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Physics
Teach Yourself Series
Topic 12: Light as a wave (Unit 4)

A: Level 14, 474 Flinders Street Melbourne VIC 3000
T: 1300 134 518 **W:** tssm.com.au **E:** info@tssm.com.au

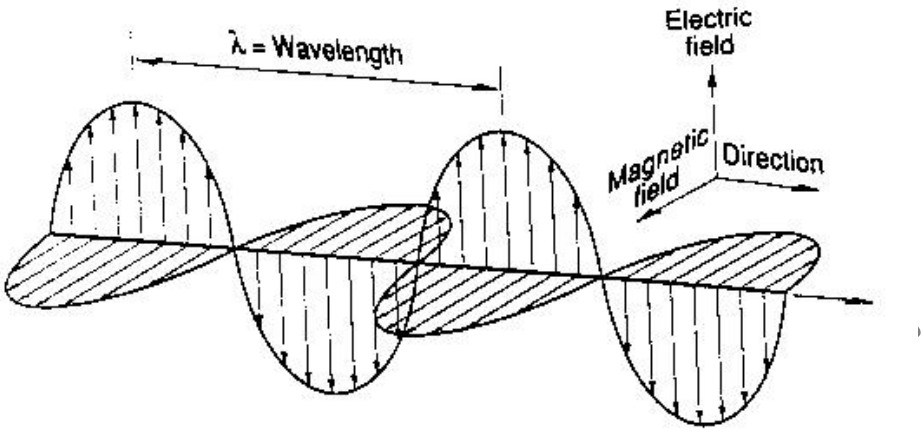
Contents

What you shouldknow

As it appears in Unit 4

- describe light as an electromagnetic wave which is produced by the acceleration of charges, which in turn produces changing electric fields and associated changing magnetic fields
- identify that all electromagnetic waves travel at the same speed, *c*, in a vacuum
- compare the wavelength and frequencies of different regions of the electromagnetic spectrum,including radio, microwave, infrared, visible, ultraviolet, x-ray and gamma, and identify the distinct uses each has in society
- explain polarisation of visible light and its relation to a transverse wave model
- investigate and analyse theoretically and practically the behaviour of waves including:
    - refraction using Snell's Law$n_i \sin\theta_i = n_r \sin\theta_r$ and $n_1 v_1 = n_2 v_2$
    - total internal reflection and critical angle including applications: $\sin\theta_c = \frac{n_r}{n_i}$
- investigate and explain theoretically and practically colour dispersion in prisms and lenses with reference to refraction of the components of white light as they pass from one medium to another

Electromagnetic waves
As it appears in Unit 4



Electromagnetic waves are made up of oscillating electric and magnetic fields that generate each other. An electromagnetic wave travels in three dimensions simultaneously. The electric and magnetic vectors oscillate in mutually perpendicular planes.

Electromagnetic waves are ***transverse waves***, as the electric and magnetic fields both vibrate at right angles to the direction of propagation of the waves. Electromagnetic waves can travel through vacuum.Electromagnetic waves are produced by the acceleration of electric charges.

Visible light can be produced in a synchrotron when electrons are accelerated in circular orbits by deflecting magnetic fields.All electromagnetic waves travel through vacuum with the same speed, $c = 3\times10^{8}\,\mathrm{m\,s^{-1}}$

Frequency and wavelength can be measured for all electromagnetic waves

The wave equation for electromagnetic waves is

$$c = f\lambda$$

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Solutions to Review Questions

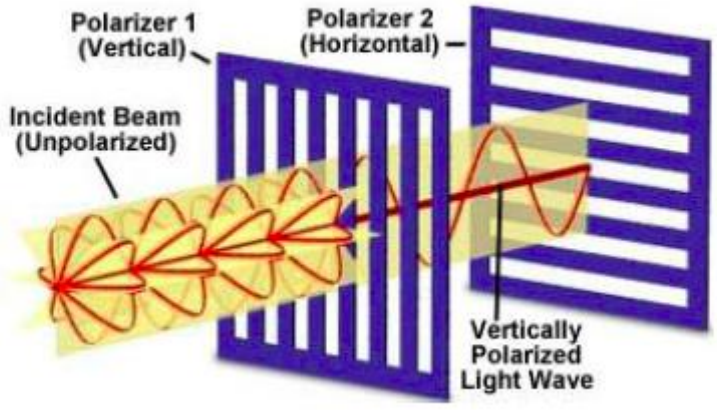
1. Ultraviolet and X-ray.

2. Speed stays constant.

3. $v = f\lambda$
$3.0 \times 10^{8} = 3.0 \times 10^{13} \times \lambda$
$\lambda = 1.0 \times 10^{-5}\text{m}$
Therefore from the diagram on page 6 this would be infrared.

4. Penetrating power is proportional to energy and as $E = hf$ as the frequency increases the amount of energy increases therefore so does the penetrating power. Therefore the low frequency or radio end of the spectrum would be the least penetrating.

5. Polarisers are made up of either vertical or horizontal filters. They absorb all waves that are not travelling in their line of propagation. The first filter below only allows waves travelling on a vertical plane through while the second one allows none through due to the horizontal plane.



6. Sound can not be polarised as sound is a longitudinal wave.Sound will pass through a polarising filter and will notbe affected by the alignment of the filters

7.
a. 15^{o}
b. 15^{o}

8. Medium 2 must have a higher refractive index, meaning light travels more slowly within it. For agiven frequency (this remains constant) this would reduce the wavelength as shown in the diagram.

9. $n_i \sin\theta_i = n_r \sin\theta_r$

$1.52 \sin\theta_i = 1.0 \sin 60$
$\theta_i = 34.73^0$

10. $n_i \sin\theta_i = n_r \sin\theta_r$
$1.0 \sin 30 = n_r \sin 20$
$n_r = 1.46$

11.

a. A
b. B
c. B

12. $\sin\theta_c = \frac{n_2}{n_1} = \frac{1}{1.52}$
$\theta_c = 41.14^0$

The incident angle of $38^0 < \theta_c$, therefore refraction will occur and some light will enter the air.

13. $\sin\theta_c = \frac{n_2}{n_1} = \frac{1.44}{1.46}$
$\theta_c = 80.5^0$

The incident angle of $82^0 > \theta_c$, so at this angle light no longer refracts. It willbe totally reflected.

14. D