**6. WAVES**

1. Waves in air, fluids and solids
2. *Practical activity (physics only): investigate the reflection of light by different types of surface and the refraction of light by different substances.*
3. Electromagnetic waves
4. *Practical activity: investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.*
5. Black body radiation (physics only)

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| **4.6 Waves** |  |  |  |
| *4.6.1 Waves in air, fluids and solids* |  |  |  |
| **4.6.1.1 Transverse and longitudinal waves** |  |  |  |
| 1. Waves may be either transverse or longitudinal.
2. The ripples on a water surface are an example of a transverse wave.
3. Longitudinal waves show areas of compression and rarefaction.
4. Sound waves travelling through air are longitudinal.
5. Students should be able to describe the difference between longitudinal and transverse waves.
6. Students should be able to describe evidence that, for both ripples on a water surface and sound waves in air, it is the wave and not the water or air itself that travels.
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| **4.6.1.2 Properties of waves** |  |  |  |
| 1. Students should be able to describe wave motion in terms of their amplitude, wavelength, frequency and period.
2. The amplitude of a wave is the maximum displacement of a point on a wave away from its undisturbed position.
3. The wavelength of a wave is the distance from a point on one wave to the equivalent point on the adjacent wave.
4. The frequency of a wave is the number of waves passing a point each second.
* $period= \frac{1}{frequency}$
* $T= \frac{1}{f}$

period, *T*, in seconds, sfrequency, *f*, in hertz, Hze) The wave speed is the speed at which the energy is transferred (or the wave moves) through the medium. |  |  |  |
| a) All waves obey the wave equation:* $wave speed=frequency x wavelength$
* $v=f x λ$

wave speed, *v*, in metres per second, m/sfrequency, *f*, in hertz, Hzwavelength, *λ*, in metres, mStudents should be able to:1. identify amplitude and wavelength from given diagrams
2. describe a method to measure the speed of sound waves in air
3. describe a method to measure the speed of ripples on a water surface.
4. (Physics only) Students should be able to show how changes in velocity, frequency and wavelength, in transmission of sound waves from one medium to another, are inter-related.
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| **Required practical activity 8:** make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in a ripple tank and waves in a solid and take appropriate measurements. |  |  |  |
| **4.6.1.3 Reflection of waves (physics only)** |  |  |  |
| 1. Waves can be reflected at the boundary between two different materials.
2. Waves can be absorbed or transmitted at the boundary between two different materials.
3. Students should be able to construct ray diagrams to illustrate the reflection of a wave at a surface.
4. Students should be able to describe the effects of reflection, transmission and absorption of waves at material interfaces.
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| **Required practical activity 9** (physics only): investigate the reflection of light by different types of surface and the refraction of light by different substances. |  |  |  |
| **4.6.1.4 Sound waves (physics only) (HT only)** |  |  |  |
| 1. Sound waves can travel through solids causing vibrations in the solid.
2. Within the ear, sound waves cause the ear drum and other parts to vibrate which causes the sensation of sound. The conversion of sound waves to vibrations of solids works over a limited frequency range. This restricts the limits of human hearing.
3. Students should be able to describe, with examples, processes which convert wave disturbances between sound waves and vibrations in solids.
	* Examples may include the effect of sound waves on the ear drum
4. explain why such processes only work over a limited frequency range and the relevance of this to human hearing.
5. Students should know that the range of normal human hearing is from 20 Hz to 20 kHz.
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| **4.6.1.5 Waves for detection and exploration (physics only) (HT only)** |  |  |  |
| 1. Students should be able to explain in qualitative terms, how the differences in velocity, absorption and reflection between different types of wave in solids and liquids can be used both for detection and exploration of structures which are hidden from direct observation.
2. Ultrasound waves
* have a frequency higher than the upper limit of hearing for humans.
* are partially reflected when they meet a boundary between two different media.
* The time taken for the reflections to reach a detector can be used to determine how far away such a boundary is.
* This allows ultrasound waves to be used for both medical and industrial imaging.
1. Seismic waves are produced by earthquakes.
* P-waves are longitudinal, seismic waves. P-waves travel at different speeds through solids and liquids.
* S-waves are transverse, seismic waves.
1. S-waves cannot travel through a liquid. P-waves and S-waves provide evidence for the structure and size of the Earth’s core.
2. Echo sounding, using high frequency sound waves is used to detect objects in deep water and measure water depth.
3. Students should be aware that the study of seismic waves provided new evidence that led to discoveries about parts of the Earth which are not directly observable.
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| *4.6.2 Electromagnetic waves* |  |  |  |
| **4.6.2.1 Types of electromagnetic waves** |  |  |  |
| 1. Electromagnetic waves are transverse waves that transfer energy from the source of the waves to an absorber.
2. Electromagnetic waves form a continuous spectrum and all types of electromagnetic wave travel at the same velocity through a vacuum (space) or air.
3. The waves that form the electromagnetic spectrum are grouped in terms of their wavelength and their frequency. Going from long to short wavelength (or from low to high frequency) the groups are: radio, microwave, infrared, visible light (red to violet), ultraviolet, X-rays and gamma rays.

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| long wavelength short wavelength |
| radio waves | microwaves | infrared | visible light | ultraviolet | X-rays | gamma rays |
| low frequency high frequency |

d) Our eyes only detect visible light and so detect a limited range of electromagnetic waves.e) Our skin can detect temperature so we can detect infra-red waves.f) Students should be able to give examples that illustrate the transfer of energy by electromagnetic waves. |  |  |  |
| **4.6.2.2 Properties of electromagnetic waves 1** |  |  |  |
| 1. (HT only) Different substances may absorb, transmit, refract or reflect electromagnetic waves in ways that vary with wavelength.
2. (HT only) Some effects, for example refraction, are due to the difference in velocity of the waves in different substances.
3. Students should be able to construct ray diagrams to illustrate the refraction of a wave at the boundary between two different media.
4. (HT only) Students should be able to use wave front diagrams to explain refraction in terms of the change of speed that happens when a wave travels from one medium to a different medium.
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| **Required practical activity 10**: investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface. |  |  |  |
| **4.6.2.3 Properties of electromagnetic waves 2** |  |  |  |
| 1. (HT only) Radio waves can be produced by oscillations in electrical circuits.
2. (HT only) When radio waves are absorbed they may create an alternating current with the same frequency as the radio wave itself, so radio waves can themselves induce oscillations in an electrical circuit.
3. Changes in atoms and the nuclei of atoms can result in electromagnetic waves being generated or absorbed over a wide frequency range. Gamma rays originate from changes in the nucleus of an atom.
4. Ultraviolet waves, X-rays and gamma rays can have hazardous effects on human body tissue. The effects depend on the type of radiation and the size of the dose.
5. Radiation dose (in sieverts) is a measure of the risk of harm resulting from an exposure of the body to the radiation.
6. 1000 millisieverts (mSv) = 1 sievert (Sv)

Students will not be required to recall the unit of radiation dose.1. Students should be able to draw conclusions from given data about the risks and consequences of exposure to radiation.
2. Ultraviolet waves can cause skin to age prematurely and increase the risk of skin cancer.
3. X-rays and gamma rays are ionising radiation that can cause the mutation of genes and cancer.
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| **4.6.2.4 Uses and applications of electromagnetic waves** |  |  |  |
| 1. Electromagnetic waves have many practical applications. For example:
* radio waves – television and radio
* microwaves – satellite communications, cooking food
* infrared – electrical heaters, cooking food, infrared cameras
* visible light – fibre optic communications
* ultraviolet – energy efficient lamps, sun tanning
* X-rays and gamma rays – medical imaging and treatments.
1. (HT only) Students should be able to give brief explanations why each type of electromagnetic wave is suitable for the practical application.
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| **4.6.2.5 Lenses (physics only)** |  |  |  |
| 1. A lens forms an image by refracting light.
2. In a convex lens, parallel rays of light are brought to a focus at the principal focus. The distance from the lens to the principal focus is called the focal length.
3. Ray diagrams are used to show the formation of images by convex and concave lenses.
4. The image produced by a convex lens can be either real or virtual.
5. The image produced by a concave lens is always virtual.
6. Students should be able to construct ray diagrams to illustrate the similarities and differences between convex and concave lenses.
7. The magnification produced by a lens can be calculated using the equation:
* $magnification= \frac{image height}{object height}$
* Magnification is a ratio and so has no units.
* Image height and object height should both be measured in the same unit e.g. cm.

h) In ray diagrams a convex lens will be represented by: i) A concave lens will be represented by: |  |  |  |
| **4.6.2.6 Visible light (physics only)** |  |  |  |
| 1. Each colour within the visible light spectrum has its own narrow band of wavelength and frequency.
2. Reflection from a smooth surface in a single direction is called specular reflection.
3. Reflection from a rough surface causes scattering: this is called diffuse reflection.
4. Colour filters work by absorbing certain wavelengths (and colour) and transmitting other wavelengths (and colour).
5. The colour of an opaque object is determined by which wavelengths of light are more strongly reflected.
6. Wavelengths that are not reflected are absorbed.
7. If all wavelengths are reflected equally the object appears white.
8. If all wavelengths are absorbed the objects appears black.
9. Objects that transmit light are either transparent or translucent.

Students should be able to explain:1. how the colour of an object is related to the differential absorption, transmission and reflection of different wavelengths of light by the object
2. the effect of viewing objects through filters or the effect on light of passing through filters
3. why an opaque object has a particular colour.
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| *4.6.3 Black body radiation (physics only)* |  |  |  |
| **4.6.3.1 Emission and absorption of infrared radiation** |  |  |  |
| 1. All bodies (objects), no matter what temperature, emit and absorb infrared radiation.
2. The hotter the body, the more infrared radiation it radiates in a given time.
3. A perfect black body is an object that absorbs all of the radiation incident on it. A black body does not reflect or transmit any radiation.
4. Since a good absorber is also a good emitter, a perfect black body would be the best possible emitter.
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| **4.6.3.2 Perfect black bodies and radiation** |  |  |  |
| 1. Students should be able to explain:
* that all bodies (objects) emit radiation
* that the intensity and wavelength distribution of any emission depends on the temperature of the body.
1. (HT only) A body at constant temperature is absorbing radiation at the same rate as it is emitting radiation. The temperature of a body increases when the body absorbs radiation faster than it emits radiation.
2. (HT only) The temperature of the Earth depends on many factors including: the rates of absorption and emission of radiation, reflection of radiation into space.
3. (HT only) Students should be able to explain how the temperature of a body is related to the balance between incoming radiation absorbed and radiation emitted, using everyday examples to illustrate this balance, and the example of the factors which determine the temperature of the Earth.
4. (HT only) Students should be able to use information, or draw/ interpret diagrams to show how radiation affects the temperature of the Earth’s surface and atmosphere.
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**PHYSICS EQUATIONS TO LEARN BY HEART (SEPARATE PHYSICS)**

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| **WAVES** |
|  | **Quantity** | **Unit** | **Equation** |
| *WAVES* | *23* | **v****f****λ** | velocityfrequencywavelength | metre per secondhertzmetre | m/sHzm | $$v=f x λ$$ |