Physics Revision Guide

Normanhurst School

Year 10: My world

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1. Waves

- All waves are oscillations or vibrations
- These oscillations travel through a medium or through space
- Waves carry energy as they travel.

Types of waves

- Sound waves
- Light waves (electromagnetic waves)
- Water waves
- Seismic waves (Earthquakes).

Waves characteristics

All waves have:

- Wavelength
- Frequency
- Wave speed
- Amplitude.

All waves carry or transfer energy.

Wavelength

Waves have:

- A repeating pattern
- High points on the wave are called crests
- Low points on the wave are called troughs
- The wavelength is the smallest repeating unit of the wave
- Wavelength is the distance from crest to crest or trough to trough.
- Wavelength is measured in metres (standard unit).

Frequency

- Frequency is the number of oscillations or vibration per second
- An oscillation is one crest & trough
- One oscillation per second is 1 Hertz (1 Hz)
- 1000 Hz = 1 kHz
- 1,000,000 Hz = 1 MHz
- 1,000,000,000 = 1 GHz

Wave speed

- All waves travel at a certain speed
- Wave speed is measured in metres per second (m/s)
- Wave speed depends on the type of wave and the medium through which the wave is travelling
- Light waves travel at 300,000,000 m/s
- Sound waves in air travel at 300 m/s.

Displacement

- All waves are vibrations or oscillations
- Like a pendulum they oscillate about a middle position
- The movement from this middle position is called displacement.

Amplitude

- All waves are vibrations
- These vibrations create a disturbance or displacement
- Amplitude is the maximum size of this displacement
- It is the distance from the middle of a wave to a crest or trough
- Amplitude is a measure of how much energy is carried by the wave.

Reflection, refraction & diffraction

Reflection

- All waves will bounce or reflect off a solid surface
- Angle of incidence = angle of reflection.

Refraction

- Waves bend or refract when going from one medium to another
- A medium is the material or substance through which the wave is travelling.

Diffraction

- Waves spread out or diffract after going through a gap.

2. Electromagnetic waves

Light

- Light is a transverse wave
- The speed of light is 300,000,000 m/s
- Light is an electromagnetic vibration or wave
- Light is part of a family of waves called the electromagnetic spectrum
- All electromagnetic waves travel at the speed of light.

The electromagnetic spectrum (from the lowest frequency to the highest)

- Radio waves
- Microwaves
- Infrared (IR)
- Visible light (red, orange, yellow, green, blue, indigo, violet)
- Ultraviolet (UV)
- X-rays
- Gamma rays.

The Doppler effect with light
When a source of light is moving fast:

- If it approaches then the frequencies is shifted towards the blue end of the spectrum
- If it moves away then the frequencies shifts to the red end of the spectrum.

Radio waves

- Very low frequency electromagnetic waves
- Emitted by stars and galaxies
- Used to transmit signals for radio, TV, blue-tooth & mobile phone
- Transmitted by aerials
- Received by aerials and large dishes (radio astronomy).

Microwaves

- Emitted by cool bodies
- Used to send phone, TV & data signals via satellites
- Transmitted & received using microwave (satellite) dishes
- Heats food from inside by vibrating water & salt ions
- See also Cosmic Microwave Background Radiation (CMBR).

Infrared Radiation (IR)

- Beyond the red, visible part of the spectrum
- Emitted by warm & hot bodies
- Detected by infrared cameras & night sights
- Used to grill food & toast bread
- Used to transmit signals in TV remote controls etc.

Visible light

- Emitted by hot objects
- Focused by lenses (eye, camera)
- Red & blue regions used in photosynthesis
- Red is the lowest frequency visible light
- Violet is the highest frequency visible light.

Ultraviolet

- Beyond the visible violet light
- Emitted by very hot bodies
- Used to sterilize food & equipment.

X-rays

- Emitted by extremely hot bodies
- Produced in stars and supernova explosions
- Produced in Xray machines using electron beams
- Powerful waves that pass through flesh but not bones
- Used to detect broken bones and defects in materials.

Gamma rays

- Extremely high energy waves
- Created during radioactive decay
- Created when stars and black holes collide
- Will pass through very dense materials
- Used to check for defects in metals.

3. Atoms & elements

- Atoms are the tiny units of all matter
- There are about 100 different types of atoms
- These different types of atoms are called the elements
- The elements are arranged in ‘families’ in the Periodic Table
- Hydrogen is the lightest element.

The size of atoms

- Atoms are very small
- The diameter of a helium atom is about 100 pm
- A pm stands for picometre
- A picometre is one millionth millionth of a metre.

The Periodic Table

- The Periodic Table groups the elements by their properties
- Elements on the left are metals
- Metals are generally shiny
- Metals conduct heat and electricity
- Elements on the right are non-metals
- Non-metals are generally dull
- Non-metals do not conduct heat or electricity as well
- Elements in the left-hand column are highly reactive
- Elements in the right-hand column do not react at all.

The atomic nucleus

- Most of the mass of an atom is at the centre, called the nucleus
- The nucleus contains protons and neutrons
- Protons are heavy, positively charged particles
- Neutrons are heavy particles with no charge.

Electrons

- Electrons are tiny and light
- They have a negative charge
- They go around the nucleus, like planets around the Sun.

Electrons & the nucleus

- The negative electrons are attracted to the positive protons
- This is what holds atoms together
- Normally, atoms are neutral
- There are equal numbers of protons (+) and electrons (-)
- The proton number determines the element
- The electrons determine the chemical properties.

Electron shells

- Electrons go around the nucleus
- Electrons are arranged in layers like an onion
- These layers are called shells.

Filling shells

- Each shell only holds a certain number of electrons
- When the inner shell is full, the next shell starts to fill up and so on.

Ions

- It is very difficult to change the nucleus of an atom
- It is fairly easy to add or remove electrons
- An atom that has lost or gained electrons is called an ion
- When electrons are removed the atom becomes a positive ion
- When electrons are added the atom becomes a negative ion.

4. Atomic number & atomic mass

Atomic number

- The proton number determines the element
- The number of protons is called the atomic number
- Hydrogen is the first element (atomic number: 1)
- Helium is the second element (atomic number: 2)
- Lithium is the third element (atomic number: 3) and so on.

Atomic mass

- Protons & neutrons are heavy
- Protons & neutrons are 2000 times heavier than electrons
- Nearly all of an atom's mass is in the nucleus
- Atomic mass is the number of protons + neutrons
- Protons & neutrons are collectively called nucleons
- Nucleons are in the nucleus
- The number of nucleons gives the atomic mass of that atom.

Element symbols

Every element has its own unique symbol, for example:

- Hydrogen is H
- Helium is He
- Lithium is Li
- Carbon is C
- Oxygen is O, and so on.

Hydrogen in detail

- Normal hydrogen has 1 proton, no neutrons
- The nucleon count for hydrogen is therefore 1
- The proton count is also 1
- The combined information for hydrogen is $^{1}_{1}H$
- The top number is the nucleon count
- The bottom number is the proton count.

Helium in detail

- Helium has 2 proton and 2 neutrons
- The nucleon count for hydrogen is therefore 4
- The proton count is 2
- The combined information for hydrogen is $^{4}_{2}He$
- The top number is the nucleon count
- The bottom number is the proton count.

Other detailed examples

Potassium:

- Element symbol K
- Has 19 protons and 20 neutrons
- Nucleon count is 39
- Potassium is therefore $^{39}_{19}K$.

Sodium:

- Element symbol Na
- Has 11 protons
- Has 23 nucleons
- Sodium is therefore $^{23}_{11}Na$.

How many neutrons are there in sodium?

Simplifying the symbols

- Hydrogen has 1 proton
- Any atom with one proton is hydrogen
- Lithium has 3 protons
- Any atom with 3 protons is lithium
- Therefore, there is no need to state the element and the proton count.

Examples:

- Hydrogen $^{1}_{1}H = {}^{1}H$
- Potassium $^{39}_{19}K = {}^{39}K$

Isotopes

- An isotope is an element with a different number of neutrons
- As long as the proton count does not change it is still the same element
- Isotopes of an element behave the same in chemical reactions
- They are, however, heavier or lighter depending on the number of neutrons.

Isotopes of hydrogen

- Normal hydrogen has no neutrons so the symbol is $^{1}_{1}H$
- Some hydrogen atoms also have a neutron so the symbol is then $^{2}_{1}H$
- This is an isotope of hydrogen
- It also combines with oxygen to make water H_2O
- This types of water is called ‘heavy water’
- There is no problem drinking heavy water
- In ordinary water about 1 in 5000 water molecules is heavy.

5. Radioactivity

Neutrons add stability

- Positive charges repel
- Protons in the nucleus repel
- We would expect the nucleus to fly apart
- Neutrons help to make the nucleus stable
- The higher the element, the more neutrons are needed for stability.

Some isotopes are unstable

- If a nucleus has too many or too few neutrons it can be unstable
- This means the nucleus can change into another element by emitting radiation.

Nuclear radiation

There are 3 types of radiation:

- Alpha particles
- Beta particles
- Gamma rays.

Alpha particles:

- These are helium nuclei
- They contain 2 protons (2+) and 2 neutrons
- They are large and easily stopped
- They only travel through 1cm of air
- They are stopped by paper or skin
- Because they have 2 protons they are highly ionizing
- Alpha particles are written as α^{++} or as $^{4}_{2}He^{++}$
- Note: an alpha particle is NOT an atom – it has no electrons.

Beta particles:

- Are electrons (-1)
- Because they only have one charge they are only slightly ionizing
- They are very small
- They will travel through air, paper, skin & thin aluminium
- They are stopped by thick aluminium
- The beta particle symbol is β^- or e^-.

Gamma rays:

- Part of the electromagnetic spectrum
- High frequency, highly energetic waves
- Ionizing radiation
- Only stopped by thick lead and concrete.

Radioactive decay

If a nucleus is unstable then:

- The nucleus can emit radiation
- The nucleus changes into another element
- This is called radioactive decay.

There are 2 types of decay process:

- Alpha decay
- Beta decay.

Radioactive decay is a random process

- We cannot predict when a radioactive atom will decay
- We can measure the time for half of the atoms to decay
- This time is called the half-life
- Different elements have half-lives varying from a fraction of a second to billions of years.

Isotope & half-life

- Half-life is unique to each isotope
- It cannot be changed by temperature or pressure or anything else
- Depending on the isotope, half-life can range from fractions of a second to billions of years.

Examples of half-lives

- Lanthanum (^{138}La): 10 billion years
- Radium (^{226}Ra): 1,600 years
- Bismuth (^{210}Bi): 5 days.

Radiocarbon dating

All living things contain carbon

- Normal carbon is C12 (6 protons, 6 neutrons)
- C14 is a radioactive isotope
- C14 has 6 protons & 8 neutrons
- The half-life of C14 is 5,600 years
- Measure the C14:C12 ratio in a dead organism
- This tells you how long ago it died.

Uranium dating

- Uranium has a half-life of 4,500 million years
- Uranium decays into lead
- Measure the ratio of lead to uranium
- From this we can calculate the age of the Earth.

Energy & mass

- Albert Einstein () is remembered for his theory of General Relativity
- The great discovery here was the relationship between mass and energy
- This is encapsulated in the formula:

. $E = mc^2$

Where:

- Mass m has an intrinsic energy (E) within it
- And c is the velocity of light.

If 5 tonnes of matter could be converted into pure energy it would be enough to run the whole planet for a year.

Hydrogen fusion

- Fusion means joining together
- A star's energy comes from the fusion of hydrogen into helium
- If you could compare the mass of the hydrogen atoms before with the helium atom after the nuclear reaction then a small amount of mass would have been 'lost'
- This lost mass would have turned into energy in the form of heat and light
- This is the process of hydrogen fusion that goes on in stars.

Fusion of higher elements

- Nuclear fusion doesn't have to stop with making helium
- Helium can be fused together to make higher elements
- At each stage, energy is released
- The process stops, however, with iron
- Beyond iron, it takes energy to produce the fusion
- Inside normal stars the fusion stops at iron.

Creating elements beyond iron

- Elements higher than iron can only be produced in a supernova
- See Section 9: Creating the higher elements
- If one of these higher elements can be split into 2 lighter elements then energy will be released
- This is the principle behind nuclear fission.

6. Space & the Universe

The Earth & the Solar System

- Our planet Earth goes round the Sun
- All of the planets go round the Sun
- The path of a planet around the Sun is called its orbit
- The Sun and planets make the Solar System.

Telescopes

- The first telescopes only collected visible light
- These are called optical telescopes
- But light is only one part of the electromagnetic spectrum.

We now have telescopes that can collect

- Radio waves
- Microwaves
- Infrared
- Ultraviolet
- X-rays
- Gamma rays.

Measuring distances in space

- The stars and the galaxies are so far away that we need a different unit to measure distance
- We use the Light-Year (LYr) which is the distance light will travel in a year.

The speed of light is so fast that:

- 1 LYr = 9 million million kilometres
- 1 LYr = 6 million million miles.

The Milky Way galaxy

If you look up at the sky on a clear night well away from street lights, you will see a milky band of light across the sky.

- This is the Milky Way galaxy
- It is not really a milky band – it is made of millions of stars that can only be seen with binoculars or telescopes
- Our Sun is part of this galaxy
- It is difficult to see the shape of this galaxy because we are inside it!

Features of the Milky Way galaxy

- It contains more than 100 billion stars
- It is shaped like a pancake with a bulge at the centre
- Its diameter is about 100,000 LYr
- It contains two major spiral arms and is therefore called a spiral galaxy
- The stars rotate about a common axis through the centre of the galaxy
- The galaxy rotates in about 250 million years
- Our Sun is situated about 2/3 from the centre.

The Universe

- The Universe is everything we can see with our telescopes
- Our Milky Way galaxy is 100,000 Light Years across
- The nearest galaxy to ours is 2 million LYr away
- The most distant objects are over 11 billion LYr away
- It is estimated that the Universe contains more than 100 billion galaxies.

Distant galaxies & the red shift

- Light from distant galaxies is red-shifted
- The galaxies are moving away from us
- This is the Doppler effect.

The expanding Universe

- Light from distant galaxies is red-shifted
- This is the Doppler effect
- Galaxies are moving away from us
- The greater the distance, the faster they are moving
- This suggests that the Universe is expanding.

The Big Bang theory

- The Universe is expanding
- In the past, the galaxies were closer together
- At the beginning, the Universe was very small & dense
- The temperature would have been very high
- This was the moment of the Big Bang
- Time & space start at this point.

The Cosmic Background Microwave Radiation

- The Universe was once hot and dense
- Intense gamma rays were created.

As the Universe expanded, space was stretched:

- The radiation wavelength was stretched
- This means longer wavelengths, lower frequencies
- The radiation is now microwaves
- This was predicted and has now been measured.

Evidence for the Big Bang

The 2 major pieces of evidence for the Big Bang are:

- The red-shift of distant galaxies (the expanding Universe)
- The Cosmic Microwave Background (CMB) radiation.

These 2 pieces of evidence suggest:

- The Universe was more dense in the past
- The Universe was much hotter in the past.

7. The evolution of the Universe

The early Universe

- After the Big Bang the Universe expanded & cooled
- When it had cooled sufficiently, atoms could form.

Of the atoms that formed after the Big Bang:

- 80% were hydrogen
- About 20% were helium
- Plus a tiny amount of lithium and nothing else.

The formation of galaxies

As the Universe expanded:

- Gravity pulled the gas into clumps
- These would become swirling discs of gas
- Within the disc further clumping took place
- In each clump the gas density increased

As gravity pulls the gas clouds inwards:

- The atoms lose gravitational potential energy and
- Gain kinetic energy.

This would increase the number of collisions between gas particles:

- The density increased
- The pressure would rise
- The temperature would rise.

Fusion

When the temperature & pressure reach a critical value

- Hydrogen atoms join (fuse) to make helium
- This is called nuclear fusion
- In this process a large amount of energy is released
- This energy appears as heat and light
- This process is called nuclear fusion
- Nuclear fusion happens inside all stars.

The star becomes stable

- There are now 2 forces acting on the star
- Gravity is pulling the matter inwards
- The energy pressure (heat & light) is pushing outwards
- The star is stable as hydrogen is turned into helium.

Making the higher elements

When all the hydrogen has been turned into helium:

- Helium is turned into carbon, nitrogen & oxygen
- At every stage, more energy is produced
- This process continues up to iron (Atomic Number 26).

Beyond iron:

- Energy is needed to make the higher elements energy is not produced
- The fusion process stops.

Supernova
When a large star reaches the iron limit:

- Nuclear fusion stops
- Gravity wins over the energy force
- The star collapses
- Potential energy is turned into kinetic energy
- More heat is produced
- Fusion beyond iron takes place
- The star explodes (supernova)
- All elements ejected into space.

Birth of the Solar System

- Supernove eject heavy elements into space
- Gravity brings all elements into clumps
- One clump collapses under gravity
- A spinning disc develops
- The central region forms the Sun
- Other clumps in the disc form the planets.

Light & heavy elements

- Hydrogen & helium atoms dispersed thinly in space
- Supernova eject heavier elements into space
- Supernova shock wave forms where atoms collide.

The shock wave starts the process of gravitational collapse and the formation of the Solar System.

Order of abundance of elements in the Milky way:

- Hydrogen (most)
- Helium
- Oxygen
- Carbon
- Neon
- Iron
- Nitrogen
- Silicon
- Magnesium
- Sulphur
- Traces of others.

Formation of compounds in space
Chemical reactions between elements happen in space. These are enhanced by the energy of UV light from the stars. Compounds include:

- Water
- Carbon monoxide
- Carbon-based compounds
- Metal oxides, silicates and sulphides.

8. The structure of the Earth

The Earth is divided into 3 main sectors:

- The core
- The mantle
- The crust.

The core is divided into 2 regions:

- Inner core of solid crystalline iron
- Outer core of liquid iron.
- Some radioactive elements generate heat.

The mantle contains the following elements:

- 44% oxygen
- 23% magnesium
- 22% silicon
- 6% iron
- 2% calcium
- 0.3% sodium.
- Other elements in smaller quantities.

The fluid mantle
The mantle is made up mainly from magnesium & iron silicates.

- The pressure & temperature are high
- The material is a dense, viscous fluid
- Slow convection currents move through the mantle
- These currents make the crust move (Plate Tectonics).

The Earth's crust is mainly

- Quartz (silicon oxide)
- Feldspar (potassium, aluminium & calcium silicates)
- Olivine (magnesium & iron silicates).

The surface of the Earth

- The atmosphere of the early Earth was rich in carbon dioxide
- Water was also abundant
- When combined with the minerals in the Earth's crust, carbonates were formed
- The main mineral was calcium carbonate.

Biological activity, however, has added significant amounts of carbonates (mainly calcium carbonates) in the form of:

- Limestone
- Chalk.