GRADE 8 SCIENCE UNIT: OPTICS Chapter 4 Questions

Reading Check Answers, p. 134

1. The early Greeks described light as being made up of tiny paticles.
   Some philosophers believed that beams of light particles came from objects that reached the eye and carried information about the object. (PYTHAGORUS)
   Other philosophers believed that the eyes sent out fibres of light that touched objects and told the eyeswhat the object looked like.

2. The first object that was used to help people read small print was called a reading stone.
   It was a section of a glass sphere with one flat side.

3. By experimenting with the shape of the lenses, Leeuwenhoek discovered that he could increase the magnifying power of a lens by increasing its curvature.

4. In the early 1600s, Galileo built and used the first telescope to magnify objects in space.

5. (a) One example of a technology that was developed before the science was understood is the use of lenses to improve and enhance vision.
   People began using lenses before scientists fully understood the properties of light.

   (b) One example of a technology that made scientific discoveries possible is the invention of the microscope. With a microscope, scientists made many discoveries of micro-scopic living organisms and non-living things, which previously could not be seen with the naked eye.
   Another example of a technology that helped scientists make new discoveries is the development of The telescope. With the telescope, scientists were able to expand our knowledge of theuniverse.

Reading Check Answers, p. 136

1. As scientists began to study light more carefully, they discovered that some properties of light could be better explained if light behaved like a wave, rather than a stream of particles.
   For example, light spread out as it passed through narrow openings and bent a bit around corners.

2. **Galileo's** efforts to measure the speed of light were unsuccessful because in his experiment, the time it took to uncover the lanterns was greater than the time it took for the light to travel between the lanterns.

3. The first person to accurately measure the speed of light was **Albert Michelson**. The equipment he used in his experiment included a light source, an eight-sided wheel with mirrors on each side, and a large distant mirror.

4. The **speed of light (approximately 300 000 km/s)** is much faster than the **speed of sound (343 m/s).**

Section 4.1 Assessment, p. 137

Check Your Understanding Answers
Checking Concepts

1. Some early Greek philosophers believed that beams of light, made up of tiny particles, travelled from an object to the eye, carrying information about the object.
Others believed that the eyes sent out fibres of light that touched an object and gave the eyes information about the object.

2. A **reading stone** is a section of a **glass sphere with one flat side.**
By placing the reading stone on a page, the print was magnified.

3. The first spectacles (glasses) were made by attaching two magnifying glasses together at the handles.

4. Leeuwenhoek improved the magnification of the microscope by increasing the curvature of the lens.

5. As more experiments were performed after the 1500s, scientists questioned the theory that light was made up of particles.

   Instead, some scientists began to believe that light behaved like a wave.

6. **Galileo** was the first person to try to measure the speed of light. Unfortunately, his experiment did not work. He also **developed an early telescope.**

7. The **speed of light** is 299 792.458 km/s (or approximately **300 000 km/s).**

8. You can determine how far away a lightning strike is by measuring the time between seeing the lightning and hearing the thunder (in seconds), and multiplying that measurement by the speed of sound (343 m/s).

Understanding Key Ideas

1. People were able to make lenses and build telescopes and microscopes without fully understanding the nature of light by experimenting with the materials that were available.

2. It was difficult to measure the speed of light because the time it took light to travel a short distance was much too quick to be measured accurately.

3. Students may use a chart or Venn diagram to compare and contrast Leeuwenhoek's micro-scope with modern microscopes.

   Students' answers could include the following:

   Leeuwenhoek's m icroscope Modern m icroscope
   – used the properties of light and lenses to magnify tiny objects
   – sample was placed on the point of the screw
   – contained a single convex lens found on the opposite side of the opening
   – magnified objects 200· larger
   – uses properties of light and lenses to magnify tiny objects
   – sample is placed onto a slide which rests on top - of the stage
   – contains more than one lens, located in the objective and eyepiece
   – magnifies objects up to 2000·

4. In his experiment, **Galileo i**ntended to calculate the speed of light by measuring the time it took for light to travel between two lanterns, and dividing that measurement by the total distance that the light travelled during that time.
   He was unsuccessful because the time it took to uncover the lanterns was greater than the time it took for the light to travel between the lanterns.

5. Scientists can measure the time it takes the laser beam to travel to the mirror and multiply this measurement by the speed of light to find the distance between the Earth and the Moon.

What Did You Find Out? Answers

1. Tapping the water with your pencil creates waves that travel outward in concentric circles.

2. The spacing of the water waves decreases as the rate of tapping increases.

TR 2- MHR • Optics 4 **Reading Check Answers, p. 142**

1. **A crest** is the highest point of a wave and a trough is the lowest.

2. The **three ways to measure wavelength** are from:

   - crest to crest
   - trough to trough
   - by picking any point on the wave and measuring the distance to the same place on the next wave.

3. The **frequency of a wave** is measured in hertz.

4. As the **wavelength of a wave increases**, the **frequency decreases.**

   This relationship is called an **inverse relationship**.

5. In a **transverse wave**, the matter moves **perpendicular** to the direction that the wave travels.

   A **compression wave**, the matter moves **along the same direction** that the wave travels

What To Do Answers

1. (a) 24 swings/6s
= 4 Hz

(b) time = 2 min
= 120 s;

frequency = cycles/per
=12 revolutions/120 sec
= 0.1 Hz

(c) time = 0.5 min
= 30 s;
frequency = cycles/sec

= 1 Hz

(d) frequency = cycles/sec

= 0.9 Hz

(e) time = 1 min
= 60 s;
frequency = cycles/sec
= 1998 cycles/60 sec
= 33.3 Hz

What Did You Find Out? Answers

1. In order to **calculate frequency measured in hertz,**
   the **time unit** must be **converted to seconds before dividing**.

CATCH A WAVE

What Did You Find Out? Answers

1. The sound of the vibrating metre stick changed when the amount of stick extending out from the desk was changed.
   The shorter length overhang vibrated with a louder volume and a higher pitch than the longer length overhang.

2. The longer length overhang produced waves with the longest wavelengths.

3. The shorter length overhang produced the most vibrations.

4. **As the wavelength increases, the frequency decreases.**

5. Increasing the wavelength decreases the frequency, and vice versa.

6. The wave with the greatest wavelength cannot have the greatest frequency because a greater wavelength means there must be fewer vibrations in the same time period.

CONDUCT an investigation 4-2d wire wave P144-145

Analyze Answers

1. As the spring moved from side to side more quickly, the wavelength in the spring decreased.

2. The marked coil, which was in the middle, did not move from side to side.

   If it was at a node, students will say it did not move at all.

   If it was not at a node, students will say it moved up and down only.

3. (a) **Frequency and amplitude are not related.**

   However, students' experiences will vary and some students may find that to get high frequency, they tend to have high amplitude simply because they are working hard to move the spring back and forth.
   (b) A low frequency wave can sometimes have a high amplitude and other times have a low amplitude. It depends on how much side-to-side motion is used to generate the wave. More side-to-side motion means greater amplitude.

Conclude and Apply Answers

1. (a)and (b)

crest
amplitude
amplitude
wavelength
wavelength
trough
crest
trough

2. (a) As the frequency increases, the amount of energy transferred by the spring also increases.

   (b) As the wavelength increases, the amount of energy transferred by the spring decreases.

Section 4.2 Assessment, p. 147

Check Y our Understanding Answers

Checking Concepts

1.

crest amplitude
1
1 2 3 4 cm
0
–1
wavelength trough

2. (a) frequency = _9_0_01_ t _ism_ _e_s = 900 Hz
   (b) frequency = _8_8_02_ t _ism_ _e_s = 440 Hz
   (c) frequency = _1_0_ t_im__e_s
   50 s
   = 0.2 Hz

3. (a)

transverse
wave:
compression
wave:

   (b) Students' answers could include the following:
   An example of a transverse wave is a water wave on the lake, or a coiled spring moving from side to side.
   An example of a compression wave is a sound wave moving through the air.

4. frequency = 0.5 Hz = 0.5 waves/s;
   number of waves in 8 s = 0.5 waves/s · 8 s =
   4 waves

Understanding Key Ideas

5. (a) Recall the inverse relationship between wavelength and frequency.
   To make the wavelength shorter, you need to shake the rope more quickly.
   (b) To increase the energy carried by the wave, you need to either increase the amplitude by increasing the side-to-side motion, or increase the frequency by shaking the rope faster.

6. Water waves moving under a raft raise the raft higher and then lower as the crest and trough pass beneath it. The motion is perpendicular to the direction of the waves, so the raft only moves up and down, and not horizontally.

7. (a) The distance between the crest of a wave and the trough of a wave is two times the amplitude. So, in this case, the crest will be 30 m above the trough.

   (b) 10 km = 10 000 m and 1 h = 60 min
   Therefore, one hundred 100 m waves will pass by in 60 min, or 10 waves will pass by every 6 min.

8. (a) Pendulum A: frequency = 32 swings/ 8s
   = 4 Hz

   Pendulum B: frequency = 72 swings/ 9s
   = 8 Hz

   Pendulum C: time = 1 min 20 s
   = 80 s;
   frequency = 210 swings/80 s
   = 2.6 Hz

   (b) From lowest to highest frequency: **C, A, B**

9. (a) The baritone singing a lower pitch produces waves of a longer wavelength.
   Lower pitch means **lower frequency**, which implies **longer wavelength.**

   (b) If both singers sing at an equal volume, the singer with **the higher pitch** sends out **more energy.**
   Every vibration sends out energy, and the higher pitch sends it morefrequently
   (i.e., **higher frequency**).

What Did You Find Out? Answers

1. The glass prism may have produced a rainbow on the wall, with all the colours of the **visible spectrum (ROY G BIV: red, orange, yellow, green, blue, indigo, and violet).**
   The soap bubbles tend to show irregular ribbons of different colours of light.
   In both cases, the colours came out of the white light that was shone on the materials.

Reading Check Answers, p. 150

1. **All the colours of the spectrum are present in white light.**
   The different colours, each of which has a different wavelength, are refracted, or bent, by a different amount. The colours then exit the prism in different directions, producing the spectrum.

2. **Red** has the **longest wavelength.**

3. **Violet** has the **shortest wavelength.**

4. **Violet has the highest frequency.**

5. **Red** has **the lowest frequency.**

Reading Check Answers, p. 153

1. Newton observed that white light was split by the prism into different colours. He concluded that the colours were already present in the white light, rather than being produced by the prism, when he was able to rejoin the colours together with a second prism to produce white light.

2. A combination of any two of the three primary colours produces a secondary colour.

3. A green shirt looks green in white light because green is reflected and all other colours are absorbed.

4. A blue hat in a dark room looks black because there is no light to reflect off its surface.

   So no colour is generated and the hat looks black.

COLOUR YOUR RAINBOW Activity 4-3 B page 153

What Did You Find Out? Answers

1. Students may have seen various colours of the rainbow in their CDs.
   Filters let only one colour of light pass at a time.

2. (a) The rainbow made by the CD in white light contains most or all of red, orange, yellow, green, blue, indigo, and violet.

(b) When a red filter is held in front of the rainbow, only the red appears to be present.
The other parts simply appear dark.

(c) It does not make any difference whether the filter is held between the CD and the eye or between the CD and the source because the filter removes light coming from the source, and it does not matter where this light was removed.

(d) A coloured filter permits one colour to pass and absorbs the rest.

Career Connect Answers

1. The lights for a concert, each with different lenses and prisms, are integrated into one automated unit that is controlled by a central board. The board is equipped with a computer that has been programmed to move the lights and adjust the position, colour, intensity, and focus of the lights automatically.

2. The designer needs to understand how different lenses and prisms work in order to focus and direct the light and create patterns to achieve a desired effect.

3. If you wanted to become a lighting designer, you would need to be able to position lights around the stage as well as light the stage correctly.

   This process is planned and carried out using a computer. Using a computer-aided design program will help to produce good designs for both of these tasks.

Section 4.3 Assessment, p. 155

Check Y our Understanding Answers

Checking Concepts

1. (a) A model is a way of representing something in order to understand it better and to make predictions.

   (b) According to the wave model, light is a type of wave that travels through empty space and transfers energy from one place to another.

2. **Red light** has **a longer wavelength** than **green light.**

3. **Blue light** **refracts** more in a prism than **yellow light**.

4. **Sunlight contains all the colours of the rainbow.**

   Each colour has a different wavelength, and the prism bends, or refracts, each colour by a different amount.
   This phenomenon causes the colours to emerge from the prism in slightly different directions, producing the spectrum.

5. **Refraction** is the bending or changing direction of a wave as it passes from one material to another.

   Reflection occurs when a light wave strikes an object and bounces off.

6. (a) A minimum of three coloured lights are needed to produce all possible colours, including white.

(b) **White light** can be produced by combining red, green, and blue.

It can also be produced by combining yellow, cyan, and magenta.

7. In the acronym **ROY G BIV**, the **B stands for blue** and the **V stands for violet.**

Understanding Key Ideas

8. (a) **Red light is the colour that passes through the red filter.**

   (b) **Green light is absorbed by the red filter.**

9. A shirt can look green even though the light falling on it contains red, blue, and green because the red and blue colours are absorbed, while the green is reflected.

10. The particles of water left in the air from the rain refract the white light from the Sun and separate it into the spectrum.

11. Student's answers may vary. Sample concept map:

Wavelength
colour
frequency
amplitude
brightness
long
wavelength
red
determines

determines
blue
short
wavelength
low
frequency
high
frequency
dim–
low amplitude
bright–
high amplitude
light wave
determines

12. (a) Light with a wavelength of 200 nm is in the region lower than violet and is invisible to humans.

    (b) 1 nanometre = 0.000 000 001 metres

    (i) 200 nm = 0.2 micrometres
    (ii) 200 nm = 0.000 2 millimetres
    (iii) 200 nm = 0.000 000 2 metres

13. (a) Sound representing red light will be one octave lower in pitch than middle C.

    (b) Green will be higher than middle C (yellow) but lower than C in the next octave up (blue).
    Orange will be lower than middle C (yellow) but not as low as red.
    Violet will be two octaves higher than C above middle C (blue).

SEEING the INVISIBLE Activity 4-4A page 157**What Did You Find Out? Answers**

1. Under normal light, tonic water is either colourless or has a slightly yellow tinge to it.
   Under black light, it has a blue/purple glow.

2. (a) When the beaker was covered with sunscreen, the tonic water no longer glowed.

(b) The sunscreen absorbs UV light from the black light.
The UV light is what causes tonic water to glow.

3. Tanning lotion that did not include sunscreen would not be able to block out UV light, and the tonic water would glow blue.

4. A colour photocopy of a currency bill would not have the UV sensitive pigments in it, and would not glow under a black light, as a regularcurrency bill does.

Reading Check Answers, p. 161

1. **<u>Visible light</u>** is found **<u>between infrared waves and ultraviolet waves</u>** on the **electromagnetic spectrum.**

2. Radio waves have the longest wavelength in the electromagnetic spectrum.

3. Microwave radiation in a microwave oven causes water molecules to absorb energy and heat up.

   A plate does not contain much water and the microwaves do not interact with it.

4. Radar can be used to track the location and speed of moving automobiles, aircraft, watercraft, and spacecraft. It can also be used in weather forecasting, where radar stations mounted on satellites are used to plot the position of clouds and show the location and intensity of precipitation and the speed of the wind.

5. Another **<u>term for heat radiation</u>** is **<u>infrared radiation</u>**.

Reading Check Answers, p. 164

1. Ultraviolet waves, X rays, and gamma rays have wavelengths shorter than visible light.

2. Ultraviolet waves enable the body to make vitamin D.

   They are also used by police detectives to study fingerprints.
   Another use for ultraviolet waves is to kill bacteria in food, water, and medical supplies.

3. Overexposure to ultraviolet waves can result in sunburns, skin cancers, and damage to the surface of the eye.

4. X rays are used to photograph teeth and bones, scan luggage at airport security, and to inspect for cracks inside jet engines without taking the engine apart.

5. Gamma rays are used in radiation therapy to kill cancer cells.

<u>REFLECTION in the INFRARED Activity 4-4B page 165</u>

What Did You Find Out? Answers

1. (a) Most smooth objects will reflect the infrared beam.
   Aluminum foil, mirror, paper, and cardboard will reflect well.

   (b) Cloth will not reflect particularly well.

2. Students' answers will vary depending on materials cooled. The effect of cooling will not be systematic. Mirrors and aluminum foil are likely to still reflect infrared, though there may be some diminished ability.

3. Students' answers will depend on results.

Ice will tend to absorb infrared light. However, it may also have some reflective capacity as the infrared beam bounces off its smooth surface.

SUNSCREEN CIRCLE Activity 4-4C page 165

What Did You Find Out? Answers

1. Two of the circles made with a highlighter glowed under the black light.

2. The circles made with the highlighter only and the highlighter treated with oil both glowed, while the circle made with the highlighter treated with sunscreen did not.

3. Two circles were left untreated as a control.

4. 4. Oil was also a control, showing that something in the sunscreen besides the oil caused the light absorption.

5. A regular pen and highlighter pen were both used because the regular pen was a control. This method showed that it was something in the highlighter ink that was affected by the black light.

Section 4.4 Assessment, p. 167

Check Y our Understanding Answers

Checking Concepts

1. (a) Radio waves, microwaves, and infrared waves have wavelengths longer than those of visible light.

(b) Students' answers could include the following:
radio waves: radio and television broadcasting,
MRI imaging
microwaves: microwave ovens, satellite
communications
infrared waves: remote controls, heating
lamps

2. (a) Ultraviolet waves, X rays, and gamma rays have wavelengths shorter than those of visible light.

   (b) Students' answers could include the following:
   UV waves: production of vitamin D, forensics investigations
   X rays: medical imaging, airport security , scanning machines
   gamma rays: treatment of cancer

3. Sunscreen and a hat protect the wearer from overexposure to UV waves, which cause premature aging of the skin, wrinkles, and skin cancer.

4. (a) Radiant energy is energy that can travel through the vacuum of space.

   (b) Students' answers could include any part of the electromagnetic spectrum, including visible light.

5. Radar can be used to help predict weather by mapping the formation and movement of weather systems. Weather radar devices convert the radio waves into pictures that show the location and intensity of precipitation and the speed of the wind.

6. X rays can be used for dental imaging, and other medical imaging such as soft tissues (breast cancer screening), as well as hard tissues (broken bones).

   They are also used to examine carry-on and stowed luggage in aircraft, as well as for examining hard-to-access locations such as aircraft engines and inside welds.

7. An MRI makes use of radio waves in forming an image of a person's internal tissues.
   The person is placed inside a very strong magnetic field.
   The atoms that make up a person's tissues behave like tiny magnets.
   Adding radio energy can cause the magnets to flip, which releases radio waves that can be detected and used to create a map of the different tissues.

8. Microwaves carry energy that can easily be absorbed by water, though not by ceramic.
   For this reason, a mug will warm up more slowly than the water in it.

Understanding Key Ideas

9. Our eyes have evolved to be able to detect certain parts of the electromagnetic spectrum.
   The energy in visible light interacts with the pigments in our eye. Other energies, even more energetic ones, do not affect these light collecting pigments.

10. (a) TV broadcast signals use radio waves.

    (b) A broken arm is detected with X rays.

    (c) The inside of a weld in a pipe is examined using X rays.

    (d) A lamp used to warm a baby chick uses infrared waves.

    (e) The speed of a passing car is measured with radar, a form of microwaves (which are a form of radio waves).

    (f) An aircraft and a control tower communicate using radio waves.

    (g) Cell phones use microwaves (which are a form of radio waves).

11. (a) A beneficial effect of human exposure to ultraviolet rays is the production of vitamin D in the body, which is needed for healthy bones and teeth.

    (b) The harmful effects of human exposure to ultraviolet rays are sunburn, skin cancers, and damage to the surface of the eye.

12. (a) An oncologist would likely use gamma rays to try to kill cancer cells in a patient

    (b) Students' answers could include the following
    The only part of the body to receive a continuous exposure to the gamma rays is the part identified as being made up of cancer cells. The person is constantly moved while undergoing therapy so that the gamma rays shine on the targeted cells from different angles.

Prepare You r Own Summa ry

Students' summaries should incorporate the followingmain ideas:

1. Early Ideas About Light

• Early Greek philosophers believed that light was made up of tiny particles.

• Before scientists understood the nature of light, they made lenses and spectacles (glasses), and built simple microscopes and telescopes.

• As more experiments were conducted, scientists made observations that could not be explained by the particle model of light, so the wave model of light was introduced.

2. Features of Waves

• All waves are disturbances that result in the movement of energy from one place to another.

• Waves are characterized by wavelength, amplitude, and frequency. As the wavelength increases, the frequency decreases.

• There are two types of waves: **transverse waves and compression waves**.

In a transverse wave, matter in the medium moves perpendicular to the direction that the wave travels.

In a compression wave, matter in the medium moves back and forth along the same direction that the wave travels.

3. The Visible Spectrum

• White light contains a mixture of all the colours of the rainbow.

• ROY G BIV identifies the colours of the rainbow, in order, as red, orange, yellow, green, blue, indigo, and violet.

• A prism can be used to split sunlight into the visible spectrum, which can then be recombined into white light using a second prism.

4. Reflection and Refraction

• Reflection occurs when a light wave strikes an object and bounces off its surface.

• Refraction is the bending or changing direction of a wave as it passes from one material to another.

• The amount that a wave refracts, or bends, depends on its wavelength.
Longer wavelengths refract less than shorter wavelengths.

5. Benefits and Risks of Using Electromagnetic Radiation

• Electromagnetic radiation is the transmission of energy in the form of waves.

• The electromagnetic spectrum consists of (in order of decreasing wavelength): radio waves, microwaves, infrared waves, visible light, ultraviolet waves, X rays, and gamma rays.

• Each type of electromagnetic radiation has benefits and risks associated with its use.

Chapter Review Answers

Checking Concepts

1. Pythagoras was a Greek philosopher who was born around 580 .C.E.
   He believed that beams of light (made up of tiny particles) came from objects and reached the eye, carrying information about the object.

2. Students' answers could include a description of lenses used to make magnifying glasses, the first pair of spectacles, or simple microscopes and telescopes. (Refer to pages 133–134 of the student textbook for details and photographs of each early technology.)

3. Although many scientists supported the wave theory of light, the first people to provide conclusive evidence of the model were Thomas Young and Augustin Fresnel in the early 1800s.

4. (a) F: crest

   (b) G: amplitude

   (c) H: trough

   (d) J: wavelength

5. As wavelength increases, frequency decreases, and vice versa. Another way to say this fact is that they are inversely related.

6. Light waves and sound waves both carry energy. Their waves both can be characterized by frequency, wavelength, and amplitude.

7. Students' answers could include the following:

   One way to measure the wavelength of a small water wave is to hold a ruler over the top and sight two wave crests at the same instant along the ruler.

8. (a) All colours of light have waves with the same general shape as that of a transverse wave. Also, the light waves move at the same speed in a vacuum, regardless of colour.

   (b) Different colours of light have waves with different wavelengths and frequencies.

9. Hertz (Hz) is the unit used to measure frequency.
   1 hertz means one vibration or cycle per second.

10. Wavelength measures the distance from crest to crest, or trough to trough (or any place on a wave to the same place on the next wave).

Wave amplitude measures the distance from the crest (or trough) to the equilibrium position, which in a water wave is the position of the surface of the water when there is no wave.

11. (a) The amplitude of Wave A is 0.5 m.

(b) The wavelength of Wave A is 1.0 m.

12. (a) The amplitude of Wave B is 0.4 m.

(b) The wavelength of Wave B is 2.1 m.

13. (a) The amplitude of Wave C is 0.6 m.

    (b) The wavelength of Wave C is 2.0 m.

14. A shirt can appear blue in white light because the pigment in the blue shirt absorbs non-blue colours such as red and green, while at the same time reflecting blue.

15. Radio waves and infrared waves have waves that are longer than visible light, while ultraviolet waves, X rays, and gamma rays have waves that are shorter than visible light.

16. Radio waves are used in MRI technology to form an image of soft tissues such as those in the brain. The person is placed in a very strong magnetic field. The atoms that make up the tissue behave like little magnets. When stimulated with a small amount of radio waves, the magnets can flip.

    This action causes a radio signal to be released, which is detected by the MRI machine. These signals represent information about the tissues that can be converted into pictures.

Understanding Key Ideas

17. Students' answers could include the following:
    Early philosophers and scientists always include vision in their ideas about the nature of light because the eyes are able to see objects in the presence of light.
    Vision is our only sense that detects light.
    A person's vision is limited in the darkness, and darkness is sometimes even associated with blindness.

18. Lightning and thunder occur at the same time.
    However, you see lightning before you hear the thunder because
    the speed of light (about 300 000 km/s) is much faster than the **speed of sound (342 m/s).**

19. Light waves and waves in a fish pond are both disturbances that carry energy. They can both be characterized by wavelength, amplitude, and frequency.

20. (a) frequency = _1_4 _cycles/7s
    = 2 Hz

(b) frequency = _3_0 _cycles/5s
= 6 Hz

(c) frequency = _0_.51_ /____
= 0.05 Hz

21. Wavelength and frequency cannot both increase together because as the wavelength gets longer, the troughs and crests get farther and farther apart.
    This result means that the frequency must decrease rather than increase.

22. Students' answers could include the following:

Radiation T ype Differences Similarities

Infrared waves

– lowest frequency and energy of the three types of radiation
`– **invisible** to the human eye

– All three types of radiation **move in the form of waves**.
– All three types of radiation **move at the same speed.**
– All three types of radiation **carry energy.**

Visible light

– intermediate frequency and energy of the three types of radiation
– visible to the human eye

X rays

– highest frequencyand energy of the three types of radiation
– can pass through humans
– **invisible** to the human eye

23. (a) The red light has the longest wavelength.
(b) The violet (or blue, if that is what she sees) has the highest frequency.
(c) If Mei Lin were to remove the middle colours of the spectrum, leaving only red and blue, then the colour she would see when these are recombined is magenta.

24. Students' answers could include:
X rays cause cancer if received in too great a dosage.
A huge overexposure could even cause burns or other direct damage to tissues.