Waves and Radiation

Electromagnetic Radiation and Light

N4/5 Summary Notes
Content Level 4

SCN 4-11b
By carrying out a comparison of the properties of parts of the electromagnetic spectrum beyond the visible, I can explain the use of radiation and discuss how this has impacted upon society and our quality of life.

SCN 4-16a
I have carried out research into novel materials and can begin to explain the scientific basis of their properties and discuss the possible impacts they may have on society.

SCN 4 - 20a
I have researched new developments in science and can explain how their current or future applications might impact on modern life.

SCN4-20 b
Having selected scientific themes of topical interest, I can critically analyse the issues and use relevant information to develop an informed argument.

Content National 3

Light
Light travels in straight lines
Reflection of light
Convex and concave lenses

Colour

Optical Instruments

Electromagnetic Radiation
Content National 4

Electromagnetic Spectrum
Applications and hazards associated with electromagnetic radiations.
Approaches to minimising risks associated with electromagnetic radiations.

Content National 5

Electromagnetic Spectrum
Relative frequency and wavelength of bands of the electromagnetic spectrum with reference to typical sources and applications
Qualitative relationship between the frequency and energy associated with a form of radiation
All radiations in the electromagnetic spectrum travel at the speed of light.

Light
Refraction of light including identification of the normal, angle of incidence and angle of refraction.
Description of refraction in terms of change of wave speed.
Total internal reflection including relevant applications
Learning Outcomes

At National 4 level, by the end of this section you should be able to:

Electromagnetic Spectrum

1. Describe applications and hazards associated with electromagnetic radiations.

2. Describe approaches to minimising risks associated with electromagnetic radiations.

At National 5 level, by the end of this section you should be able to:

Electromagnetic Spectrum

1. List the different sections of the electromagnetic spectrum in order of increasing wavelength (or frequency as appropriate)

2. State possible sources for each section of the electromagnetic spectrum

3. Describe possible applications for each section of the electromagnetic spectrum.

4. Name a suitable detector for each section of the electromagnetic spectrum.

5. State that the higher the frequency the greater the energy associated with a form of radiation.

6. State that all radiations in the electromagnetic spectrum travel at the speed of light.
All the parts of the electromagnetic spectrum travel at the *speed of light*. 
\((3 \times 10^8 \text{ m/s or } 300,000,000 \text{ m/s})\)

The equations \(v = f\lambda\) and \(\text{speed} = \frac{\text{distance}}{\text{time}}\) can be used to calculate information about the waves.

The higher the frequency the greater the energy.
## Radio and TV

### Typical source
Electrical Aerial/ radio transmitter.
Also produced by stars, sparks and lightning which is why you hear interference in a thunderstorm.

### Application
Telecommunications
- Broadcasting radio and tv programmes
- Radio signals used for communication
- Mobile phones, wireless networking and amateur radio.

### Detector
Aerial

### Possible hazards
Potential increased cancer risk

Large doses of radio waves are believed to cause cancer, leukaemia and other disorders.
Microwaves

**Typical source**
Stars
Magnetron in a microwave or radar.

Mobile phones (radio transmission at a different frequency)

**Application**
Heating food in a microwave oven (causes water and fat molecules to vibrate, creating heat)
Used in radars - navigation of ships and aircraft / Used to predict weather
- Speed cameras
Mobile phones - only needs a small antenna, which keeps down size, but means low power.

**Detector**
Aerial, diode probe

**Possible hazards**
Heating of body tissues
Prolonged exposure to microwaves is known to cause "cataracts" in your eyes, which is a clouding of the lens, preventing you from seeing clearly (if at all!)
Recent research indicates that microwaves from mobile phones can affect parts of your brain - after all, you're holding the transmitter right by your head.
People who work on aircraft carrier decks wear special suits which reflect microwaves, to avoid being "cooked" by the powerful radar units in modern military planes.
## Infra-Red

<table>
<thead>
<tr>
<th>Typical source</th>
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<tbody>
<tr>
<td>Heat-emitting objects - stars, flames, lamps, people etc.</td>
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<tr>
<td>Remote controls</td>
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<table>
<thead>
<tr>
<th>Application</th>
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<tbody>
<tr>
<td>Thermograms</td>
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<tr>
<td>Used by physiotherapists to help muscle healing - heat lamps.</td>
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<tr>
<td>Used to heat buildings more efficiently - heat lamps in corners of large halls.</td>
</tr>
<tr>
<td>Detection of infra-red radiation can be used to help diagnose illnesses which cause heat and inflammation Used to find people lost at sea.</td>
</tr>
<tr>
<td>Used to check for heat loss in pipes. Used for security on banknotes.</td>
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</table>

<table>
<thead>
<tr>
<th>Detector</th>
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<tbody>
<tr>
<td>Phototransistor, blackened thermometer</td>
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<tr>
<td>Web cam with filter removed.</td>
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</table>

<table>
<thead>
<tr>
<th>Possible hazards</th>
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</thead>
<tbody>
<tr>
<td>Heating of body tissues</td>
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</table>
Visible Light

Typical source
Stars
Anything that glows - light bulbs etc.

Application
Vision
Lasers - printers, CD's, weapon aiming systems, DVD's

Detector
Eye, photographic film

Possible hazards
Intense light can damage the retina
Too much light can damage the retina in your eye.
This can happen when you look at something very bright, such as the Sun.
Although the damage can heal, if it's too bad it'll be permanent.
Ultraviolet

Typical source
Sunlight
UV lamps - e.g. the ones seen in shops selling food.
Bank note testers.

Application
Treating skin conditions. Helps body produce vitamin D.
Used to set or harden some filling materials at the dentist.
Used as a tracer in biological experiments.
Fluorescence is used to mark valuables and to identify real bank notes.
UV can kill bacteria and microbes, so is used as a sterilizer.

Detector
Fluorescent paint
Tonic water
Fluorescent pens

Possible hazards
Skin cancer
Large doses of UV can damage the retina in your eyes, so it's important to check that your sunglasses will block UV light.

Cheap sunglasses can be dangerous because they may not block UV light as effectively as the more expensive ones. The pupil of your eye opens up more because some of the sunlight is being blocked, allowing the UV light through to damage your eye. Check the information before you buy!

Large doses of UV cause sunburn and even skin cancer. Fortunately, the ozone layer in the Earth's atmosphere screens us from most of the UV given off by the Sun. Think of a sun tan as a radiation burn!

Other sources of UV burns – snowblindness, welder's flash.
**X-Rays**

**Typical source**
X-ray tube in a machine, cosmic sources

**Application**
Medical imaging - to detect broken bones, or with contrast material to investigate the stomach and intestines. Radiotherapy is the use of X-rays to treat tumours.
Used to check weld quality in pipes etc.
Scanning luggage at airports. Used in astronomy.

**Detector**
Photographic plates

**Possible hazards**
Destroys cells which can lead to cancer
X-Rays can cause cell damage and cancers.
This is why Radiographers in hospitals stand behind a shield when they X-ray their patients. Although the dose is not enough to put the patient at risk, they take many images each day and could quickly build up a dangerous dose themselves.
Gamma Rays

Typical source
Nuclear decay
Given off by stars

Application
Treating tumours - to kill cancerous cells. (Radiotherapy)
Used as a tracer in the body to see what is happening in parts of the body which don't show up well on x-rays e.g. blood flow through kidneys, air flow through lungs.

Detector
Geiger-Müller tube and counter
Photographic Film
Scintillation counter

Possible hazards
Destroys cells which can lead to cancer
Gamma rays cause cell damage and can cause a variety of cancers. They cause mutations in growing tissues, so unborn babies are especially vulnerable.
Learning Outcomes

At Nat 3, by the end of this section you should be able to:

Light

☆ 1. State that light travels in straight lines.
☆ 2. Label a diagram showing reflection in a plane mirror including
   o Incident ray
   o Reflected ray
   o Incident angle
   o Reflected angle
   o Normal
☆ 3. State that the normal is a reference line.
☆ 4. State that the angle of reflection is equal to the angle of incidence.
☆ 5. State that the path followed by light in reflection is reversible.
☆ 6. Identify convex and concave lenses
☆ 7. Draw the ray diagram associated with both convex and concave lenses.

At National 5 level, by the end of this section you should be able to:

Light

○ 1. Draw diagrams showing refraction in a rectangular block and in a semicircular block including
   o Incident ray
   o Refracted ray
   o Incident angle
   o Angle of refraction
   o Normal
○ 2. State that the normal is a reference line drawn at right angles to the surface.
○ 3. Describe refraction in terms of change of wave speed.
Reflection

We know that light travels in straight lines because it casts shadows when something that light cannot pass through is placed in the way.

Reflection in a Mirror

When light is reflected in a mirror it bounces off at the same angle as it hits the surface.
Angles are measured relative to the 'normal' which is a reference line at 90° to the surface.
If light is shone back along the same path it comes out at the starting point.
When light passes into a material of higher density it slows down, which also causes it to change direction.

Light entering a block at right angles to the surface will pass straight through. If it meets the surface at an angle, it appears to ‘bend’.

The normal is a reference line, drawn at right angles to the surface where the incident ray touches it. All angles are measured between the ray and the normal.

Triangular Prism

Light passing through a prism will change direction as it enters and as it leaves the block. If it is white light, the light leaving the block will split up into the visible spectrum. (See Dynamics and Space notes)
Lenses

Convex Lens

A convex lens brings rays of light together at the focal point. The thicker the lens the shorter the focal length. Also called a converging lens.

Concave Lens

A concave lens spreads rays of light out. The thicker the lens the shorter the focal length and the more the rays are spread out. Also called a diverging lens.

Focusing on near and far objects

<table>
<thead>
<tr>
<th>Near objects</th>
<th>Distant objects</th>
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<tbody>
<tr>
<td><img src="image1" alt="Near objects diagram" /></td>
<td><img src="image2" alt="Distant objects diagram" /></td>
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</tbody>
</table>
Long and Short Sight

Long Sight

Definition - can see far objects clearly, but cannot focus on near objects (like a newspaper)

The rays of light would come together behind the retina - this means the image on the retina is out of focus.

Short Sight

Definition - can see near objects clearly but cannot focus on far away objects.

The rays of light would come together in front of the retina - this means the image on the retina is out of focus.

A concave lens causes the rays of light to spread out before they enter the eye so that the image on the back of the eye is in focus.
Focal Length

Image on the retina

The image on the retina is
- Upside down
- Back to front

How to find the focal length of a convex lens

Method 1
- Take a ruler, a lens and a piece of paper and find something outside the window to focus on.
- As someone to hold the piece of paper as a screen, with the ruler held below it to measure the distance from the screen.
- Move the lens until you have a sharp image on the piece of paper. (it will be upside down)
- The distance between the lens and the piece of paper is the focal length of the lens.

Method 2
- Using a raybox, shine three rays of light through a lens so that they come to a focus behind the lens. (like the diagram above).
- Measure the distance from the lens to the focal point.
- This is the focal length of the lens.
Power of a Lens

\[ P = \frac{1}{f} \]

- \( P \) = power of the lens (Dioptres, D)
- \( f \) = focal length of the lens (metres, m)

**Example 1.**
If a convex lens has a focal length of +2m, what is its power?

\[ P = \frac{1}{f} = \frac{1}{2} = +0.5D \]

**Example 2.**
A concave lens has a power of -10 D. What is its focal length?

\[ f = \frac{1}{-10} = -0.1m \]

**Example 3**
If a convex lens has a focal length of +25cm, what is its power?

\[ P = \frac{1}{f} = \frac{1}{0.25} = +4D \]

**Example 4**
Two lenses are listed as having powers of +8D and -3D respectively. Calculate which has the shortest focal length. Could this lens be used to correct long sight?

\[ f = \frac{1}{-3} = -0.33m \]
\[ f = \frac{1}{8} = 0.125m \]
Yes - it is a convex lens.
Total Internal Reflection

Small angles of incidence

When the angle of incidence is small the light is refracted out of the block.

Large angles of incidence

When the angle of incidence is large the light reflects on the back wall of the block – total internal reflection

Critical angle

At a specific angle of incidence - the critical angle - the light passes along the back wall of the block.
Applications of Total Internal Reflection

Fibre Optics

How it works.

Light is totally internally reflected on the inside wall of the glass fibre.

Endoscope

The endoscope has two bundles of optical fibres. One carries light into the patient, the other carries the image out to the surgeon. This gives close images of internal structures without surgery. It also allows samples to be taken. Benefits to the patient are minimal time in hospital and no surgery to recover from.