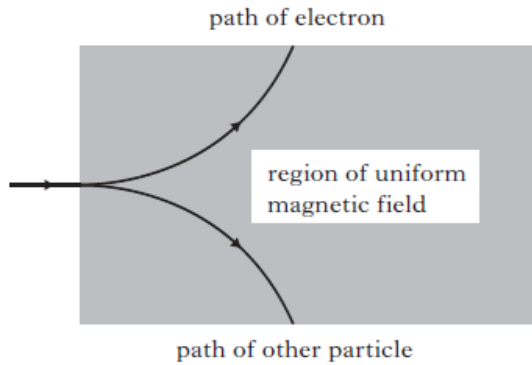
- I An antiparticle has the same mass as its equivalent particle.
- II An antiparticle has the same charge as its equivalent particle.
- III Every elementary particle has a corresponding antiparticle.

Which of the statements is/are correct?

- A I only
- B II only
- C I and III only
- D II and III only
- E I, II and III

**2012 Revised Higher:**

16. An electron and another particle of identical mass pass through a uniform magnetic field. Their paths are shown in the diagram.



This observation provides evidence for the existence of

- A neutrinos
- B antimatter
- C quarks
- D protons
- E force mediating particles.

**What are the fermions?:**

- The fermions (quarks and leptons) are split into their particles and anti-particles.

The 6 **quarks** quite literally have strange names:

- Up and down
- Strange and charm
- Top and bottom

The 6 **leptons** are made up of:

- Electron and electron neutrino
- Muon and muon neutrino
- Tau and tau neutrino

**CfE Specimen Paper:**

11. A student makes the following statements about an electron.

- I An electron is a boson.
- II An electron is a lepton.
- III An electron is a fermion.

Which of these statements is/are correct?

- A I only
- B II only
- C III only
- D I and II only
- E II and III only

### What holds them all together?

- There are four fundamental forces that allow the particles to interact with each other:
  1. The electromagnetic force
  2. Strong nuclear force
  3. Weak nuclear force
  4. Gravity

### What are the force carrier particles (also known as bosons)?

The force carriers describe the ways in which the particles interact with each other. These are known as **bosons** and there are four of them:

- Photon
- Z boson
- W boson
- gluon

### The Strong Nuclear Force:

- The strong nuclear force acts inside the nucleus to keep the protons from flying apart.
- The electromagnetic force (like charges repel) means that protons should repel one another.
- The nuclear force acts against the electromagnetic force and they balance each other out.
- This allows the protons to stay inside the nucleus.
- The gluon force works in a range of approximately  $\times 10^{-14}$  m

A table of the force carrier particles, their associated forces and uses is listed below:

<b>Boson</b>	<b>Force</b>	<b>Use</b>
Gluon	Strong	Holding nucleus together
W and Z	Weak	Fermion decay
Photon	Electromagnetic	Causes like charges to repel and opposite charges to attract

## The Standard Model of Fundamental Particles and Interactions:

The standard model was developed in the early 1970's in an attempt to tidy up the number of particles being discovered and the phenomena that physicists were observing.

At present physicists believe that there are 12 fundamental mass particles (called *Fermions*) split into two groups:

*quarks (and antiquarks)*

*leptons (and antileptons)*

There are also 4 force carrying particles called *bosons*.

The fundamental mass particles interact with each other by exchanging force particles.

### Elementary Particles

Quarks	$u$ up	$c$ charm	$t$ top	$g$ gluon	Force Carriers
	$d$ down	$s$ strange	$b$ bottom	$\gamma$ photon	
Leptons	$\nu_e$ electron neutrino	$\nu_\mu$ muon neutrino	$\nu_\tau$ tau neutrino	$W$ $W$ boson	
	$e$ electron	$\mu$ muon	$\tau$ tau	$Z$ $Z$ boson	

### Hadrons:

Quarks can combine together to form hadrons:

- **Baryons** are made up of **3 quarks**
- **Mesons** are made of **2 quarks** (a quark and an anti- quark).

Quarks have fractional charges so combine to give hadrons with an overall charge.

Each quark has a partner with the same size but opposite charge. These are called anti-quarks.

### Revised Specimen Paper:

16. Which row in the table shows an example of a hadron, lepton and boson?

	<i>Hadron</i>	<i>Lepton</i>	<i>Boson</i>
A	neutron	photon	electron
B	electron	neutron	photon
C	photon	electron	neutron
D	neutron	electron	photon
E	electron	photon	neutron

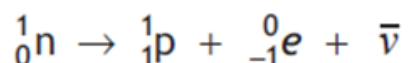
### Examples of Baryons and Mesons:

(you don't need to know these just that 2 quarks means Mesons and 3 means Baryons)

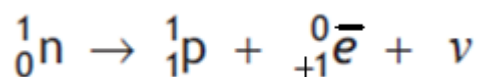
Name	Baryon/ Meson	Combination of quarks	Combination of charges	Overall charge
Proton	Baryon	2u + 1d	+2/3 +2/3 -1/3	+1
Neutron	Baryon	2d + 1u	-1/3 -1/3 +2/3	0
Lambda	Baryon	1u + 1d + 1s	+2/3 -1/3 -1/3	0
Sigma	Baryon	2u + 1s	+2/3 +2/3 -1/3	+1
Delta	Baryon	3u	+2/3 +2/3 +2/3	+2
Pion	Meson	1u + 1ad	+2/3 +1/3	+1
Kaon	Meson	1u + 1as	+2/3 +1/3	+1

### Beta Decay:

- In nuclear physics, beta decay ( $\beta$  decay) is a type of radioactive decay in which a neutron is transformed into a proton (or vice versa) inside an atomic nucleus.
- As a result, the nucleus emits a detectable beta particle – which is an electron or an anti-electron (positron).
- Beta decay is mediated by the weak force. There are two types of beta decay:
- **Beta minus ( $\beta^-$ ):** produces an electron and an antineutrino

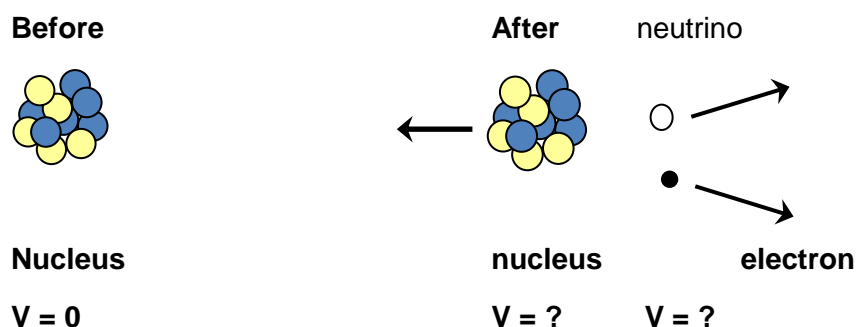


- **Beta plus ( $\beta^+$ ):** produces an anti-electron (positron) and a neutrino



## Neutrinos:

Neutrinos were 'discovered' in the 1930s during the study of ***beta decay***. The law of the conservation of momentum was not being observed by the particles:



Momentum before and after the decay did not match up so the hypothesis was that another particle, which couldn't be seen, must be moving to the right.

This particle was named the *neutrino* and was not detected by experiment until 1956. It has a very small mass and weak interaction with other particles.

## Example – 2014 Revised Higher

*MAAT*

26. Physicists study subatomic particles using particle accelerators.

(a) Pions are subatomic particles made up of two quarks.

There are three types of pion:

$\pi^+$  particles which have a charge of +1;  
 $\pi^-$  particles which have a charge of -1;  
and  $\pi^0$  particles which have a zero charge.

The  $\pi^+$  particle is made up of an up quark and an anti-down quark.

(i) Is a pion classed as a baryon or a meson?

Justify your answer.

1

(ii) The charge on an up quark is  $+\frac{2}{3}$ .

Determine the charge on an anti-down quark.

1

(iii) The  $\pi^-$  particle is the antiparticle of the  $\pi^+$  particle.

State the names of the quarks that make up a  $\pi^-$  particle.

1



## Example 2 – Revised Specimen Paper:

15. The letters X, Y and Z represent the missing words from the following passage.

*There are four fundamental forces.*

*Gravity and the electromagnetic force act over a ...X... range.*

*The strong and weak force act over a ...Y... range.*

*The ...Z... force is responsible for beta decay.*

Which row in the table identifies the missing words represented by the letters X, Y and Z?

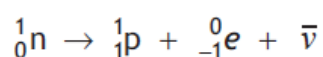
	X	Y	Z
A	short	long	strong
B	long	short	strong
C	long	short	weak
D	long	long	electromagnetic
E	short	long	weak

## Paper 2 Examples:

### CfE Specimen Paper:

7. Protons and neutrons are composed of combinations of up and down quarks. Up quarks have a charge of  $+\frac{2}{3}e$  while down quarks have a charge of  $-\frac{1}{3}e$ .

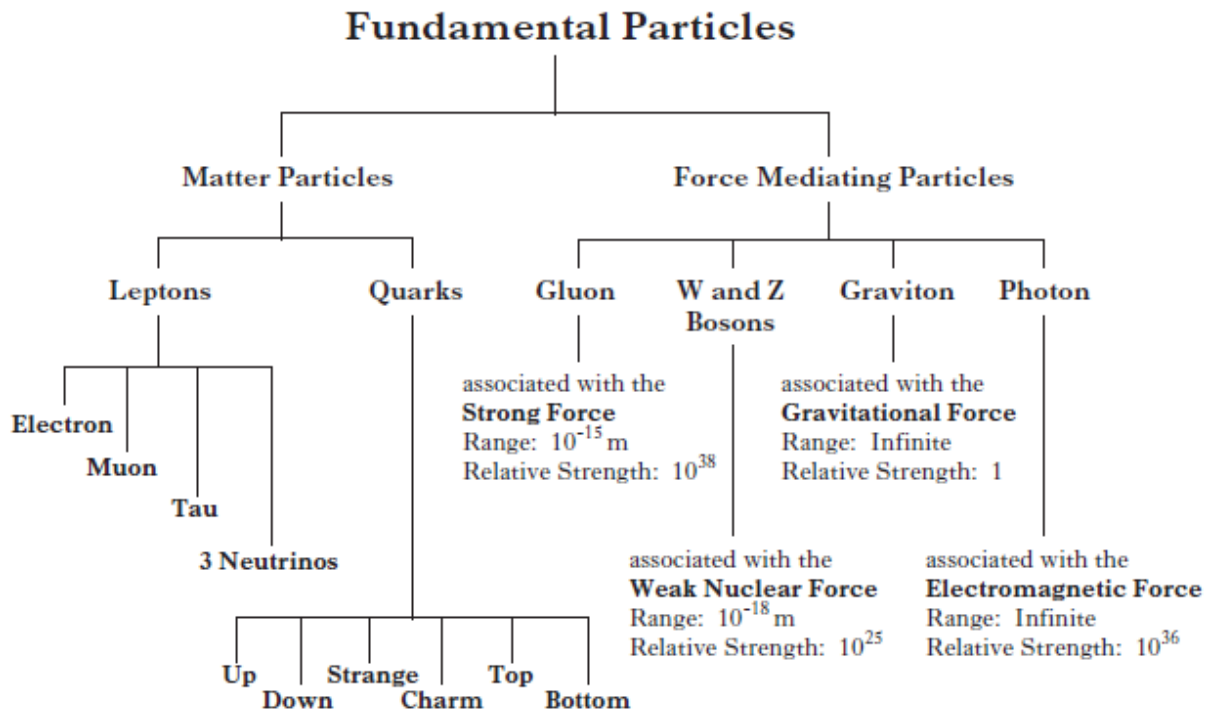
- (a) (i) Determine the combination of up and down quarks that makes up:
- (A) a proton; 1
- (B) a neutron. 1
- (ii) Name the boson that is the mediating particle for the strong force. 1
- (b) A neutron decays into a proton, an electron and an antineutrino.



Name of this type of decay. 1

**2012 Revised Higher:**

26. The following diagram gives information on the Standard Model of Fundamental Particles and Interactions.



Use information from the diagram and your knowledge of physics to answer the following questions.

- (a) Explain why particles such as leptons and quarks are known as *Fundamental Particles*. 1
- (b) A particle called the sigma plus ( $\Sigma^+$ ) has a charge of +1. It contains two different types of quark. It has two up quarks each having a charge of  $+\frac{2}{3}$  and one strange quark.  
What is the charge on the strange quark? 1
- (c) Explain why the gluon cannot be the force mediating particle for the gravitational force. 1

**Revised Specimen Paper:**

26. (a) A conversation is overheard between two young pupils who are discussing their science lessons.

Pupil A *“We learned in science today that the nucleus of an atom is made of protons which are positively charged and neutrons which have no charge.”*

Pupil B *“That’s interesting because we learned in science that like charges repel. How come the protons in the nucleus don’t fly apart?”*

Pupil A *“I don’t know.”*

Write a paragraph that would explain to the pupils why the protons in a nucleus do not fly apart.

3

- (b) Protons and neutrons each contain two different types of quark: the up quark which has an electric charge of  $+\frac{2}{3}$  and the down quark which has an electric charge of  $-\frac{1}{3}$ .

Use this information to show:

- (i) the overall charge on the proton is +1;
- (ii) the overall charge on the neutron is zero.

2

1.

A student makes the following statements about the Standard Model.

- I Every particle has an antiparticle.
- II Alpha decay is evidence for the existence of the neutrino.
- III The W-boson is associated with the strong nuclear force.

Which of these statements is/are correct?

- A I only
- B II only
- C III only
- D I and II only
- E I and III only

2.

How many types of quark are there?

- A 8
- B 6
- C 4
- D 3
- E 2

3.

An electron is a

- A boson
- B hadron
- C baryon
- D meson
- E lepton.

4.

Scientists have recently discovered a type of particle called a pentaquark. Pentaquarks are very short lived and contain five quarks.

A lambda b ( $\Lambda_b$ ) pentaquark contains the following quarks: 2 up, 1 down, 1 charm, and 1 anticharm quark.

(a) Quarks and leptons are fundamental particles.

(i) Explain what is meant by the term *fundamental particle*.

1

(ii) State the name given to the group of matter particles that contains quarks and leptons.

1

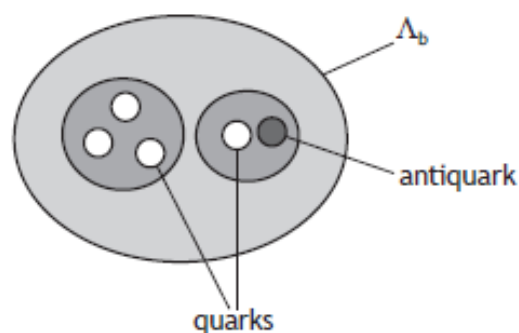
(b) The table contains information about the charge on the quarks that make up the  $\Lambda_b$  pentaquark.

Type of quark	Charge
up	$+\frac{2}{3}e$
down	$-\frac{1}{3}e$
charm	$+\frac{2}{3}e$
anticharm	$-\frac{2}{3}e$

Determine the total charge on the  $\Lambda_b$  pentaquark.

2

(c) One theory to explain the structure of the  $\Lambda_b$  pentaquark suggests that three of the quarks group together and one quark and the antiquark group together within the pentaquark.



(i) State the type of particle that is made of a quark-antiquark pair.

1

- (ii) The mean lifetime of another quark-antiquark pair is  $8.0 \times 10^{-21}$  s in its own frame of reference.

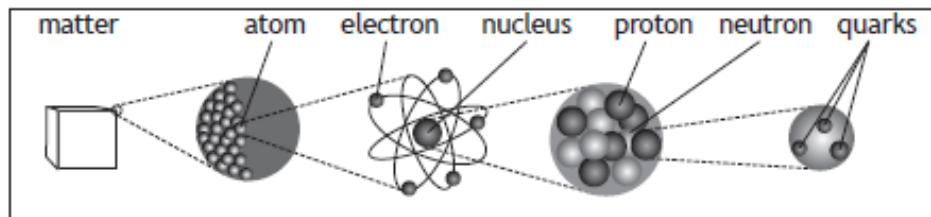
During an experiment the quark-antiquark pair is travelling with a velocity of  $0.91c$  relative to a stationary observer.

Calculate the mean lifetime of this quark-antiquark pair relative to the stationary observer.

3

5.

The following diagram gives information on the Standard Model of fundamental particles.



- (a) Explain why the proton and the neutron are not fundamental particles. 1

- (b) An extract from a data book contains the following information about three types of sigma ( $\Sigma$ ) particles. Sigma particles are made up of three quarks.

Particle	Symbol	Quark Content	Charge	Mean lifetime (s)
sigma plus	$\Sigma^+$	up up strange	$+1e$	$8.0 \times 10^{-11}$
neutral sigma	$\Sigma^0$	up down strange	0	$7.4 \times 10^{-20}$
sigma minus	$\Sigma^-$	down down strange	$-1e$	$1.5 \times 10^{-10}$

- (i) A student makes the following statement.  
*All baryons are hadrons, but not all hadrons are baryons.*

Explain why this statement is correct.

2

- (ii) The charge on an up quark is  $+\frac{2}{3}e$ .  
Determine the charge on a strange quark.

1

- (c) (i) State the name of the force that holds the quarks together in the sigma ( $\Sigma$ ) particle. 1

- (ii) State the name of the boson associated with this force. 1

- (d) Sigma minus ( $\Sigma^-$ ) particles have a mean lifetime of  $1.5 \times 10^{-10}$  s in their frame of reference.

$\Sigma^-$  are produced in a particle accelerator and travel at a speed of  $0.9c$  relative to a stationary observer.

Calculate the mean lifetime of the  $\Sigma^-$  particle as measured by this observer.

3

### 3. Electric Fields

#### Learning Outcomes:

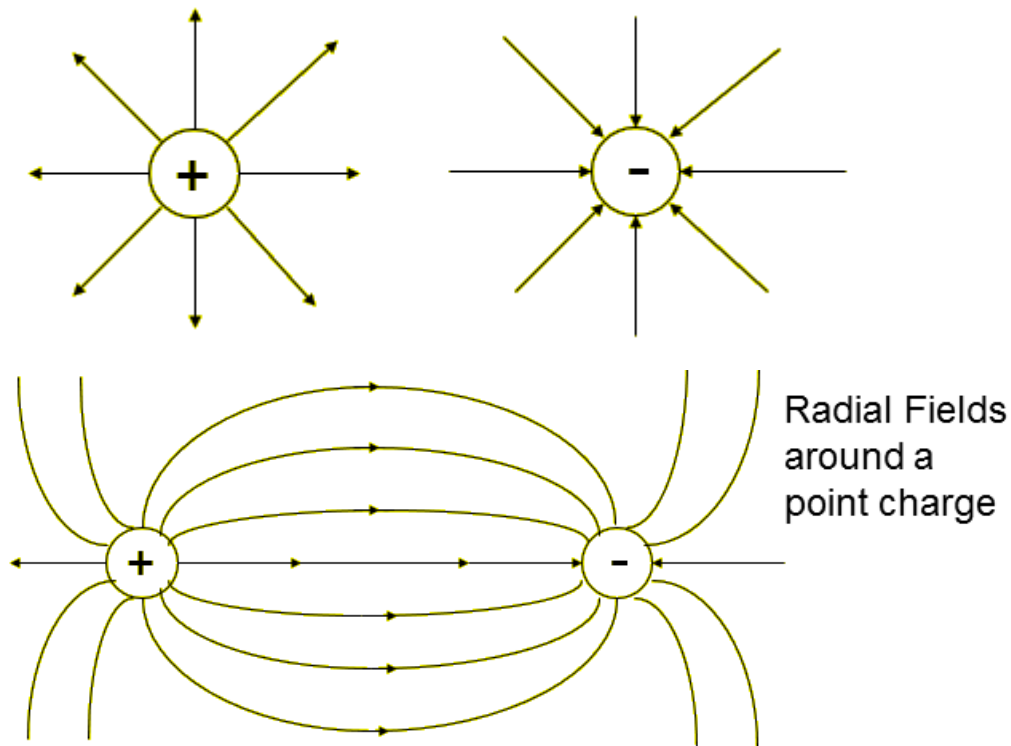
- Fields exist around a charged particle and between charged parallel plates.
- Examples of electric field patterns for single-point charges, systems of two-point charges and between parallel plates.
- Movement of charged particles in an electric field.

#### Forces on a charged particle – Electric fields:

In an electric field, a charge experiences a force.

Electric field lines show the direction of a force (on a **positive** charge).

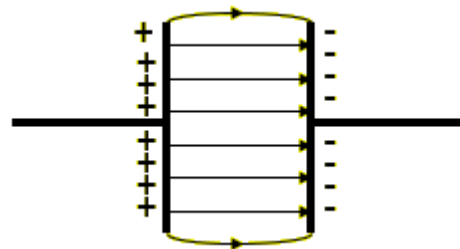
The separation of the field lines is an indication of the strength of the field.



### Uniform Electric Field:

A uniform electric field exists between two parallel charged plates.

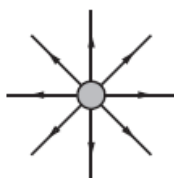
- The space around an electric charge where the influence of that charge on another charge can be detected, is called an electric field.
- Like charges repel. Unlike charges attract.
- Field lines are continuous, starting on a +ve charge and ending on a -ve charge. They give the direction of the force acting on a positive charge at a point in the field.



### Multi-choice examples:

#### CfE Specimen Paper:

13. The diagram represents the electric field around a single point charge.



A student makes the following statements about this diagram.

- I The separation of the field lines indicates the strength of the field.
- II The arrows on the field lines indicate the direction in which an electron would move if placed in the field.
- III The point charge is positive.

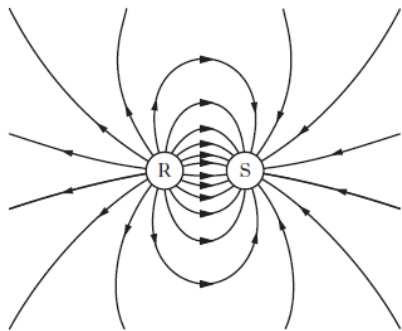
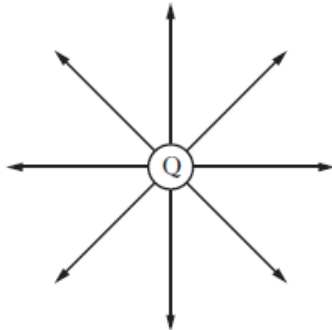
Which of these statements is/are correct?

- A I only
- B II only
- C I and III only
- D II and III only
- E I, II and III



**Revised Higher 2014:**

8. The electric field patterns around charged particles Q, R and S are shown.



Which row in the table shows the charges on particles Q, R and S?

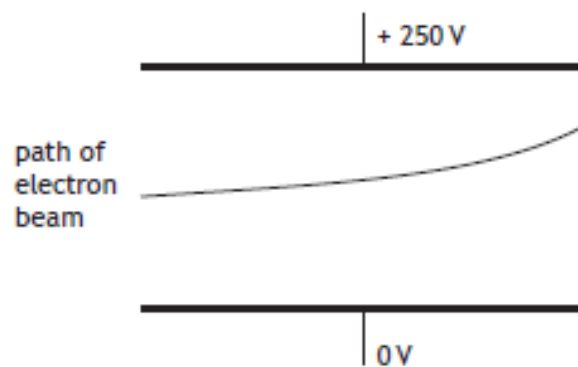
	Charge on Q	Charge on R	Charge on S
A	positive	positive	negative
B	negative	negative	positive
C	negative	positive	negative
D	negative	negative	negative
E	positive	positive	positive

**CfE Higher 2016 Qu: 7**

(c) The switch S is now closed.

The potential difference between the metal plates is 250 V.

The path of the electron beam between the metal plates is shown.



Complete the diagram to show the electric field pattern between the two metal plates.

1

## 4. Potential Difference

### Learning Outcomes:

- The relationship between potential difference, work and charge gives the definition of the volt.
- Calculation of the speed of a charged particle accelerated by an electric field.

### Potential Difference:

When a charge  $Q$  is moved in an electric field, **work**  $W$  is done.

If one joule of work is done moving one coulomb of charge between two points in an electric field, the **potential difference** between the two points is one volt.

The potential difference (p.d.) =  $\frac{\text{Work done}}{\text{Charge}}$

$V$	=	$\frac{W}{Q}$
-----	---	---------------

What is meant by potential difference between two points in an electric field (or in a circuit)?

It is a measure of the **work done in moving one coulomb of charge between the two points.**

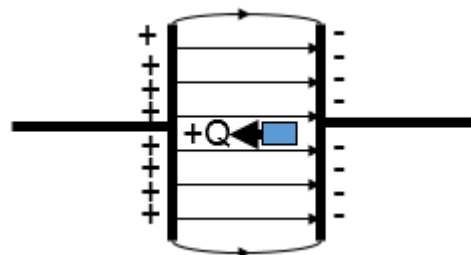
$1 \text{ volt} = 1 \text{ joule per coulomb}$
--

$1 \text{ V} = 1 \text{ JC}^{-1}$
-----------------------------------

### Worked Example:

A +ve charge of  $3 \mu\text{C}$  is moved as shown, between a p.d. of  $10 \text{ V}$ .

- Calculate the potential energy gained.
- If the charge is released, state the energy change.
- How much kinetic energy is gained on reaching the negative plate?



**Note:** In this section we will use the symbol  $W$  for work done (i.e. energy transferred). We can therefore infer that in electrical terms:

Change in electrical potential energy = electric force x distance

If the force is in the direction of the electric field then it appears as kinetic energy.

If the force is against the direction of the electric field then the energy is stored as potential energy.

Through the conservation of energy we know that  $E_p = E_k$ . However we have previously stated that  $E_p = W = QV$ . This allows us to come up with the following equation for conservation of energy for charges in an electric field:

$$QV = \frac{1}{2} mv^2$$

When carrying out problems on charges in an electric field the data sheet at the beginning of the exam supplies us with lots of information regarding the charges and masses of various charged particles:

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	$c$	$3.00 \times 10^8 \text{ m s}^{-1}$	Planck's constant	$h$	$6.63 \times 10^{-34} \text{ J s}$
Magnitude of the charge on an electron	$e$	$1.60 \times 10^{-19} \text{ C}$	Mass of electron	$m_e$	$9.11 \times 10^{-31} \text{ kg}$
Universal Constant of Gravitation	$G$	$6.67 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$	Mass of neutron	$m_n$	$1.675 \times 10^{-27} \text{ kg}$
Gravitational acceleration on Earth	$g$	$9.8 \text{ m s}^{-2}$	Mass of proton	$m_p$	$1.673 \times 10^{-27} \text{ kg}$
Hubble's constant	$H_0$	$2.3 \times 10^{-18} \text{ s}^{-1}$			

**Worked example:**

An electron is accelerated (from rest) through a potential difference of 200 V.

- Calculate:
- (a) the kinetic energy gained
  - (b) the final speed of the electron.

### **Common Problem Solving Questions:**

Very often the question may change one of two possible factors and ask you to comment on how this would affect the velocity of the charged particle.

You should refer to the equation ( $QV = \frac{1}{2} mv^2$ ) to see if the velocity is affected by the change:

1. **The distance of the field** (i.e. is halved or doubled) – This **would not affect** the velocity of the charge as it is only dependent on the variables in the equation which are Q, V and m. These have not changed so neither does the velocity.
2. **The charge of the particle**: This **would affect** the velocity of the charged particle. A smaller charge (value for Q) means a smaller value for QV so this results in a smaller value for velocity, v (as long as mass is kept constant). Conversely if Q increases then so will velocity, v.

### **Multi-choice examples:**

#### **2010 Qu: 7**

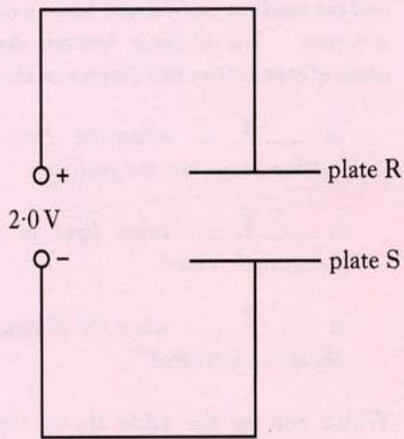
7. The potential difference between two points is
- A the work done in moving one electron between the two points
  - B the voltage between the two points when there is a current of one ampere
  - C the work done in moving one coulomb of charge between the two points
  - D the kinetic energy gained by an electron as it moves between the two points
  - E the work done in moving any charge between the two points.

#### **2005 Qu: 7**

7. One volt is
- A one coulomb per joule
  - B one joule coulomb
  - C one joule per coulomb
  - D one joule per second
  - E one coulomb per second.

**2003 Qu: 8:**

8. Two parallel metal plates, R and S, are connected to a 2.0 V d.c. supply as shown.



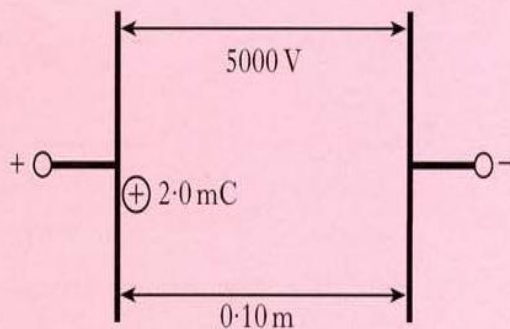
An electron is moved from plate R to plate S.

The gain in electrical potential energy of the electron is

- A  $8.0 \times 10^{-20} \text{ J}$
- B  $1.6 \times 10^{-19} \text{ J}$
- C  $3.2 \times 10^{-19} \text{ J}$
- D  $6.4 \times 10^{-19} \text{ J}$
- E  $1.3 \times 10^{-19} \text{ J}$ .

**2005 Qu: 8:**

8. A potential difference of 5000 V is applied between two metal plates. The plates are 0.10 m apart. A charge of +2.0 mC is released from rest at the positively charged plate as shown.



The kinetic energy of the charge just before it hits the negative plate is

- A  $4.0 \times 10^{-7} \text{ J}$
- B  $2.0 \times 10^{-4} \text{ J}$
- C 5.0 J
- D 10 J
- E 500 J.

**2008 Qu: 8:**

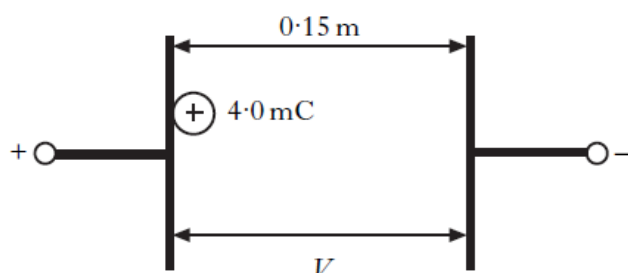
8. An electron is accelerated from rest through a potential difference of 2.0 kV.

The kinetic energy gained by the electron is

- A  $8.0 \times 10^{-23} \text{ J}$
- B  $8.0 \times 10^{-20} \text{ J}$
- C  $3.2 \times 10^{-19} \text{ J}$
- D  $1.6 \times 10^{-16} \text{ J}$
- E  $3.2 \times 10^{-16} \text{ J}$ .

**2009 Qu: 8:**

8. A potential difference,  $V$ , is applied between two metal plates. The plates are 0.15 m apart. A charge of +4.0 mC is released from rest at the positively charged plate as shown.



The kinetic energy of the charge just before it hits the negative plate is 8.0 J.

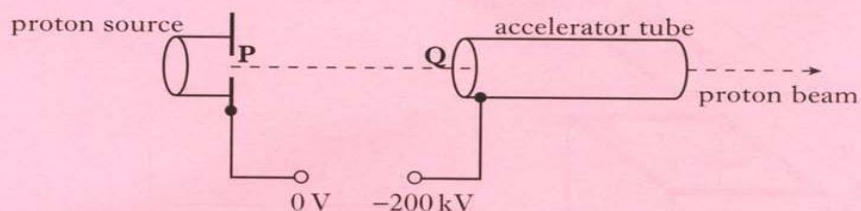
The potential difference between the plates is

- A  $3.2 \times 10^{-2} \text{ V}$
- B 1.2 V
- C 2.0 V
- D  $2.0 \times 10^3 \text{ V}$
- E  $4.0 \times 10^3 \text{ V}$ .

**Paper 2 examples:**

**2006 Qu: 24:**

24. The diagram below shows the basic features of a proton accelerator. It is enclosed in an evacuated container.

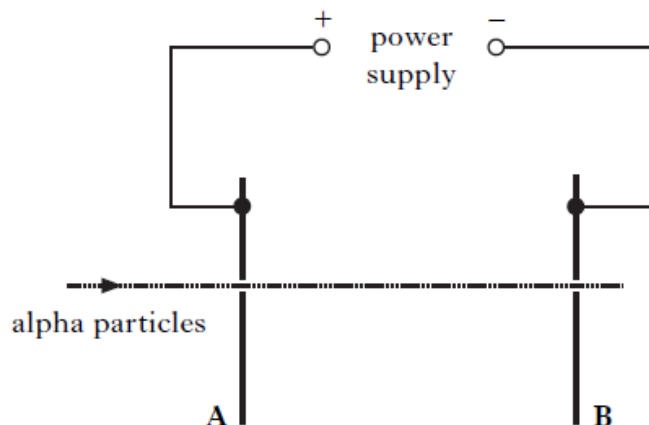


Protons released from the proton source start from rest at **P**.  
A potential difference of 200 kV is maintained between **P** and **Q**.

- (a) What is meant by the term *potential difference of 200 kV*? 1
- (b) Explain why protons released at **P** are accelerated towards **Q**. 1
- (c) Calculate:
- (i) the work done on a proton as it accelerates from **P** to **Q**; 2
  - (ii) the speed of a proton as it reaches **Q**. 2
- (d) The distance between **P** and **Q** is now halved.  
What effect, if any, does this change have on the speed of a proton as it reaches **Q**? Justify your answer. 2

**2007 Qu: 24:**

24. The apparatus shown in the diagram is designed to accelerate alpha particles.



An alpha particle travelling at a speed of  $2.60 \times 10^6 \text{ m s}^{-1}$  passes through a hole in plate A. The mass of an alpha particle is  $6.64 \times 10^{-27} \text{ kg}$  and its charge is  $3.2 \times 10^{-19} \text{ C}$ .

- (a) When the alpha particle reaches plate B, its kinetic energy has increased to  $3.05 \times 10^{-14} \text{ J}$ .

Show that the work done on the alpha particle as it moves from plate A to plate B is  $8.1 \times 10^{-15} \text{ J}$ .

- (b) Calculate the potential difference between plates A and B.
- (c) The apparatus is now adapted to accelerate **electrons** from A to B through the same potential difference.

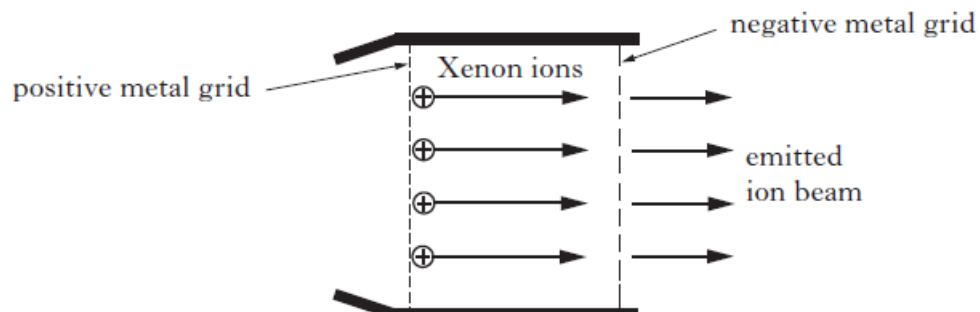
How does the increase in the kinetic energy of an electron compare with the increase in kinetic energy of the alpha particle in part (a)?

Justify your answer.



**Revised Higher 2012:**

23. An ion propulsion engine can be used to propel spacecraft to areas of deep space. A simplified diagram of a Xenon ion engine is shown.



The Xenon ions are accelerated as they pass through an electric field between the charged metal grids. The emitted ion beam causes a force on the spacecraft in the opposite direction.

The spacecraft has a total mass of 750 kg.

The mass of a Xenon ion is  $2.18 \times 10^{-25}$  kg and its charge is  $1.60 \times 10^{-19}$  C. The potential difference between the charged metal grids is 1.22 kV.

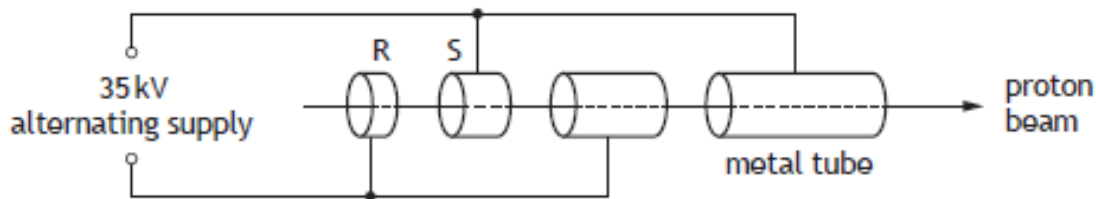
- (a) (i) Show that the work done on a Xenon ion as it moves through the electric field is  $1.95 \times 10^{-16}$  J.
- (ii) Assuming the ions are accelerated from rest, calculate the speed of a Xenon ion as it leaves the engine.
- (b) The ion beam exerts a constant force of 0.070 N on the spacecraft. Calculate the change in speed of the spacecraft during a 60 second period of time.
- (c) A different ion propulsion engine uses Krypton ions which have a smaller mass than Xenon ions. The Krypton engine emits the same number of ions per second at the same speed as the Xenon engine.

Which of the two engines produces a greater force?

Justify your answer.

**CfE Higher Specimen Paper:**

8. A linear accelerator is used to accelerate protons.  
The accelerator consists of hollow metal tubes placed in a vacuum.



The diagram shows the path of protons through the accelerator.

Protons are accelerated across the gaps between the tubes by a potential difference of 35 kV.

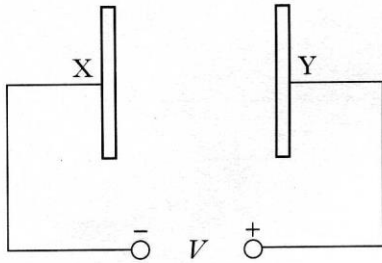
- (a) The protons are travelling at  $1.2 \times 10^6 \text{ m s}^{-1}$  at point R.
- (i) Show that the work done on a proton as it accelerates from R to S is  $5.6 \times 10^{-15} \text{ J}$ . 2
- (ii) Calculate the speed of the proton as it reaches S. 5
- (b) Suggest one reason why the lengths of the tubes increase along the accelerator. 1

**Electric fields and potential difference homework**

**Due date:** \_\_\_\_\_

1.

Two parallel metal plates X and Y in a vacuum have a potential difference  $V$  across them.



An electron of charge  $e$  and mass  $m$ , initially at rest, is released from plate X.

The speed of the electron when it reaches plate Y is given by

A  $\frac{2eV}{m}$

B  $\sqrt{\frac{2eV}{m}}$

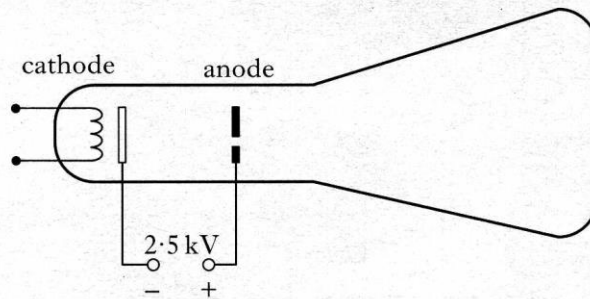
C  $\sqrt{\frac{2V}{em}}$

D  $\frac{2V}{em}$

E  $\frac{2mV}{e}$

2.

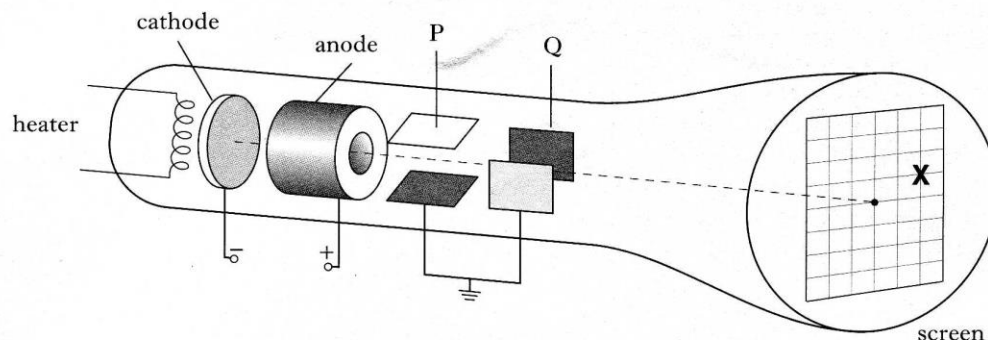
The diagram shows an arrangement which is used to accelerate electrons. The potential difference between the cathode and the anode is 2.5 kV.



Assuming that the electrons start from rest at the cathode, calculate the speed of an electron just as it reaches the anode.

3.

The diagram below shows a cathode ray tube used in an oscilloscope.

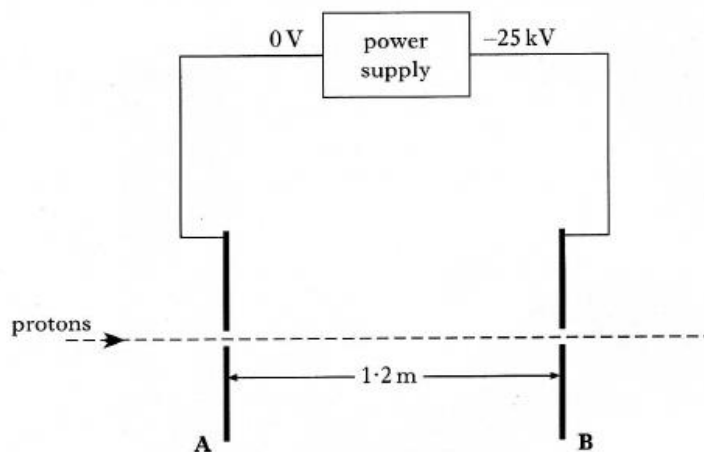


The electrons which are emitted from the cathode start from rest and reach the anode with a speed of  $4.2 \times 10^7 \text{ m s}^{-1}$ .

- (a) (i) Calculate the kinetic energy in joules of each electron just before it reaches the anode.  
 (ii) Calculate the p.d. between the anode and the cathode.
- (b) Describe how the spot at the centre of the screen produced by the electrons can be moved to position **X**.  
 Your answer must make reference to the relative sizes and polarity (signs) of the voltages applied to plates P and Q.

4.

A particle accelerator increases the speed of protons by accelerating them between a pair of parallel metal plates, **A** and **B**, connected to a power supply as shown below.



The potential difference between **A** and **B** is 25 kV.

- (a) Show that the kinetic energy gained by a proton between plates **A** and **B** is  $4.0 \times 10^{-15} \text{ J}$ .
- (b) The kinetic energy of a proton at plate **A** is  $1.3 \times 10^{-16} \text{ J}$ .  
 Calculate the velocity of the proton on reaching plate **B**.
- (c) The plates are separated by a distance of 1.2 m.  
 Calculate the force produced by the particle accelerator on a proton as it travels between plates **A** and **B**.

## **5. Deflection of particles**

### **Learning outcomes:**

- A moving charge produces a magnetic field
- The determination of the direction of the force on a charged particle moving in a magnetic field for negative and positive charges (right-hand rule for negative charges).
- Basic operation of particle accelerators in terms of acceleration, deflection and collision of charged particles.

### **Electric fields:**

- When an electric field is applied to a conductor, the free electric charges in the conductor move.

### **Multi-choice examples:**

#### **Revised Higher 2013**

11. A student writes the following statements about electric fields.
- I There is a force on a charge in an electric field.
  - II When an electric field is applied to a conductor, the free electric charges in the conductor move.
  - III Work is done when a charge is moved in an electric field.

## CfE Higher Specimen Paper

15. A student makes the following statements about charges in electric fields.
- I An electric field applied to a conductor causes the free electric charges in the conductor to move.
  - II When a charge is moved in an electric field work is done.
  - III An electric charge experiences a force in an electric field.

Which of these statements is/are correct?

- A II only
- B III only
- C I and II only
- D II and III only
- E I, II and III

### How do electricity and magnetism interact?

- The discovery of the interaction between electricity and magnetism, and the resultant ability to produce movement, has to rank as one of the most important developments in physics in terms of the impact on everyday lives.
- When a charged particle moves a magnetic field is generated. A current carrying wire will have a magnetic field around it.

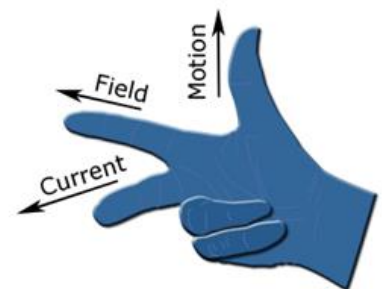
### What will happen when a moving electric charge is brought into a static magnetic field?

- The moving electric charge is surrounded by an (electro) magnetic field.
- This interacts with the static magnetic field which causes the charge to experience a force.
- Simple rules can be used to determine the direction of force on a charged particle in a magnetic field.

### What happens to electrons (-ve charges)?

- We use the **right-hand motor rule**.
- The current, field and motion of force are all **perpendicular** to one another.
- **C**urrent – **C**entral finger
- **F**ield – **F**ore finger
- **M**otion of **force** - **Th**u**M**b

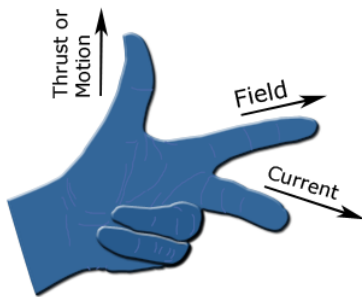
For electron flow, the right-hand motor rule applies:



## What happens to protons (+ve charges)?

For conventional current (i.e. a flow of positive charge) the **left-hand motor rule** applies:

- We use the **left-hand motor rule**.
- (Same representation as previous)



## Things to note

- An x usually symbolises that the magnetic field goes into the page:

xxxx

xxxx

- A • usually symbolises that the field is coming out of the page:

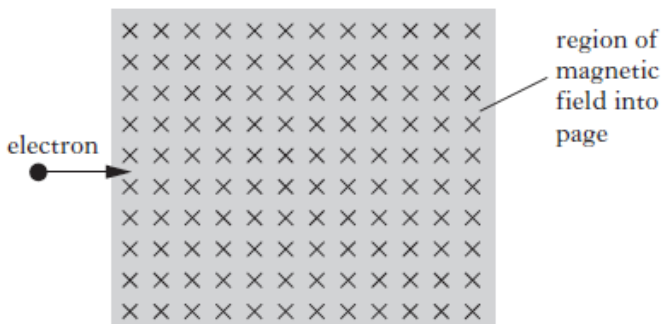
• • •

• • •

## Multi-choice example:

### Revised Higher 2014:

9. An electron enters a region of magnetic field as shown.

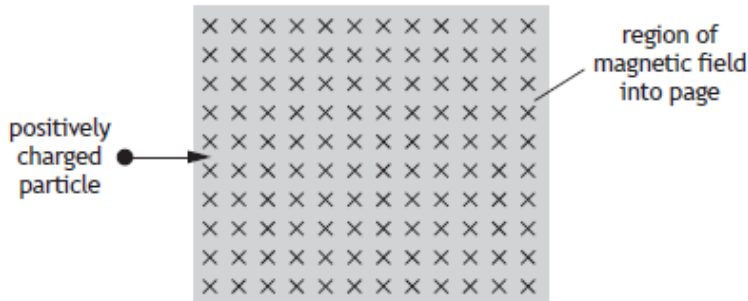


The direction of the force exerted by the magnetic field on the electron as it enters the field is

- A to the left
- B into the page
- C out of the page
- D towards the top of the page
- E towards the bottom of the page.

**CfE Higher 2016:**

- (d) The plasma consists of charged particles. A positively charged particle enters a region of the magnetic field as shown.

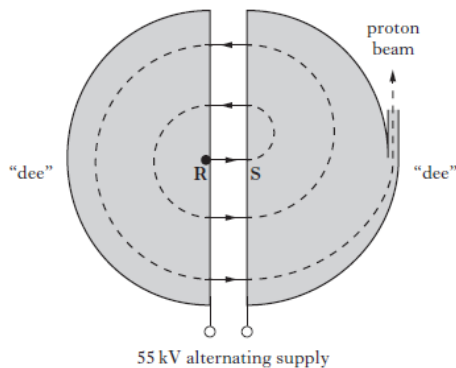


Determine the direction of the force exerted by the magnetic field on the positively charged particle as it enters the field.

1

**Revised Higher 2013:**

26. A cyclotron is used in a hospital to accelerate protons that are then targeted to kill cancer cells.  
The cyclotron consists of two D-shaped, hollow metal structures called "dees", placed in a vacuum. The diagram shows the cyclotron viewed from above.



Protons are released from rest at R and are accelerated across the gap between the "dees" by a voltage of 55 kV.

- (b) Inside the "dees" a uniform magnetic field acts on the protons.  
Determine the direction of this magnetic field.

1



### Do we have evidence of this?

- The Sun produces a solar wind (a flow of charged particles) which can cause significant damage to life and electrical equipment.
- The power of the solar wind can fluctuate over time.
- Fortunately for us, Earth has a strong magnetic field (North and South poles) that interact with these charged particles.
- The force produced by the magnetic field on the particles deflect them to the poles.
- This is why Aurora (Northern and Southern lights) are produced.

### How do we use this in practice? Particle Accelerators

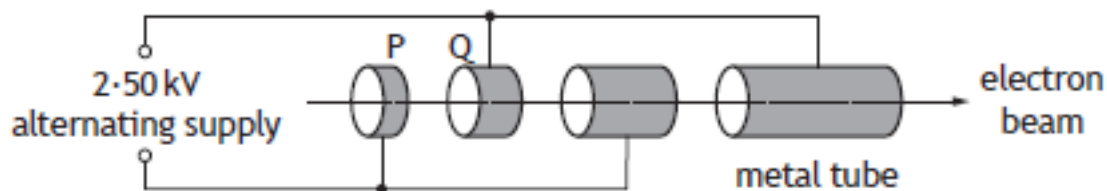
- The movement of charged particles in an electric field is a key component in particle accelerators.
- Accelerators were invented to provide energetic particles to investigate the structure of the atomic nucleus.
- Since then, they have been used to investigate many aspects of particle physics. Their job is to speed up and increase the energy of a beam of particles by:

- generating **electric fields** that **accelerate** the particles
- **magnetic fields** that **deflect** (steer and focus) them – the more deflection, the bigger the magnetic field.

- A.C. is used to ensure that the particles travel in the same direction.

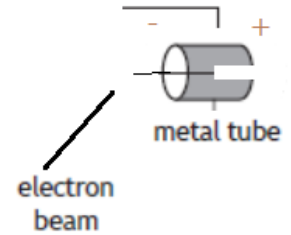
### How does a particle accelerator actually work?

- A charged particle, say an electron, is accelerated through several metal tubes close together that have an alternating current passing through them as shown below:

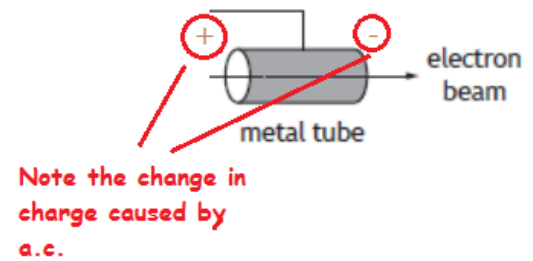


- As it passes through the first metal tube P, the far end of the tube is positively charged and the electron is attracted to it.
- Once the electron reaches and passes this plate the alternating current changes it to a negative charge.
- The electron is repelled by the negative charge and this also helps to accelerate it. This process is constantly repeated and as the electron travels it accelerates fast so the metal tubes have to be longer.

- As it passes through the first metal tube P, the far end of the tube is positively charged and the electron is attracted to it.



- Once the electron reaches and passes this plate the alternating current changes it to a negative charge.
- The electron is repelled by the negative charge and this also helps to accelerate it. This process is constantly repeated and as the electron travels it accelerates fast so the metal tubes have to be longer.



**Revised Higher 2014 Qu: 26**

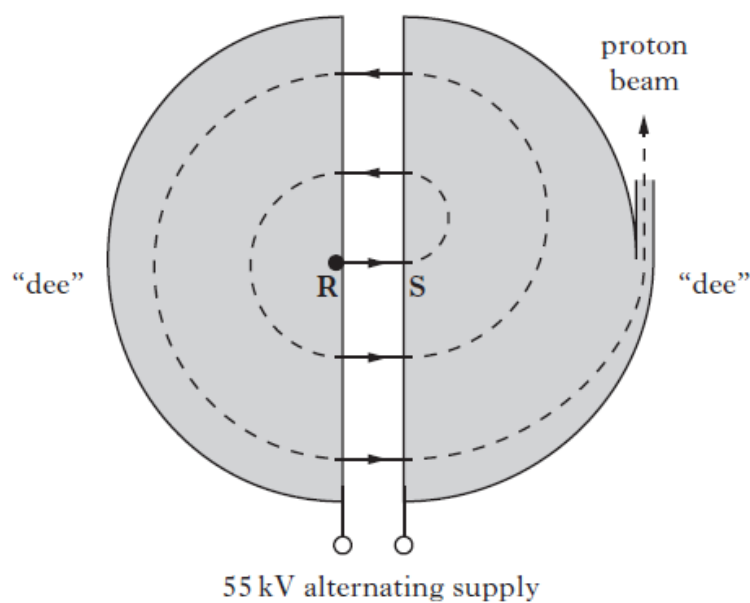
- (b) Explain how particle accelerators, such as the Large Hadron Collider at CERN, are able to:
- |                                   |   |
|-----------------------------------|---|
| (i) accelerate charged particles; | 1 |
| (ii) deflect charged particles.   | 1 |

**Section 2 Past Paper Examples:**

**Revised Higher 2013 Qu: 26**

26. A cyclotron is used in a hospital to accelerate protons that are then targeted to kill cancer cells.

The cyclotron consists of two D-shaped, hollow metal structures called “dees”, placed in a vacuum. The diagram shows the cyclotron viewed from above.



Protons are released from rest at **R** and are accelerated across the gap between the “dees” by a voltage of 55 kV.

- (a) (i) Show that the work done on a proton as it accelerates from **R** to **S** is  $8.8 \times 10^{-15} \text{ J}$ .
- (ii) Calculate the speed of a proton as it reaches **S**.
- (b) Inside the “dees” a uniform magnetic field acts on the protons. Determine the direction of this magnetic field.
- (c) Explain why an alternating voltage is used in the cyclotron.

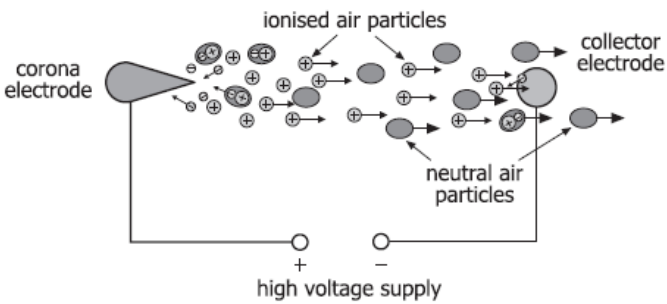
## Revised Higher Specimen Qu: 26

27. The following article features in a “How Things Work” website.

HOW THINGS WORK

### HOW THINGS WORK

Scientists have created several working prototypes of a corona discharge cooler, which can silently but effectively cool the microprocessor of a computer.



The diagram illustrates the operation of a corona discharge cooler. On the left, a corona electrode is connected to the positive terminal of a high voltage supply. On the right, a collector electrode is connected to the negative terminal. Ionised air particles (positive ions) are shown moving from the corona electrode towards the collector electrode. Neutral air particles are shown being pushed towards the collector electrode by the ionised air particles.

The corona discharge cooler works in the following manner.

A strong electric field is created at the tip of the corona electrode, which is placed on one side of the microprocessor. This causes the oxygen and nitrogen molecules in the air to become ionised (positively charged) and create a cloud (corona) of charged particles.

Placing a negative electrode at the opposite end of the microprocessor causes the charged ions to accelerate towards this electrode, colliding with neutral air molecules on the way. During these collisions, momentum is transferred from the ionised gas to the neutral air molecules, resulting in movement of gas towards the collector electrode.

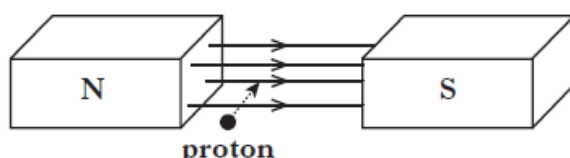
The advantages of the corona-based cooler are: it has no moving parts, it operates with a near-zero noise level and it has a very low power consumption of 0.1 W.

- (a) Describe how the gas molecules “become ionised”.
- (b) Explain why the charged ions accelerate towards the collector electrode.
- (c) The p.d. between the electrodes is 1.0 kV. Assuming that the field between the electrodes is uniform and the charge on each ion is  $1.6 \times 10^{-19}$  C:
- calculate the work done in moving one ion between the electrodes;
  - calculate how many ions are created each second.
- (d) Explain how this device cools the microprocessor.

**Revised Higher 2012 Qu: 26**

(d) In the Large Hadron Collider (LHC) beams of hadrons travel in opposite directions inside a circular accelerator and then collide. The accelerating particles are guided around the collider using strong magnetic fields.

(i) The diagram shows a proton entering a magnetic field.



In which direction is this proton deflected?

1

(ii) The neutron is classified as a hadron.

Explain why neutrons are **not** used for collision experiments in the LHC.

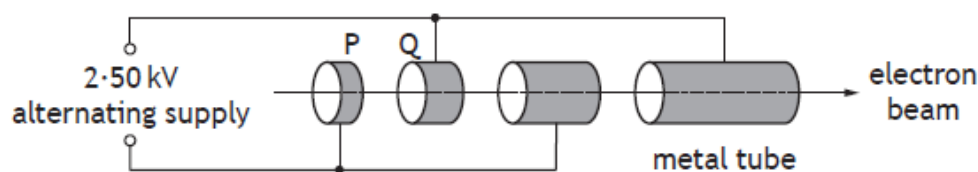
1

**CfE Higher 2017 Qu: 8**

8. X-ray machines are used in hospitals.

An X-ray machine contains a linear accelerator that is used to accelerate electrons towards a metal target.

The linear accelerator consists of hollow metal tubes placed in a vacuum.



Electrons are accelerated across the gaps between the tubes by an alternating supply.

(a) (i) Calculate the work done on an electron as it accelerates from P to Q.

3

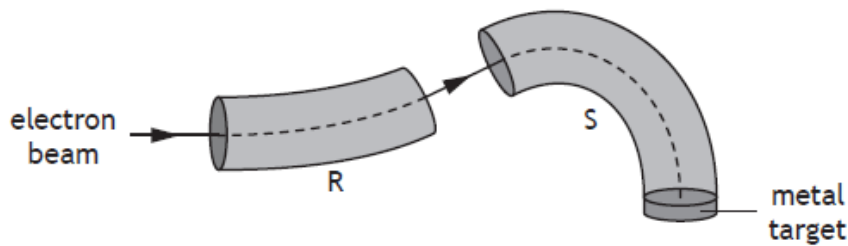
(ii) Explain why an alternating supply is used in the linear accelerator.

1

- (b) The electron beam is then passed into a “slalom magnet” beam guide. The function of the beam guide is to direct the electrons towards a metal target.

Inside the beam guides R and S, two different magnetic fields act on the electrons.

Electrons strike the metal target to produce high energy photons of radiation.



- (i) Determine the direction of the magnetic field inside beam guide R. 1
- (ii) State two differences between the magnetic fields inside beam guides R and S. 2
- (c) Calculate the minimum speed of an electron that will produce a photon of energy  $4.16 \times 10^{-17}$  J. 3

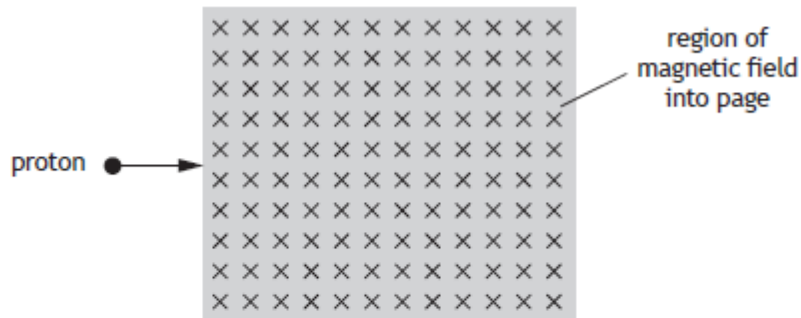
### Revised Higher Specimen

31. The Sun is constantly ejecting positive and negative charged particles at very high speed. This flow of charged particles is called the solar wind. The charged particles can cause significant damage to life and also to electrical equipment if they reach the surface of the Earth. We are protected from the charged particles by a field. This field, produced by the Earth, deflects the solar wind.

Using your knowledge of physics, explain whether the protecting field is electric, magnetic or gravitational. (3)

1.

A proton enters a region of magnetic field as shown.

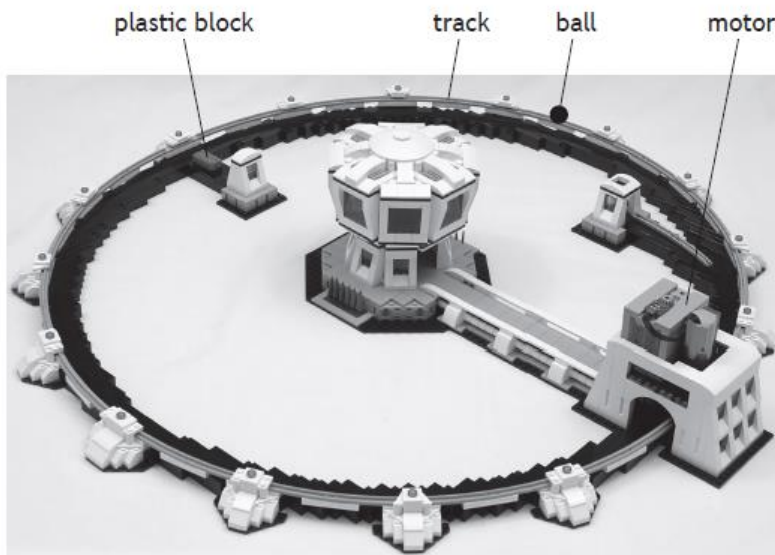


On entering the magnetic field the proton

- A deflects into the page
- B deflects out of the page
- C deflects towards the top of the page
- D deflects towards the bottom of the page
- E is not deflected.

2.

A student builds a model of a particle accelerator. The model accelerates a small ball on a circular track. A battery-operated motor accelerates the ball each time it passes the motor. To cause a collision a plastic block is pushed onto the track. The ball then hits the block.



Using your knowledge of physics comment on the model compared to a real particle accelerator, such as the large hadron collider at CERN.

3

## 6. Radioactive Decay

### Learning Outcomes:

- Nuclear equations to describe radioactive decay, fission and fusion reactions with reference to mass and energy equivalence including calculations.

### Nuclear Reactions

#### **Structure and Symbols**

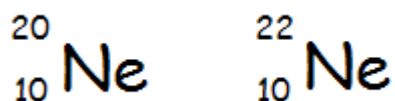
- Atomic Number – The number of protons in the nucleus (Z) – also equal to the number of orbiting electrons.
- Mass number - The total number of protons + neutrons (A), known as nucleons.
- This is normally written:
- ${}^A_ZX$  where X is the chemical symbol for that element

#### Example

- Carbon can be represented by  ${}^{12}_6C$
- Where no. of protons (atomic no.) = 6
- No. of protons and neutrons (mass no.) = 12

#### Atomic Number & Isotopes

- Every element has a different atomic number and these are arranged in increasing order in the periodic table.
- Nuclei which have the same atomic number can have different mass numbers, i.e. same number of protons but different numbers of neutrons, eg:



- These nuclei (neon in the case above) are known as isotopes.
- It is also possible for atoms of different elements to have the same mass number.



## The relative masses and charges of the proton, neutron and electron are

Particle	Mass	Charge	Symbol
Proton	1	+1	${}^1_1\text{p}$
Neutron	1	0	${}^1_0\text{n}$
Electron	1/1840	-1	${}^0_{-1}\text{e}$

## Radioactive decay

- Many nuclei are unstable. In order to achieve stability, they can emit nuclear radiation in the form of alpha, beta or gamma.
- Such unstable nuclei are called radioisotopes (or radionuclides).
- This process of emitting radiation is called decay.

## Decay Summary

Radiation	Nature	Symbol
Alpha particle	Helium nucleus	${}^4_2\text{He } \alpha$
Beta particle	Fast electron	${}^0_{-1}\text{e } \beta$
Gamma ray	High frequency em wave	$\gamma$

- In **alpha decay**, the mass number loses 4 and the atomic number loses 2.
- The resulting isotope (known as the daughter isotope) is a different element.
- In **beta decay**, the mass number remains the same and the atomic number gains one.
- The daughter isotope is a different element.
- In **gamma decay**, there is no change in the isotope, only energy is emitted.

## Example 1 – alpha decay

- Radioactive decay of Radium (226)
- ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^4_2\text{He}$

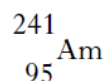
### Example 2 - beta decay

- Radioactive decay of Polonium (218)
- ${}_{84}^{218}\text{Po} \rightarrow {}_{85}^{218}\text{At} + {}_{-1}^0\text{e}$

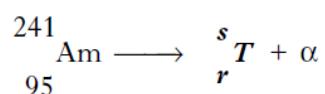
### Section 2 Past Paper Example:

#### Old Higher 2010 Qu: 30

30. A smoke alarm contains a very small sample of the radioactive isotope Americium-241, represented by the symbol



- (a) How many neutrons are there in a nucleus of this isotope? 1
- (b) This isotope decays by emitting alpha particles as shown in the following statement.



- (i) Determine the numbers represented by the letters *r* and *s*. 1
- (ii) Use the data booklet to identify the element *T*. 1

## 7. Decay Examples and Fission & Fusion

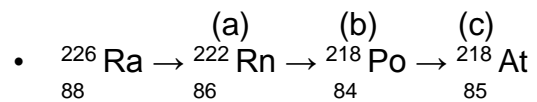
### Learning Outcomes:

- Nuclear equations to describe radioactive decay, fission and fusion reactions with reference to mass and energy equivalence including calculations.
- Coolant and containment issues in nuclear fusion reactors.

### Radioactive decay examples

#### Example 1

- Identify the particle emitted at each stage in the decay series shown:



(a)

(b)

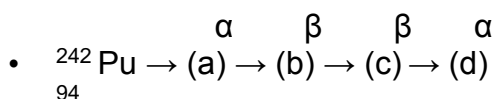
(c)

## Example 2

- We do not have to learn values from the periodic table. All information will be included in any relevant questions
- Information from part of the periodic table is shown below:

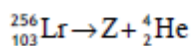
91 Pa (Protactinium)	92 U (Uranium)	93 Np (Neptunium)	94 Pu (Plutonium)
----------------------------	----------------------	-------------------------	-------------------------

- Use a periodic table to identify the missing isotope at each stage in the decay series shown:

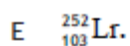
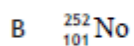
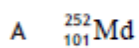


## CfE Higher 2017

8. The following statement represents a nuclear reaction.

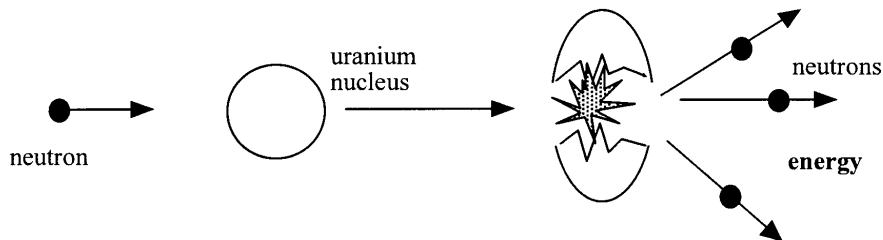


Nucleus Z is



## Nuclear Fission

- In fission, a large nucleus splits into two nuclei of smaller mass with the release of several neutrons and energy.



- This fission can occur at random (spontaneous) with a fixed half-life, or stimulated.
- In stimulated fission, the nucleus is hit by an incident neutron causing it to undergo fission.
- When measured it is found that the mass of the nucleus before the fission is **bigger than** the mass of all components after the collision.

## $E = mc^2$

- This lost mass is converted into energy according to Einstein's famous equation:

$$E = mc^2$$

- E - Energy (J)
- m – mass (kg)
- c – velocity of light ( $3 \times 10^8 \text{ms}^{-1}$ )
- NB: only c is squared –  $c^2 = 9 \times 10^{16}$

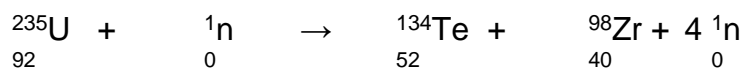
## Why is energy produced in $E = mc^2$ reactions?

- Some mass is lost in the reaction and this is **converted** to energy

**Example - (it is very important that you do not round up too early for these calculations)**

$^{236}_{92}\text{U}$	$3.901 \times 10^{-25} \text{ kg}$
$^{134}_{52}\text{Te}$	$2.221 \times 10^{-25} \text{ kg}$
$^{98}_{40}\text{Zr}$	$1.626 \times 10^{-25} \text{ kg}$
$^1_0\text{n}$	$0.017 \times 10^{-25} \text{ kg}$

Find the energy given out by this reaction:



### The electron-volt

- Another unit for energy is the electron-volt.
- Where  $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$

### Section 2 Past Paper Examples:

#### CfE Higher 2015 Qu: 6

- (b) In July 2012 scientists at CERN announced that they had found a particle that behaved in the way that they expected the Higgs boson to behave. Within a year this particle was confirmed to be a Higgs boson.

This Higgs boson had a mass-energy equivalence of 126 GeV.

( $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$ )

- (i) Show that the mass of the Higgs boson is  $2.2 \times 10^{-25} \text{ kg}$ .

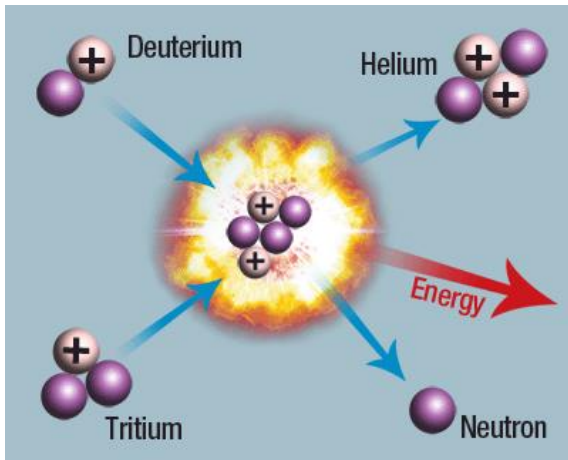
3

### Nuclear Fusion

- Fusion is process of joining things together.
- Nuclear fusion is when two light nuclei combine to form a nucleus of larger mass number and a neutron.
- **Like in fission, there is a decrease in mass after the fusion, this loss in mass produces the Energy ( $E = mc^2$ )**
- However, the energy released is produced as **kinetic energy** of the fusion products.
- Fusion only occurs at massive temperatures, this explains why the energy released by the Sun and other stars is produced by nuclear fusion.

## Nuclear Fusion diagram

- Note the two smaller nuclei forming a larger nucleus.



## Coolant and Containment issues in Nuclear Fusion Reactors

- There are a number of safety issues and concerns surrounding nuclear fusion reactors that are up for debate. These are mainly:
- **Coolant** – As nuclear fusion creates incredibly high (and potentially dangerous) temperatures, coolants are required to remove the excess energy.
- **Containment** – After the nuclear fuel has been used in can still remain dangerously radioactive for a number of years. It has to be kept in thick concrete and hidden away from the general public.

### Section 2 Past Paper Examples:

#### CfE Higher Specimen Qu: 9(a)(iii)

9. (a) (continued)

(iii) Fusion reactors are being developed that use this type of reaction as an energy source.

Explain why this type of fusion reaction is hard to sustain in these reactors.

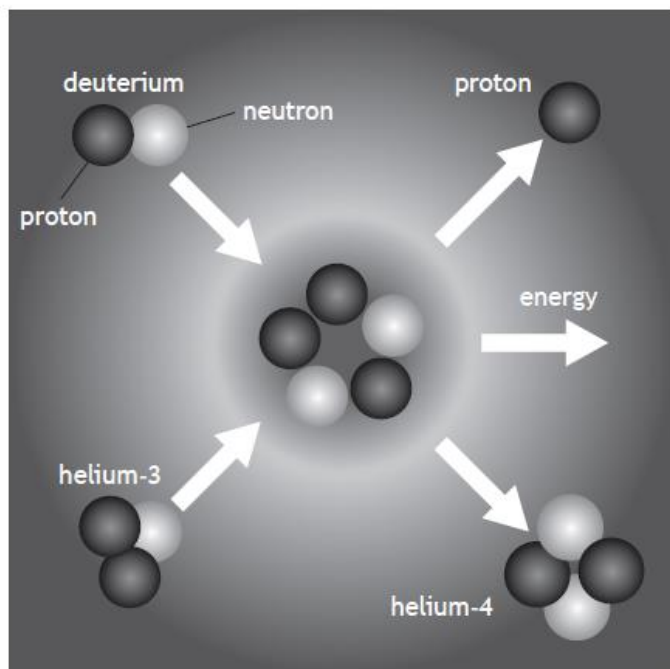
1



**CfE Higher 2017 Qu: 9**

9. A diagram from a 'How Things Work' website contains information about a nuclear fusion reaction.

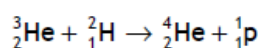
Reaction of helium-3 with deuterium



- (a) State what is meant by the term *nuclear fusion*.

1

- (b) The following statement represents this fusion reaction.



The mass of the particles involved in the reaction are shown in the table.

Particle	Mass (kg)
${}^3_2\text{He}$	$5.008 \times 10^{-27}$
${}^2_1\text{H}$	$3.344 \times 10^{-27}$
${}^4_2\text{He}$	$6.646 \times 10^{-27}$
${}^1_1\text{p}$	$1.673 \times 10^{-27}$

- (i) Explain why energy is released in this reaction.

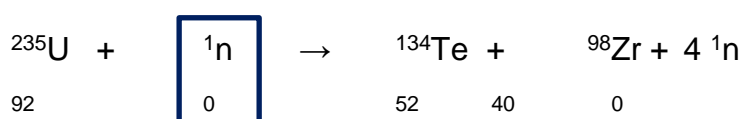
1

- (ii) Determine the energy released in this reaction.

4

### **Recognising Fission and Fusion**

- In Fission reactions, the large nucleus is at the start of the reaction with the smaller at the end.
- In Fusion it is vice versa.
- In **stimulated (induced) Fission** reactions, the reactants (on LHS) will contain a **neutron**, eg shown in the box below:

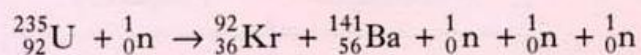


- If there is no neutron at the start we say the reaction is **spontaneous**.

## Multi-choice - Past Paper Examples

### Old Higher 2000 Qu: 18

18. The statement below represents a nuclear reaction.

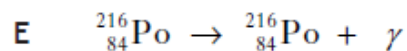
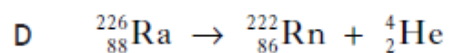
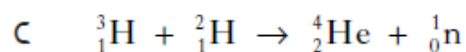
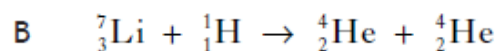
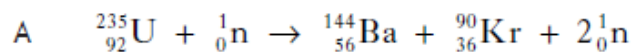


This is an example of

- A nuclear fusion
- B alpha particle emission
- C beta particle emission
- D spontaneous nuclear fission
- E induced nuclear fission.

### CfE Exemplar Paper Qu: 11

11. Which of the following statements describes a spontaneous nuclear fission reaction?

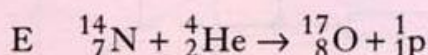
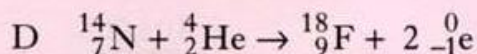
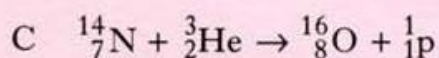
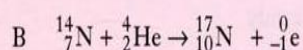
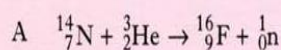


## Old Higher Past Paper Examples

### 2001 Qu: 20

20. Under certain conditions, a nucleus of nitrogen absorbs an alpha particle to form the nucleus of another element and releases a single particle.

Which one of the following statements correctly describes this process?



### 2003 Qu: 20

20. Which of the following statements describes nuclear fission?

A A nucleus of large mass number splits into two nuclei, releasing several neutrons.

B A nucleus of large mass number splits into two nuclei, releasing several electrons.

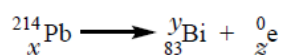
C A nucleus of large mass number splits into two nuclei, releasing several protons.

D Two nuclei combine to form one nucleus, releasing several electrons.

E Two nuclei combine to form one nucleus, releasing several neutrons.

### 2003 Qu: 20

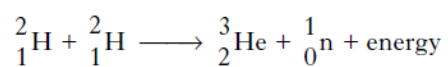
20. For the nuclear decay shown, which row of the table gives the correct values of  $x$ ,  $y$  and  $z$ ?



	$x$	$y$	$z$
A	85	214	2
B	84	214	1
C	83	210	4
D	82	214	-1
E	82	210	-1

**2010 Qu: 18**

18. The following statement describes a fusion reaction.



The total mass of the particles before the reaction is  $6.684 \times 10^{-27}$  kg.

The total mass of the particles after the reaction is  $6.680 \times 10^{-27}$  kg.

The energy released in this reaction is

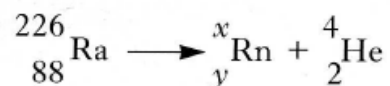
- A  $6.012 \times 10^{-10}$  J
- B  $6.016 \times 10^{-10}$  J
- C  $1.800 \times 10^{-13}$  J
- D  $3.600 \times 10^{-13}$  J
- E  $1.200 \times 10^{-21}$  J.

**2000 Qu: 29(a)**

29. Radium (Ra) decays to radon (Rn) by the emission of an alpha particle.

Some energy is also released by this decay.

The decay is represented by the statement shown below.



The masses of the nuclides involved are as follows.

$$\text{Mass of } {}_{88}^{226}\text{Ra} = 3.75428 \times 10^{-25} \text{ kg}$$

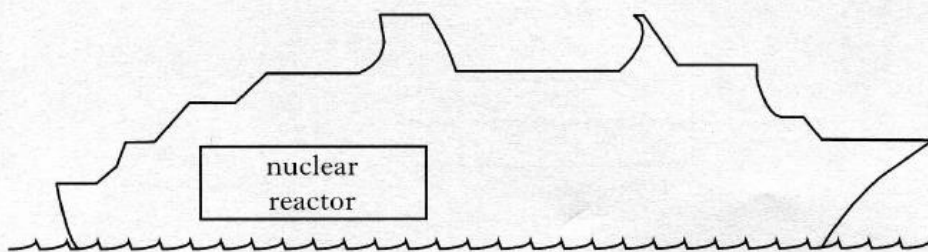
$$\text{Mass of } {}_y^x\text{Rn} = 3.68771 \times 10^{-25} \text{ kg}$$

$$\text{Mass of } {}_2^4\text{He} = 6.64832 \times 10^{-27} \text{ kg}$$

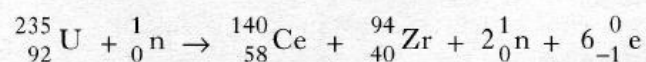
- (a) (i) What are the values of  $x$  and  $y$  for the nuclide  ${}_y^x\text{Rn}$ ?  
(ii) Why is energy released by this decay?  
(iii) Calculate the energy released by one decay of this type.

**2004 Qu: 30**

30. A ship is powered by a nuclear reactor.



One reaction that takes place in the core of the nuclear reactor is represented by the statement below.



(a) The symbol for the Uranium nucleus is  ${}_{92}^{235}\text{U}$ .

What information about the nucleus is provided by the following numbers?

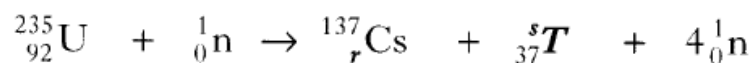
- (i) 92
  - (ii) 235
- (b) Describe how neutrons produced during the reaction can cause further nuclear reactions.
- (c) The masses of particles involved in the reaction are shown in the table.

<i>Particles</i>	<i>Mass/kg</i>
${}_{92}^{235}\text{U}$	$390.173 \times 10^{-27}$
${}_{58}^{140}\text{Ce}$	$232.242 \times 10^{-27}$
${}_{40}^{94}\text{Zr}$	$155.884 \times 10^{-27}$
${}_0^1\text{n}$	$1.675 \times 10^{-27}$
${}_{-1}^0\text{e}$	negligible

Calculate the energy released in the reaction.

**2006 Qu: 29**

(b) A nuclear fission reaction is represented by the following statement.



- (i) Is this a spontaneous or an induced reaction? You must justify your answer.
- (ii) Determine the numbers represented by the letters *r* and *s* in the above reaction.
- (iii) Use the data booklet to identify the element represented by *T*.
- (iv) The masses of the nuclei and particles in the reaction are given below.

	<i>Mass/kg</i>
${}_{92}^{235}\text{U}$	$390.219 \times 10^{-27}$
${}_r^{137}\text{Cs}$	$227.292 \times 10^{-27}$
${}_{37}^s\text{T}$	$157.562 \times 10^{-27}$
${}_0^1\text{n}$	$1.675 \times 10^{-27}$

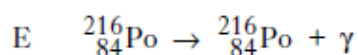
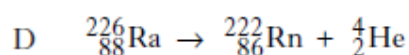
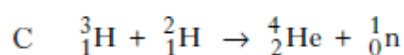
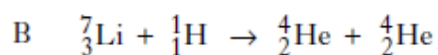
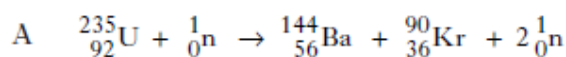
Calculate the energy released in the reaction.



## Revised and CfE Higher Past Paper Examples

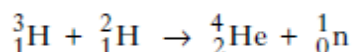
### Revised 2012 Qu: 13

13. Which of the following statements describes a spontaneous nuclear fission reaction?



### Revised 2012 Qu: 13

14. The statement below represents a nuclear reaction.



The total mass on the left hand side is  $8.347 \times 10^{-27}$  kg.

The total mass on the right hand side is  $8.316 \times 10^{-27}$  kg.

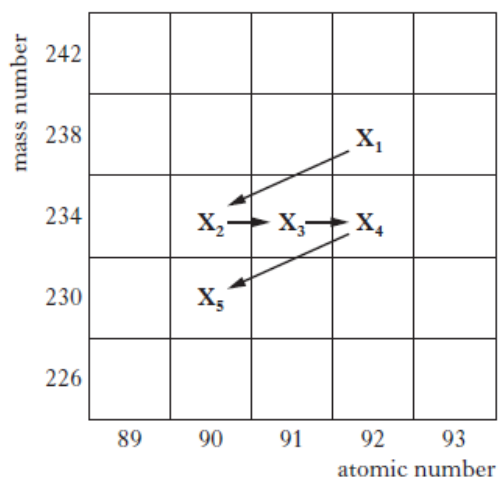
The energy released during one nuclear reaction of this type is

- A  $9.30 \times 10^{-21}$  J  
B  $2.79 \times 10^{-12}$  J  
C  $7.51 \times 10^{-10}$  J  
D  $1.50 \times 10^{-9}$  J  
E  $2.79 \times 10^{15}$  J.

### Revised 2013 Qu: 12

12. Part of a radioactive decay series is shown in the diagram.

The symbols  $X_1$  to  $X_5$  represent nuclides in this series.



A student makes the following statements about the decay series.

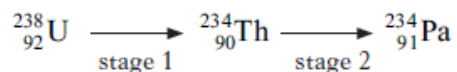
- I Nuclides  $X_2$  and  $X_3$  contain the same number of protons.
- II Nuclide  $X_1$  decays into nuclide  $X_2$  by emitting an alpha particle.
- III Nuclide  $X_3$  decays into nuclide  $X_4$  by emitting a beta particle.

Which of these statements is/are correct?

- A I only
- B II only
- C III only
- D II and III only
- E I, II and III

### Revised 2014 Qu: 10

10. An isotope of uranium decays into an isotope of protactinium in two stages as shown.

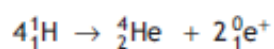


Which row in the table identifies the radiations which must be emitted at each stage?

	<i>stage 1</i>	<i>stage 2</i>
A	alpha	gamma
B	beta	gamma
C	gamma	beta
D	beta	alpha
E	alpha	beta

## CfE Specimen Paper

9. (a) The following statement represents a fusion reaction.



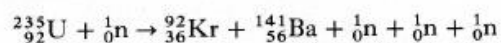
The masses of the particles involved in the reaction are shown in the table.

Particle	Mass (kg)
$\text{}^1_1\text{H}$	$1.673 \times 10^{-27}$
$\text{}^4_2\text{He}$	$6.646 \times 10^{-27}$
$\text{}^0_1\text{e}$	negligible

- (i) Calculate the energy released in this reaction. 4
- (ii) Calculate the energy released when 0.20 kg of hydrogen is converted to helium by this reaction. 3
- (iii) Fusion reactors are being developed that use this type of reaction as an energy source.  
Explain why this type of fusion reaction is hard to sustain in these reactors. 1

1.

The equation below represents a nuclear reaction.

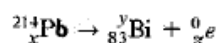


It is an example of

- A nuclear fusion
- B alpha particle emission
- C beta particle emission
- D induced nuclear fission
- E spontaneous nuclear fission.

2.

For the nuclear disintegration described below, which row of the table shows the correct values of  $x$ ,  $y$  and  $z$ ?



	$x$	$y$	$z$
A	84	214	1
B	83	210	4
C	85	214	2
D	82	214	-1
E	82	210	-1

3.

A student writes the following statement to represent a series of nuclear decays.



Which row in the table identifies the radiations represented by  $x$ ,  $y$  and  $z$ ?

	$x$	$y$	$z$
A	alpha	beta	beta
B	beta	alpha	gamma
C	gamma	beta	beta
D	beta	alpha	alpha
E	gamma	alpha	beta

4.

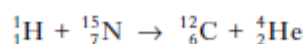
Energy is produced within the Sun by fusion reactions.

(a) State what is meant by a fusion reaction.

(b) Explain briefly why a fusion reaction releases energy.

5.

In a certain star, one of the fusion reactions taking place is represented by the following statement.



The energy released by this reaction is  $7.96662 \times 10^{-13}$  J.

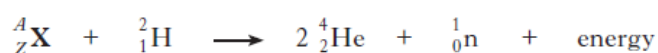
The table shows the masses of three of the particles.

<i>Particle</i>	<i>Mass/kg</i>
${}^1_1\text{H}$	$1.68706 \times 10^{-27}$
${}^{12}_6\text{C}$	$20.1031 \times 10^{-27}$
${}^4_2\text{He}$	$6.69944 \times 10^{-27}$

Calculate the mass of the nitrogen nucleus.

6. (use periodic table from relationship sheet at start of this booklet)

(a) The following statement represents a nuclear reaction.



The masses of some of the particles involved in this reaction are shown in the table.

<i>Particle</i>	<i>Mass/kg</i>
${}^2_1\text{H}$	$3.342 \times 10^{-27}$
${}^4_2\text{He}$	$6.642 \times 10^{-27}$
${}^1_0\text{n}$	$1.675 \times 10^{-27}$

(i) Use the data booklet to identify the element X.

(ii) The energy released in this reaction is  $2.97 \times 10^{-12}$  J.

Calculate the mass of the nucleus  ${}^A_Z\text{X}$ .