Misconceptions on Waves and Light from Internet searches

1. The Nature of Light and Sight

- The "Active Eye" (Outward Vision): The belief that we see because our eyes "send out" rays to look at objects, rather than light reflecting into the eye.
- Light travels "Instantly": The idea that light does not have a speed and just "is" everywhere at once.
- Light is a "Stuff": Viewing light as a physical material that fills a room like a gas, rather than an electromagnetic wave.
- The "Fading" Light: The belief that light only travels a certain distance and then just "stops" or disappears if it doesn't hit anything.
- Darkness is a Substance: Thinking that darkness is a "thing" that moves into a room, rather than the absence of light.

2. **Reflection and Refraction**

- Mirror images are "On" the mirror: The belief that the image is a flat picture on the glass surface, rather than located behind the mirror.
- Light only reflects from shiny things: Not realizing that we see non-shiny objects (like a wall) because they reflect light in many directions (diffuse reflection).
- Refraction is "Bending" the object: Thinking the object itself (like a straw in water) has physically broken or bent, rather than the light path changing.
- Shadows are "Cast" by the object: Seeing a shadow as a positive thing that an object "makes," rather than a region where light has been blocked.
- Colour is "In" the object: The belief that a red apple is red, rather than the apple reflecting red light and absorbing other colours.

3. Sound and Waves

- Waves transport matter: The belief that the water particles in a wave travel from the middle of the ocean to the shore (rather than just vibrating in place).
- Sound can travel in a vacuum: The idea that sound can travel through space (sci-fi movies).
- Pitch and Loudness are the same: Using the terms interchangeably; not distinguishing between frequency and amplitude.
- Matter "blocks" sound entirely: Not realizing that sound travels faster and more effectively through solids than through air.
- Waves "Die" out: Thinking waves lose energy because they are tired, rather than the energy spreading out or being absorbed.

4. The Electromagnetic Spectrum

- Radio waves are sound: The very common belief that radio waves are the actual sound waves coming out of a speaker.
- Gamma rays are always "Evil": The belief that all radiation is man-made and always harmful, ignoring natural background radiation or medical uses.
- Microwaves cook from the "Inside out": A myth; microwaves penetrate only a few centimetres and cook via the vibration of water molecules.
- Light and Radio are different things: Not realizing they are the same phenomenon (EM waves) at different frequencies.
- Transparent means "Nothing": Thinking that glass or water has no effect on light because we can see through it.

Waves and Light Diagnostic Quiz

Name: _____ Date: _____

Instructions: Circle the best answer for each question.

1. How do you see a book sitting on a desk in a room with a lamp?
· A) Your eyes send out "sight rays" that hit the book.
· B) The book creates its own light so you can see it.
· C) Light from the lamp reflects off the book and enters your eyes.
· D) The light from the lamp fills the room and stays there.

2. If you are standing 1 meter in front of a flat mirror, where is your image located?
· A) On the surface of the glass.
· B) 1 metre behind the mirror.
· C) 1 meter in front of the mirror, between you and the glass.
· D) Inside your own eyes.

3. Why does a straw look "broken" when you put it into a glass of water?
· A) The weight of the water pushes the straw until it bends.
· B) The light changes speed and direction as it moves from water to air.
· C) Water acts as a magnifying glass that enlarges the bottom half.
· D) The straw is physically bent by the surface tension.

4. A tree casts a shadow on the ground on a sunny day. What is a shadow?
· A) A dark "reflection" made by the tree.
· B) A region where light from the sun has been blocked by the tree.
· C) A substance that the tree spreads on the ground.
· D) The "cold" part of the ground.

5. What happens to the particles of water as a wave passes through them in the open ocean?
· A) They travel with the wave all the way to the beach.
· B) They stay in the same general place, moving up and down or in small circles.
· C) They disappear and are replaced by new particles.
· D) They move in the opposite direction of the wave.

6. If a giant explosion happened in deep space, why would a nearby astronaut see it but not hear it?
· A) Space is too cold for sound to move.
· B) Sound waves need particles (a medium) to travel, and space is a vacuum.
· C) The astronaut’s helmet blocks sound but lets in light.
· D) The light moves so fast that the sound can't catch up.

7. Why does a red shirt look red when "white" sunlight hits it?
· A) The shirt adds red energy to the light.
· B) The shirt absorbs red light and reflects all other colours.
· C) The shirt reflects the red part of the white light and absorbs the other colours.
· D) White light doesn't have colours in it until it hits the shirt.

8. Which of the following is true about "Radio Waves"?
· A) They are a type of sound wave that travels through the air.
· B) They are a type of light (electromagnetic wave) that we cannot see.
· C) They only exist inside a radio or a cell phone.
· D) They travel much slower than the speed of light.

9. When you turn off a light in a room, where does the light go?
· A) It is absorbed by the walls and furniture and turned into a tiny amount of heat.
· B) It stays in the air but becomes too dim to see.
· C) It flows back into the light bulb.
· D) It just disappears and ceases to exist.

10. In a wave, "Frequency" refers to:
· A) How tall the wave is.
· B) How many waves pass a point every second.
· C) How much energy the wave started with.
· D) How far the wave travels before it stops.

Teacher's Answer Key & Diagnostic Guide

Q#	Correct	Misconception Identified by Incorrect Answers
1	C	A: Outward vision/Sight rays; B: Non-luminous objects emit light.
2	B	A: Image is on the surface; C/D: Image location confusion.
3	B	A/D: Physical bending of the object; C: General "magnification."
4	B	A/C: Shadow as a "thing" or a "reflection."
5	B	A: Waves transport matter/particles.
6	B	C: Sound can travel in a vacuum; D: Speed vs. Medium.
7	C	B: Absorption vs. Reflection confusion; D: Nature of white light.
8	B	A: Radio waves are sound waves.
9	A	B/D: Light is a "stuff" that stays in air or disappears.
10	B	A: Frequency vs. Amplitude; C/D: General wave properties.

List of students' misconceptions and difficulties in wave optics

The following list mainly stems from the analysis of the results of studies conducted by the Washington PER group. Only the misconceptions that can be considered as relevant for our study are reported (i.e., misconceptions related to polarisation are excluded).

- Mistaken belief that diffraction pattern occur even when light hits relatively wide slits .
- Mistaken belief that geometrical optics models are adequate for predicting the path of light which hits very narrow slits (e.g., slits whose order of magnitude is similar to the order of magnitude of the light's wavelength).
- Mistaken belief that narrowing the slit leads to narrowing of the central diffraction maximum.
- Mistaken belief that light rays propagate rectilinearly through the centre of the slit, whereas diffraction effects occur at the edges of the slit, only.
- Mistaken belief that the central maximum represents the geometrical image of the laser.
- Mistaken belief that the diffraction pattern is only due to the part of light beam incident on the edges of the slit.
- Mistaken belief that the intensity of light at an arbitrary point of the screen equals the sum of light intensities originating from each of the sources.
- Mistaken belief that covering one of the two slits in two-slit diffraction merely causes the diffraction pattern to be more or less intense.
- Mistaken belief that each of the two slits in double slit interference is responsible for generating half of the interference pattern on the screen.
- Mistaken belief that covering half of the slit in the one slit diffraction experiment, results in vanishing of half of the original diffraction pattern.
- Mistaken belief that light cannot pass the slit if width of the slit is less than the wavelength of light.
- Mistaken belief that diffraction only occurs if width of the slit is less than the wavelength of light.
- Difficulty reflected in the fact that students often fail to recognize the importance of considering the differences of optical path lengths for purposes of predicting or explaining the nature of interference patterns.
- Mistaken belief that the difference in optical path lengths becomes negligible at distant points. • Difficulty reflected in the fact that students often fail to demonstrate understanding of the derivation of the formula for location of diffraction minima/interference maxima.
- Difficulty reflected in the fact that students often fail to interpret formal representations of plane electromagnetic waves.
- Difficulty reflected in the fact that students often fail to recognize the nature of interdependence of the electrical and magnetic component of the electromagnetic wave.
- Mistaken belief that the increase of wave amplitude results in the fact that the wave cannot pass the slit ("because light travels as a sinusoid").
- Mistaken belief that the electromagnetic field is spatially confined by means of the sinusoid.
- Mistaken belief that along the line of light propagation, electric and magnetic fields equal zero.
- Mistaken belief that adding more slits necessarily results in modifying all the aspects of the diffraction pattern (e.g., the location of every maximum must change if we add one more slit).
- Mistaken belief that the angle between phasors (phase difference) equals the angle which is used for purposes of locating the maxima/minima of the interference/diffraction pattern.
- Difficulty reflected in the fact that students fail to relate diffraction phenomena to the phase differences of a large number of secondary sources of light.

Common Misconceptions About Light

Examples of Students' Claims from Round Robin Journaling

- Only shiny objects that I can see myself in reflect light.
- Only metals and water reflect light.
- Everything reflects light but only if it is in the Sun.
- Light reflects off things if the angle is correct.
- The hotter an object can get the more light it can reflect. General Misconceptions About Light
- Different wavelengths of light have different energy and therefore different speeds.
- A radio wavelength is a sound wave not part of the electromagnetic spectrum.
- Black does not reflect any light and/or white does not absorb any light.
- Only shiny materials reflect light.
- Water does not reflect or absorb light but light can go through it.
- The distance that light travels depends on the amount of energy that light has.
- When a lens is moved an image will become bigger or smaller but will always remain sharp.
- The stronger the source of light the bigger the shadow and the bigger the source of light the smaller the shadow.
- Shiny objects reflect more light than dull objects.
- Light always passes straight through transparent objects (without changing direction).
- An observer can see more of himself by backing up.
- The size of the image depends on the diameter of the lens.
- Light needs air to travel.
- The distance light travels depends on day or night.
- Objects that reflect are sources of light (e.g., the Moon).
- Sunlight is hot (has energy) but visual light is not.
- Our eyes produce light so we can see things.
- Moving position when looking at a mirror image will change the amount of the image that can be seen or the position of the image in the mirror.
- Shadows are always black
- A shadow is a reflection from the Sun.

5E Instructional Model

Address student misconceptions about waves and light using the **5E Instructional Model** (Engage, Explore, Explain, Elaborate, Evaluate). Target common errors—such as the belief that eyes emit light or that waves are solid matter—by having students make predictions, test their ideas, and use digital simulations.

1. Diagnose and Elicit Beliefs

Start by identifying what students already believe before teaching new content.

- Use **concept cartoons** to show different student characters arguing about how light travels. Have students pick a side and explain their reasoning.
- Ask students to draw **ray diagrams** (lines and arrows) for vision and reflection to expose hidden ideas.

2. Challenge with Cognitive Conflict

Present demonstrations or scenarios that contradict common faulty ideas.

- Counter the belief that "eyes emit light" by asking students if they can see in a completely dark room.
- Counter the belief that waves transport physical objects by using a **slinky** to demonstrate that only energy moves while the coils stay in place.

3. Use Interactive Visual Models

Utilize digital tools to help students visualize invisible wave behaviours and light paths.

- Use the PhET Interactive Simulations website to let students test wave properties, interference, and reflection in real time.
- View light as both a particle and a wave by interacting with the Labster Wave Model of Light module.

4. Connect to Real-World Examples

Anchor abstract wave concepts in familiar daily experiences.

- Connect **refraction** (bending of light) to observing a straw appearing bent inside a glass of water.
- Connect **diffraction** (spreading of waves) to hearing sounds around a corner when you cannot see the source.

5. Assess with Targeted Questioning

Evaluate true understanding through specific, challenging prompts rather than simple definitions.

- Ask students to explain exactly why a mirror creates an image but a piece of white paper does not.
- Ask students to trace the path of light from a source, to an object, and finally into the eye.