Electromagnetic Radiation – Part 2

Electromagnetic radiation has the ability to penetrate material such as glass, bone, air and as such can be useful but also dangerous. The ability of EM radiation to penetrate material depends on the amount of energy the radiation has, which is directly linked to its frequency.

You need to be able to indicate the penetrating ability of the different kinds of EM radiation and relate this to their frequency and energy. You also need to be able to describe the dangers of each type of EM radiation.

Penetrating ability:

- *Gamma rays* have the highest frequency of the EM waves (thus highest energy). They are the most penetrative and can pass through most substances (e.g. bone, tissue).

- Lower frequency radiation (*UV*, *visible light*, and *infrared* radiation) have less energy. This amount of energy is the right amount to make molecules (in a material) vibrate. These radiations are therefore absorbed more easily, and do not penetrate matter as effortlessly.

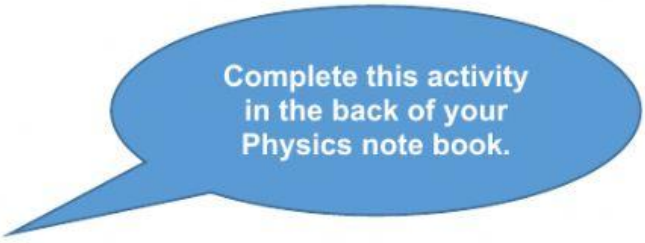
- Low frequency *radio waves* have the least energy but can travel long distances without being absorbed. These do not have enough energy to cause molecules to vibrate and so are not absorbed.

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Dangers:

- *Gamma rays*: uncontrolled exposure causes mutations, chromosome abnormality and cell death.
- High dosages of *x-rays* can cause tissue to burn and can cause cancer.
- *UV radiation* (from sun) can result in reddening and burning of the skin and ultimately skin cancer.
- *Cell phones and microwave radiation*: Cell phone radiation and health concerns have been raised, especially following the enormous increase in their use. This is because cell phones use electromagnetic waves in the microwave range. These concerns have induced a large body of research. Concerns about effects on health have also been raised regarding other digital wireless systems, such as data communication networks.

  In 2009 the World Health Organisation announced that they have found a link between brain cancer and cell phones. However, there is still no firm evidence for this and the link is tenuous at best. You can find out more at http://www.who.int/mediacentre/factsheets/fs193/en/a.



Exercise 11-2:

1. Indicate the penetrating ability of the different kinds of EM radiation and relate it to energy of the radiation.

2. Describe the dangers of gamma rays, X-rays and the damaging effect of ultra-violet radiation on skin.

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Energy of Electromagnetic Radiation

DEFINITION: Photon

A photon is a quantum (energy packet) of light.

- Calculate the energy of a photon using:

$$E = hf \qquad \text{OR} \qquad E = \frac{hc}{\lambda}$$

Where:

Unit for Energy is Joules, J.
h = Planck's constant (see below)
f = frequency of wave (Hz)
c = speed of light (3×10^8 ms^{-1})
λ = wavelength of light (m)

DEFINITION: Planck's constant

Planck's constant is a physical constant named after Max Planck.
$h = 6,63 \times 10^{-34}\ J \cdot s$

Example 1

Calculate the energy of a photon with a frequency of 3×10^{18} *Hz*

$$\begin{aligned} E &= hf \\ &= \qquad\quad J \cdot s \times 3 \times 10^{18}\ Hz \\ &= \quad \times 10^{-15}\ J \end{aligned}$$

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Example 2

What is the energy of an ultraviolet photon with a wavelength of 200 nm?

$$E = h\frac{c}{\lambda}$$

$$E = h\frac{c}{\lambda}$$

$$= (6,63 \times 10^{-34}\ \mathrm{J \cdot s})\ \frac{\mathrm{m \cdot s^{-1}}}{200 \times 10^{-9}\ \mathrm{m}}$$

$$= \quad \times \ 10^{-19}\ \mathrm{J}$$

Worksheet

Do all calculations in the back of your Physics book and fill in answers here...

Exercise 11-3:

1. How is the energy of a photon related to its frequency and wavelength?
2. Calculate the energy of a photon of EM radiation with a frequency of 10^{12} Hz
3. Determine the energy of a photon of EM radiation with a wavelength of 600 nm.

End of chapter exercises:

1. What is the energy of a photon of EM radiation with a frequency of 3×10^{8} Hz ?
2. What is the energy of a photon of light with a wavelength of 660 nm?
3. What is the energy of a photon of light with a frequency of 13THz?

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4. What is the wavelength of a photon of light with a frequency of 101,3 kHz?

5. What is the energy of a photon of light with a wavelength of 532 nm and one with a frequency of 13GHz, and which has the longer wavelength?
(tick the box next to the answer with longer wavelength)

532nm: **13GHz:**

6. List the main types of electromagnetic radiation in order of increasing wavelength.

7. List the main uses of:
a) radio waves
b) infrared
c) gamma rays
d) X-rays

8. Calculate the energy of a photon of light with a wavelength of 1×10^{2} m.

9. Calculate the frequency of a photon of light, which has a wavelength of $2x10^{-1}$ m.

10. Calculate the frequency of a photon of light, which has an energy of 2×10^{-8} J.

11. Determine the energy of a photon of light, which has a frequency of 1×10^{16} Hz.

12. Determine the wavelength of a photon with an energy of 4×10^{-11} J.

13. Calculate the speed of a sound wave if it takes 0,4 seconds to form one wave and the wavelength is 7 mm.

Hint: remember wavelength must be in metres

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14. Calculate the wavelength of a wave if the speed is 3 $km.h^{-1}$ and it takes 0,5 seconds to form one wave.

Hint: How do you convert kmh^{-1} to ms^{-1}?!

15. Calculate the speed of a sound wave if the distance from the crest to crest is 0,2 cm and it takes 1 minute to form 1 wave.

16. Skye stands at the front of the class and shouts. The sound wave takes 4,5 seconds to return to her. Calculate the distance to the back of the class (assume the speed of sound in air is 340 $m.s^{-1}$).

17. Calculate the period of a wave if the speed of the wave is 400$m.s^{-1}$ and the distance from one trough to the next is 30 pm.

18. Calculate the distance between Keroshan and Blessing if Blessing shouts and the sound takes 2 seconds to reach Keroshan.

19. Lightning strikes and 3 seconds later Bobby hears it. Calculate the distance between where the lightning hit and Bobby's house.

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20. If a light wave takes 14 seconds to travel from point A to point B, calculate the distance between point A and B.

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