Physics
Reference Table
Workbook

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About This Workbook –

Many questions on the New York State Physical Setting/PHYSICS Regents exam may be answered simply by using information given on the Reference Table. Other questions may require information from the Reference Table to set-up calculations in order to determine the answer. Knowing what information is on the Reference Table and where to find it is a very important step towards being successful on the Regents exam.

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Physics Reference Table Workbook

The Introduction – Overview, The Chart and Additional Information –
This workbook contains 36 sections, 26 dealing with the equations and 10 dealing with charts. In each section, carefully read the introduction material. Read and understand the example given for that equation and its solution. Study the *Additional Information* given. When you have a solid knowledge of that section's material, move on to the topic questions.

Set 1 – Questions and Answers –

Set 1 questions will test your understanding of that particular section. Do all questions in Set 1 and then correct your work by going to the answers for Set 1, which are at the end of the section. The explanation given will help you to understand any mistakes you may have made. If not, ask you teacher for additional help.

Set 2 – Questions –

The answers to these questions are in a separate answer key for you to use in checking your answers. Correctly answering these questions will show you and your teacher that you understand the subject matter for that particular section.

All of us at Topical Review Book Company hope that a complete understanding of the Physics Reference Table will help to increase your knowledge of Physics and that your grade will improve.

Good luck in Physics and on the Regents or the school exam. – The authors.

Physical Setting/Physics Reference Table Booklet

Table of Contents

Equations

Mechanics

Waves

Modern Physics

Electricity

Charts

Mechanics – Kinematics

Mechanics may be defined as the branch of physics that studies the motion, the causes of the motion and changes in the motion of objects. It is usually divided into two parts: kinematics and dynamics.

Kinematics: Kinematics is the study of the types of motion an object may have. Five equations are used in this area.

Speed is the rate of change of position or rate of motion of an object. Velocity is the rate of motion of an object in a particular direction. Speed is the magnitude of the velocity vector.

Average speed is calculated by dividing the total distance traveled by the time needed to travel that distance. Average velocity is displacement divided by time.

$$\bar{v} = \frac{d}{t}$$

where: $\bar{v}$ = *average velocity or average speed*
d = *displacement or distance*
t = *time interval*

Example: A person observes a fireworks display from a safe distance of 0.750 kilometer. Assuming that sound travels at 340. meters per second in air, what is the time between the person seeing and hearing a fireworks explosion?

(1) 0.453 s (2) 2.21 s (3) 410. s (4) 2.55×10^5 s

Solution: 2 Convert 0.750 km to meters to be consistent with the units given for the speed of sound. The equation gives: 340. m/s = (750. m)/t. Solving, t = 2.21 s.

Acceleration is the rate of change of velocity of an object. It is calculated by dividing the change in velocity of the object by the time needed to make that change.

$$a = \frac{\Delta v}{t}$$

where: a = *acceleration*
Δv = *change in velocity or speed*
t = *time interval*

Example: An observer recorded the following data for the motion of a car undergoing constant acceleration. What was the magnitude of the acceleration of the car?

Time (s)	**Speed** (m/s)
3.0	4.0
5.0	7.0
6.0	8.5

(1) 1.3 m/s^2 (2) 2.0 m/s^2 (3) 1.5 m/s^2 (4) 4.5 m/s^2

Solution: 3 Using any time interval and the corresponding change in velocity gives an acceleration of 1.5 m/s^2.

For example: $$a = \frac{(8.5\text{ m/s} - 4.0\text{ m/s})}{(6.0\text{ s} - 3.0\text{ s})} = \frac{4.5\text{ m/s}}{3.0\text{ s}} = 1.5\text{ m/s}^2$$

If the initial speed or velocity (v_i) is known, the final speed or velocity (v_f) may be calculated if the acceleration and time are known. If the object starts from rest, $v_i = 0$.

$$v_f = v_i + at$$

where: v_i = *initial velocity or speed*
v_f = *final velocity or speed*
a = *acceleration*
t = *time interval*

Example: An object is dropped from rest and falls freely 20. meters to Earth. When is the speed of the object 9.8 meters per second?

(1) during the entire first second of its fall
(2) at the end of its first second of fall
(3) during its entire time of fall
(4) after it has fallen 9.8 meters

Solution: 2 The acceleration of a freely falling object is the acceleration due to gravity (g), found on the List of Physical Constants in the reference table. The object starts from rest and its speed increases during each second it falls. Substitution in the equation using $t = 1.0$ s gives $v_f = 0 + (9.81 \text{ m/s}^2)(1.0 \text{ s})$. Solving, $v_f = 9.81$ m/s.

If the initial speed or velocity, acceleration and time of travel are known, the distance traveled in that time can be calculated. Again, if the object starts from rest, $v_i = 0$.

$$d = v_i t + \frac{1}{2}at^2$$

where: d = *displacement or distance*
v_i = *initial velocity or speed*
a = *acceleration*
t = *time interval*

Example: A ball is thrown horizontally at a speed of 24 meters per second from the top of a cliff. If the ball hits the ground 4.0 seconds later, approximately how high is the cliff?

(1) 6.0 m (2) 39 m (3) 78 m (4) 96 m

Solution: 3 The horizontal and vertical motion of the ball are independent of each other. The ball falls vertically for 4.0 s before it strikes the ground and has an acceleration equal to that due to gravity, found on the List of Physical Constants. Since the ball starts from rest in the vertical, $v_i = 0$. Substituting into the equation using $a = g$, $d = 0 + ½ (9.81 \text{ m/s}^2)(4.0 \text{ s})^2 = 78$ m.

If the initial speed or velocity, acceleration and distance traveled are known, the final speed or velocity may be calculated. Again, if the object starts from rest, $v_i = 0$.

$$v_f^2 = v_i^2 + 2ad$$

where: v_i = *initial velocity or speed*
v_f = *final velocity or speed*
a = *acceleration*
d = *displacement or distance*

Example: An object with an initial speed of 4.0 meters per second accelerates uniformly at 2.0 meters per second^2 in the direction of its motion for a distance of 5.0 meters. What is the final speed of the object?

(1) 6.0 m/s (2) 10. m/s (3) 14 m/s (4) 36 m/s

Solution: 1 Substituting into the equation: v_f^2 = (4.0 m/s)^2 + 2(2.0 m/s^2)(5.0 m). Solving for v_f gives 6.0 m/s.

Kinematics - Additional Information:

- When the speed is constant, it is the average speed.

- If the speed of an object changes, average speed may be calculated as follows: $\bar{v} = \frac{(v_i + v_f)}{2}$.
- The change in velocity (Δv) is calculated $\Delta v = v_f - v_i$.

- In the case of free fall and projectile motion, the vertical acceleration is that due to gravity (g). In the equations, g may then be substituted for a. The value of g is on the List of Physical Constants.

- In some questions, it is important to distinguish between scalar quantities (those having magnitude or size only) and vector quantities (those having both magnitude and direction). Speed and distance are scalars. Velocity, displacement and acceleration are vectors.

- When an object is increasing its speed, the acceleration is a positive quantity. When slowing down, the acceleration is negative (deceleration).

Set 1 — Kinematics

1. At an outdoor physics demonstration, a delay of 0.50 second was observed between the time sound waves left a loudspeaker and the time these sound waves reached a student through the air. If the air is at STP, how far was the student from the speaker?

(1) 1.5×10^{-3} m
(2) 1.7×10^{2} m
(3) 6.6×10^{2} m
(4) 1.5×10^{8} m 1 _____

2. Approximately how much time does it take light to travel from the Sun to Earth?

(1) 2.00×10^{-3} s
(2) 1.28×10^{0} s
(3) 5.00×10^{2} s
(4) 4.50×10^{19} s 2 _____

3. The speed of a car is increased uniformly from 20. meters per second to 30. meters per second in 4.0 seconds. The magnitude of the car's average acceleration in this 4.0-second interval is

(1) 0.40 m/s^2 (3) 10 m/s^2
(2) 2.5 m/s^2 (4) 13 m/s^2 3 ____

4. Velocity is to speed as displacement is to

(1) acceleration (3) momentum
(2) time (4) distance 4 _____

5. An astronaut drops a hammer from 2.0 meters above the surface of the Moon. If the acceleration due to gravity on the Moon is 1.62 meters per second^2, how long will it take for the hammer to fall to the Moon's surface?

(1) 0.62 s (3) 1.6 s
(2) 1.2 s (4) 2.5 s 5 _____

6. A rocket initially at rest on the ground lifts off vertically with a constant acceleration of 2.0×10^{1} meters per second^2. How long will it take the rocket to reach an altitude of 9.0×10^{3} meters?

(1) 3.0×10^{1} s (3) 4.5×10^{2} s
(2) 4.3×10^{1} s (4) 9.0×10^{2} s 6 _____

7. A car initially traveling at a speed of 16 meters per second accelerates uniformly to a speed of 20. meters per second over a distance of 36 meters. What is the magnitude of the car's acceleration?

(1) 0.11 m/s^2 (3) 0.22 m/s^2
(2) 2.0 m/s^2 (4) 9.0 m/s^2 7 _____

8. A stream is 30. m wide and its current is flowing at 1.5 m/s. A boat is launched with a velocity of 2.0 m/s eastward from the west bank of the stream. How much time is required for the boat to reach the opposite bank of the stream?

(1) 8.6 s (3) 15 s
(2) 12 s (4) 60. s 8 _____

9. The speed of an object undergoing constant acceleration increases from 8.0 meters per second to 16.0 meters per second in 10. seconds. How far does the object travel during the 10. seconds?

(1) 3.6×10^2 m (3) 1.2×10^2 m
(2) 1.6×10^2 m (4) 8.0×10^1 m 9 _____

10. A rock falls from rest a vertical distance of 0.72 meter to the surface of a planet in 0.63 second. The magnitude of the acceleration due to gravity on the planet is

(1) 1.1 m/s^2 (3) 3.6 m/s^2
(2) 2.3 m/s^2 (4) 9.8 m/s^2 10 _____

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11. A projectile has an initial horizontal velocity of 15 meters per second and an initial vertical velocity of 25 meters per second. Determine the projectile's horizontal displacement if the total time of flight is 5.0 seconds. [Neglect friction.] [Show all work, including the equation and substitution with units.]

____________________ m

Base your answers to question 12 *a* and *b* on the information below.

A car traveling at a speed of 13 meters per second accelerates uniformly to a speed of 25 meters per second in 5.0 seconds.

12. *a*) Calculate the magnitude of the acceleration of the car during this 5.0-second time interval. [Show all work, including the equation and substitution with units.]

b) A truck traveling at a constant speed covers the same total distance as the car in the same 5.0-second time interval. Determine the speed of the truck. [Show all work, including the equation and substitution with units.]

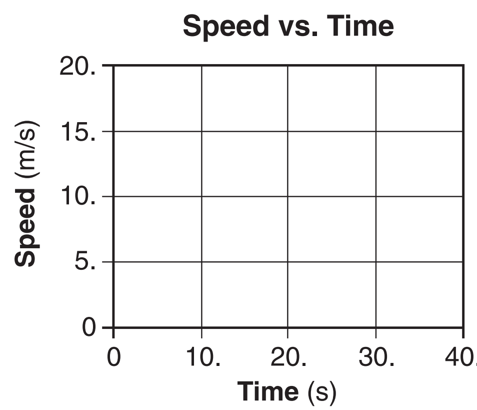
b)___________________ m/s

Base your answers to questions 13 *a*, *b*, and *c* on the information below.

A car on a straight road starts from rest and accelerates at 1.0 meter per second^2 for 10. seconds. Then the car continues to travel at constant speed for an additional 20. seconds.

13. *a*) Determine the speed of the car at the end of the first 10. seconds. ________________________m/s

b) On the accompanying grid, use a ruler or straightedge to construct a graph of the car's speed as a function of time for the entire 30.-second interval.



c) Calculate the distance the car travels in the first 10.-seconds. [Show all work, including the equation and substitution with units.]

Base your answers to questions 14 *a* and *b* on the information below.

A physics class is to design an experiment to determine the acceleration of a student on inline skates coasting straight down a gentle incline. The incline has a constant slope. The students have tape measures, traffic cones, and stopwatches.

14. *a*) Describe a procedure to obtain the measurements necessary for this experiment.

____

____

____

____

b) Indicate which equation(s) they should use to determine the student's acceleration.

15. A 2.00×10^6 -hertz radio signal is sent a distance of 7.30×10^{10} meters from Earth to a spaceship orbiting Mars. Approximately how much time does it take the radio signal to travel from Earth to the spaceship?

(1) 4.11×10^{-3} s
(2) 2.19×10^{8} s
(3) 2.43×10^{2} s
(4) 1.46×10^{17} s   15 _____

16. A projectile is fired from a gun near the surface of Earth. The initial velocity of the projectile has a vertical component of 98 meters per second and a horizontal component of 49 meters per second. How long will it take the projectile to reach the highest point in its path?

(1) 5.0 s   (3) 20. s
(2) 10. s   (4) 100. s   16 _____

17. A roller coaster, traveling with an initial speed of 15 meters per second, decelerates uniformly at –7.0 meters per second^2 to a full stop. Approximately how far does the roller coaster travel during its deceleration?

(1) 1.0 m   (3) 16 m
(2) 2.0 m   (4) 32 m   17 _____

18. An astronaut standing on a platform on the Moon drops a hammer. If the hammer falls 6.0 meters vertically in 2.7 seconds, what is its acceleration?

(1) 1.6 m/s^2 (3) 4.4 m/s^2
(2) 2.2 m/s^2 (4) 9.8 m/s^2 18 _____

19. On a highway, a car is driven 80. kilometers during the first 1.00 hour of travel, 50. kilometers during the next 0.50 hour, and 40. kilometers in the final 0.50 hour. What is the car's average speed for the entire trip?

(1) 45 km/h   (3) 85 km/h
(2) 60. km/h   (4) 170 km/h   19 _____

Base your answers to question 20 on the information below.

The combined mass of a race car and its driver is 600. kilograms. Traveling at constant speed, the car completes one lap around a circular track of radius 160 meters in 36 seconds.

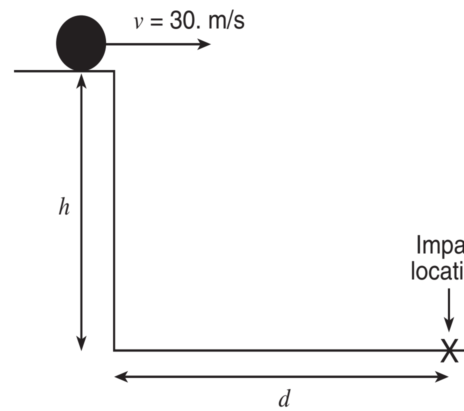
20. Calculate the speed of the car. [Show all work, including the equation and substitution with units.]

21. During a 5.0-second interval, an object's velocity changes from 25 meters per second east to 15 meters per second east. Determine the magnitude and direction of the object's acceleration.

________________________ m/s² ________________________

Base your answers to questions 22 *a*, *b* and *c* on the information and diagram below.

A projectile is launched horizontally at a speed of 30. meters per second from a platform located a vertical distance *h* above the ground. The projectile strikes the ground after time *t* at horizontal distance *d* from the base of the platform. [Neglect friction.]



22. *a*) On the accompanying diagram, sketch the theoretical path of the projectile.

b) Calculate the horizontal distance, *d*, if the projectile's total time of flight is 2.5 seconds. [Show all work, including the equation and substitution with units.]

c) Express the projectile's total time of flight, *t*, in terms of the vertical distance, *h*, and the acceleration due to gravity, *g*. [Write an appropriate equation and solve it for *t*.]

Kinematics
Answers
Set 1

1. 2 Locate the equation $\bar{v} = d/t$. The speed of sound in air at STP is found in the reference table on the List of Physical Constants. Since it is constant, it is the average speed. Substituting into the equation gives 3.31×10^2 m/s = d/(0.5 s). Solving, $d = 1.7 \times 10^2$ m.

2. 3 Under Mechanics, find the equation $\bar{v} = d/t$. The speed of light is found on the List of Physical Constants. Since it is a constant, it is the average speed. The mean distance from the Earth to the Sun is also found on the List of Physical Constants. Solving for t and substituting gives
$t = \dfrac{(1.50 \times 10^{11}\text{ m})}{(3.00 \times 10^{8}\text{ m/s})} = 5.00 \times 10^2$ s.

3. 2 The change in speed (Δv) can be expressed as $v_f - v_i$. This gives Δv = 30. m/s – 20. m/s = 10. m/s. Substitution into the equation $a = \Delta v/t$ for acceleration gives a = (10. m/s)/(4.0 s). Solving gives $a = 2.5$ m/s^2. Assuming the acceleration is constant, this is also the average acceleration.

4. 4 A vector is a quantity possessing both magnitude (size) and direction. Velocity is a vector defined as a speed measured in a particular direction. Speed is the magnitude of the velocity vector. Displacement is a vector defined as a distance measured in a particular direction. Distance is the magnitude of the displacement vector. By analogy, the correct answer is distance.

5. 3 The equation to use is $d = v_i t + \frac{1}{2}at^2$. The value of a will be the acceleration due to gravity at the surface of the Moon. Assume the hammer is dropped from rest. Substituting into the equation gives 2.0 m = 0 + ½ (1.62 m/s^2)(t^2). Solving, $t = 1.6$ s.

6. 1 Under Mechanics find the equation $d = v_i t + \frac{1}{2} at^2$. Substitution into the equation with $v_i = 0$ (the object starts from rest) gives: 9.0×10^3 m = ½ (2.0×10^1 m/s^2)(t^2). Solving, $t = 3.0 \times 10^1$ s.

7. 2 Find the equation $v_f^2 = v_i^2 + 2ad$. Substitution gives (20. m/s)^2 = (16 m/s)^2 + 2a(36 m). Solving for a yields 2.0 m/s^2.

8. 3 Under Mechanics in the reference table, find the equation $\bar{v} = d/t$. $\bar{v}$ is the constant eastern velocity of the boat and d is the width of the river. Substituting gives 2.0 m/s = (30. m)/t. Solving, t = 15 s.

9. 3 Two equations are needed: $a = \Delta v/t$ and $v_f^{\,2} = v_i^{\,2} + 2ad$.

Using the acceleration equation, $a = \dfrac{(16.0 \text{ m/s} - 8.0 \text{ m/s})}{(10. \text{ s})} = 0.80 \text{ m/s}^2$.

Substituting into the second equation gives
$(16.0 \text{ m/s})^2 = (8.0 \text{ m/s})^2 + 2(0.80 \text{ m/s}^2)(d)$. Solving, $d = 1.2 \times 10^2$ m

or

Under Mechanics, find the equation $\bar{v} = d/t$. To find the average speed, $\bar{v} = \dfrac{(v_i + v_f)}{2}$. Substituting, $\bar{v} = \dfrac{(8.0 \text{ m/s} + 16.0 \text{ m/s})}{2} = 12.0$ m/s.

Substitution into the first equation gives $(12.0 \text{ m/s}) = \dfrac{d}{(10. \text{ s})}$.

Solving, $d = 1.2 \times 10^2$ m

10. 3 Find the equation $d = v_i t + \frac{1}{2}at^2$.
Since the rock starts from rest, $v_i = 0$.
Substitution gives $0.72 \text{ m} = 0 + \frac{1}{2}(\text{a})(0.63 \text{ s})^2$. Solving, $a = 3.6 \text{ m/s}^2$.

11. Answer: 75 m

Explanation: The horizontal displacement of the projectile depends only upon the horizontal velocity and the total time of flight. Neglecting friction, the magnitude of the horizontal velocity remains constant during the flight. Under Mechanics, find the equation $\bar{v} = \dfrac{d}{t}$.
Substitution into the equation gives (15 m/s) = d/(5.0 s). Solving for d gives 75 m.

12. *a*)

$$a = \frac{\Delta v}{t}$$

$$a = \frac{25 \text{ m/s} - 13 \text{ m/s}}{5.0\text{s}}$$

$$a = 2.4 \text{ m/s}^2$$

Explanation: Given the initial speed, final speed and time, the acceleration may be calculated.

b) Example of acceptable response:

$d = v_i t + \frac{1}{2}at^2$ $d = (13 \text{ m/s})(5.0 \text{ s}) + \frac{1}{2}(2.4 \text{ m/s}^2)(5.0 \text{ s})^2 = 95$ m

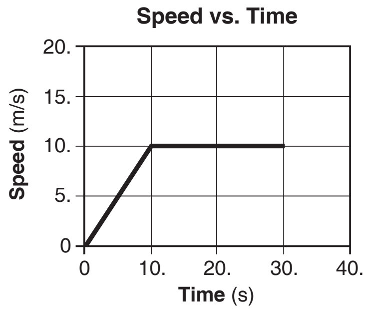
$\bar{v} = \dfrac{d}{t}$ $\bar{v} = \dfrac{95 \text{ m}}{5.0 \text{ s}} = 19$ m/s

Explanation: First, calculate the distance the car travels during the 5.0 seconds using the acceleration calculated in 12*a* (2.4 m/s²). This is the distance the truck travels during this time. Knowing the distance and time, the speed of the truck may be calculated. Since the truck is traveling at a constant speed, the average speed and the truck's constant speed are the same.

13. *a*) Answer: 10 m/s

Explanation: Under Mechanics, find the equation $v_f = v_i + at$. $v_i = 0$ since the car starts from rest. Substituting into the equation gives $v_f = (1.0\ \text{m/s}^2)(10.\ \text{s}) = 10.\ \text{m/s}$.

b)



Explanation: From 0 s to 10. s, the cars speed increases uniformly from 0 m/s to 10. m/s. From 10. s to 30. s, the car travels at a constant speed of 10. m/s.

c)

$d = v_i t + \frac{1}{2}at^2$ | $d = \text{area} = \frac{1}{2}bh$

$d = 0 + \frac{1}{2}(1.0\ \text{m/s}^2)(10.\ \text{s})^2$ ***or*** $d = \frac{1}{2}(10.\ \text{s})(10.\ \text{m/s})$

$d = 50.\ \text{m}$ | $d = 50.\ \text{m}$

Explanation: Use the equation $d = v_i t + ½\, at^2$.
Substitute into the equation using $v_i = 0$ and calculate d.
or
The distance traveled during the first 10. s is equal to the area under the triangle on the graph from 0 s to 10. s. Under Geometry and Trigonometry in the reference table, find the equation for the area of a triangle (A = ½ bh). The base of the triangle is 10. s and the height is 10. m/s. Calculate A, which is the distance traveled.

14. *a*) The class must measure the time needed for the student to travel a given measured distance.

b) $d = v_i t + ½\, at^2$

or

$a = \dfrac{2d}{t^2}$

Explanation: If the student starts from rest, $v_i = 0$. With the measured values of d and t, the acceleration of the student can be calculated.

Waves – Refraction

Refraction: Refraction is the change in direction of travel or the bending of a wave that occurs when a wave enters obliquely a medium in which its speed changes.

The absolute index of refraction of a medium is the speed of light in a vacuum divided by the speed of light the material medium.

$$n = \frac{c}{v}$$

where: n = absolute index of refraction
c = speed of light in a vacuum
v = velocity or speed

Example: In a certain material, a beam of monochromatic light ($f = 5.09 \times 10^{14}$ hertz) has a speed of 2.25×10^8 meters per second. The material could be

(1) crown glass (2) flint glass (3) glycerol (4) water

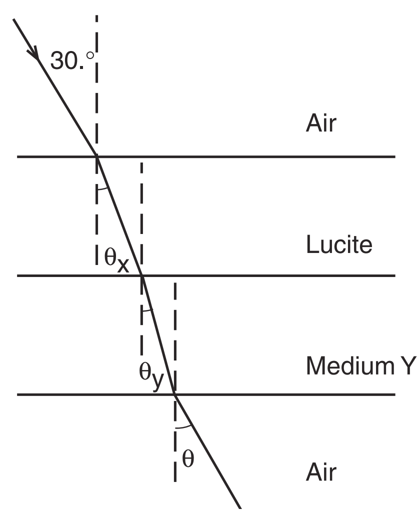
Solution: 4 c is the speed of light which is found on the List of Physical Constants. Substitution into the equation and solving for n yields $n = \frac{(3.00) \times 10^8 \text{ m/s}}{(2.25) \times 10^8 \text{ m/s}} = 1.33$. Go to the table of Absolute Indices of Refraction and find which substance has an index of refraction of 1.33. The substance is water.

The equation below is Snell's Law, which relates the absolute indices of refraction and the angles of incidence and refraction as light passes from one medium into another. n_1 is the index of refraction of the medium in which the angle of incidence is measured and n_2 is the index of refraction of the medium in which the angle of refraction is measured.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

where: n = absolute index of refraction
θ = angle

Example: Base your answer on the accompanying diagram, which represents a light ray traveling from air to Lucite to medium Y and back into air.



The sine of angle x is

(1) 0.333 (3) 0.707
(2) 0.500 (4) 0.886

Solution: 1 Use the table of Absolute Indices of Refraction to find the index of refraction of air ($n_1 = 1.00$) and Lucite ($n_2 = 1.50$). Substitution into the equation gives $(1.00)(\sin 30°) = (1.50)(\sin \theta_2)$, where angle θ_2 is angle θ_x. Solving gives $\sin \theta_x = 0.333$.

The ratio $\frac{n_2}{n_1}$ is called the relative index of refraction of medium 2 with respect to medium 1. From Snell's Law, it is also equal to $\frac{\sin\theta_1}{\sin\theta_2}$.

$$\frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

where: *n = absolute index of refraction*
v = velocity or speed
λ = wavelength

Example: A beam of monochromatic light has a wavelength of 5.89×10^{-7} meter in air. Calculate the wavelength of this light in diamond. [Show all work, including the equation and substitution with units.]

Solution:

$$\frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2}$$

$$\lambda_2 = \frac{n_1\,\lambda_1}{n_2}$$

$$\lambda_2 = \frac{(1.00)(5.89 \times 10^{-7}\text{ m})}{2.42}$$

$$\lambda_2 = 2.43 \times 10^{-7}\text{ m}$$

Explanation: In this equation, the subscript 1 refers to the original medium, in this case air, and the subscript 2 refers to the new medium, which is diamond. The indices of refraction are found on the table of Absolute Indices of Refraction. Substitution into the first (n_2/n_1) and the third part of the equation (λ_1/λ_2) gives you the correct setup as shown.

Refraction - Additional Information:

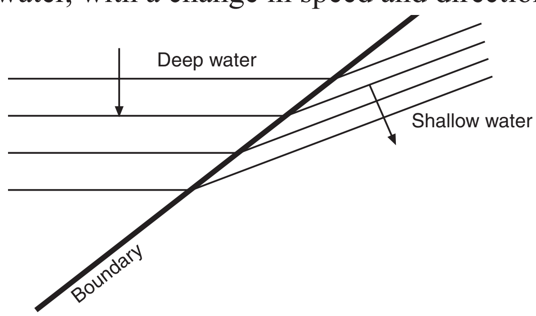
- The value of *n* is found on the Absolute Indices of Refraction table.
- When a wave travels from one medium into another, $\frac{n_2}{n_1}$ is the relative index of refraction. The subscripts 1 and 2 refer to the original medium and new medium, respectively. If $\frac{n_2}{n_1} > 1$, the speed of the wave decreases as it enters the new medium. If $\frac{n_2}{n_1} < 1$, the speed of the wave increases as it enters the new medium.
- The larger the index of refraction of a given medium, the greater the amount of refraction or bending of a ray of light as it enters that medium.
- If a ray of light enters a medium with a smaller index of refraction, its speed increases and it is refracted or bent away from the normal. If a ray of light enters a medium with a larger index of refraction, its speed decreases and it is refracted toward the normal.
- If a ray of light enters a medium with the same index of refraction, there is no change in speed, and therefore there is no refraction or bending.

Set 1 — Refraction

1. In which way does blue light change as it travels from diamond into crown glass?

   (1) Its frequency decreases.
   (2) Its frequency increases.
   (3) Its speed decreases.
   (4) Its speed increases. 1 _____

2. The diagram below represents straight wave fronts passing from deep water into shallow water, with a change in speed and direction.



   Which phenomenon is illustrated in the diagram?

   (1) reflection (3) diffraction
   (2) refraction (4) interference 2 ____

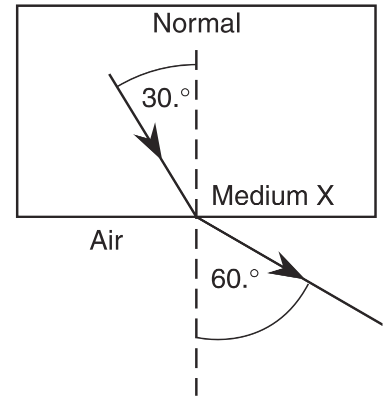
3. The speed of light ($f = 5.09 \times 10^{14}$ Hz) in a transparent material is 0.75 times its speed in air. The absolute index of refraction of the material is approximately

   (1) 0.75 (3) 2.3
   (2) 1.3 (4) 4.0 3 _____

4. What is the speed of a ray of light ($f = 5.09 \times 10^{14}$ hertz) traveling through a block of sodium chloride?

   (1) 1.54×10^8 m/s
   (2) 1.95×10^8 m/s
   (3) 3.00×10^8 m/s
   (4) 4.62×10^8 m/s 4 _____

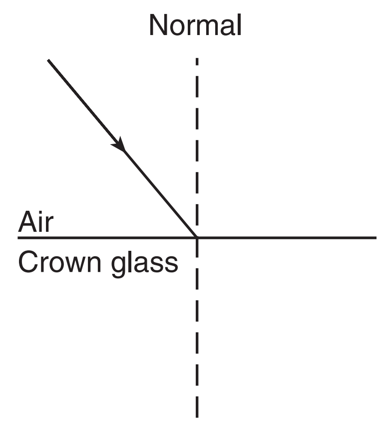
5. The diagram below shows a ray of light passing from medium **X** into air.



   What is the absolute index of refraction of medium **X**?

   (1) 0.500 (3) 1.73
   (2) 2.00 (4) 0.577 5 _____

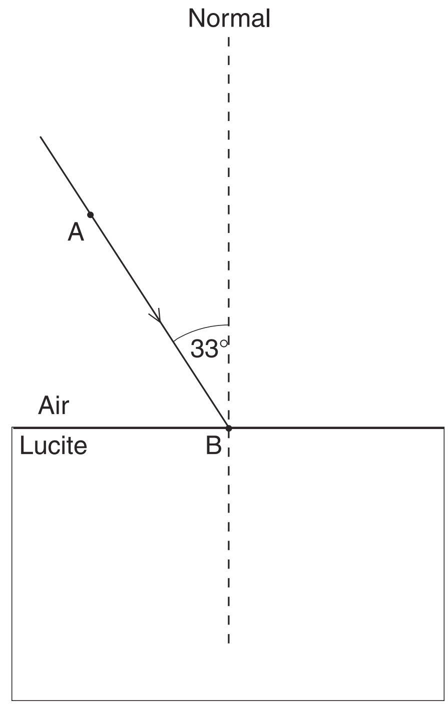
6. A ray of light ($f = 5.09 \times 10^{14}$ Hz) traveling in air is incident at an angle of 40.° on an air-crown glass interface as shown below.



   What is the angle of refraction for this light ray?

   (1) 25° (3) 40°
   (2) 37° (4) 78° 6 _____

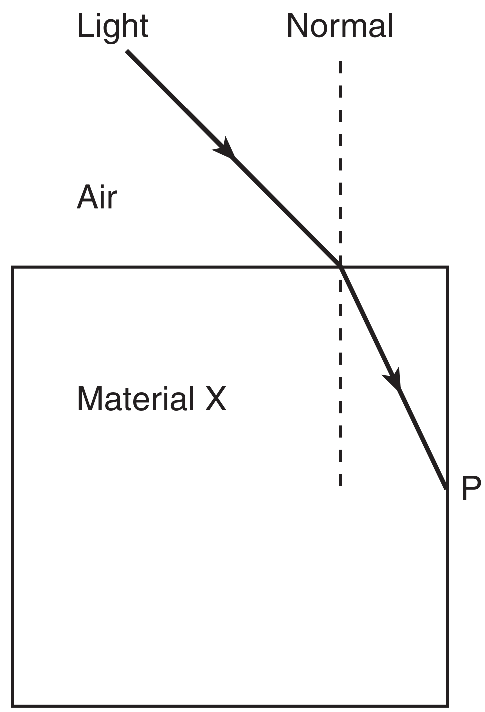
Base your answers to questions 7*a* and *b* on the information and accompanying diagram. A monochromatic beam of yellow light, *AB*, is incident upon a Lucite block in air at an angle of 33°.



7. *a*) Calculate the angle of refraction for incident beam *AB*. [Show all work, including the equation and substitution with units.]

   b) Using a straightedge, a protractor, and your answer from question 7*a*, draw an arrow to represent the path of the refracted beam.

Base your answers to questions 8*a* and *b* on the information and accompanying diagram. A ray of light passes from air into a block of transparent material *X* as shown in the accompanying diagram.



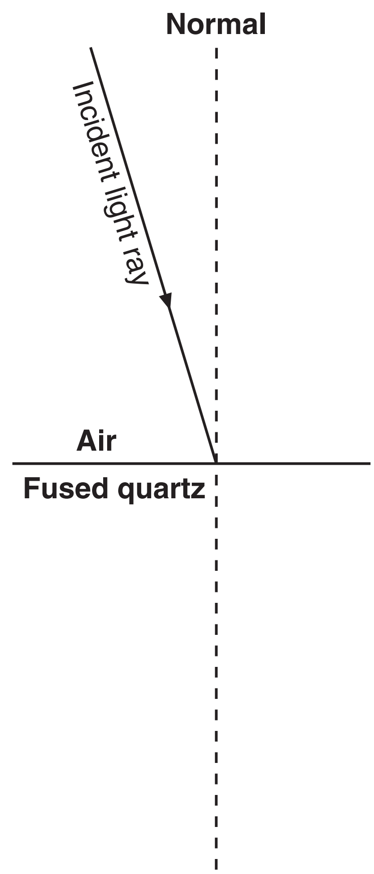
8. *a*) Measure the angles of incidence and refraction to the nearest degree for this light ray at the air into material *X* boundary and write your answers in the space below.

   angle of incidence ______________ °

   angle of refraction ______________ °

   b) Calculate the absolute index of refraction of material *X*. [Show all work, including the equation and substitution with units.]

Base your answers to questions 9*a* and *b* on the accompany diagram, which shows a light ray ($f = 5.09 \times 10^{14}$ Hz) in air, incident on a boundary with fused quartz. At the boundary, part of the light is refracted and part of the light is reflected.

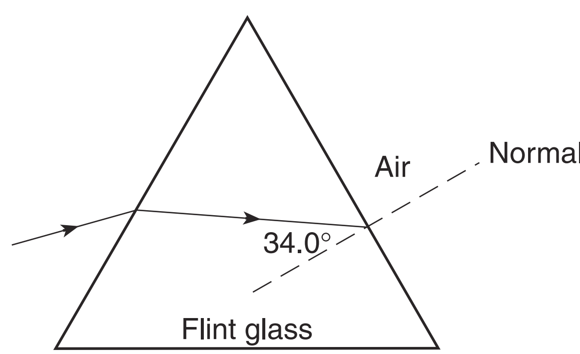


9. *a*) Using a protractor, measure the angle of incidence of the light ray at the air-fused quartz boundary.

   ________________ °

   b) Calculate the angle of refraction of the incident light ray. [Show all work, including the equation and substitution with units.]

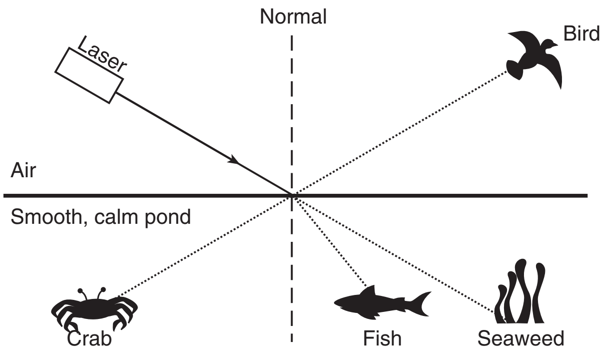
Base your answers to questions 10*a* and *b* on the accompanying diagram which shows a ray of monochromatic light ($f = 5.09 \times 10^{14}$ hertz) passing through a flint glass prism.



10. *a*) Calculate the angle of refraction (in degrees) of the light ray as it enters the air from the flint glass prism. [Show all calculations, including the equation and substitution with units.]

   b) Using a protractor and a straightedge, construct the refracted light ray in the air on the diagram above.

11. A laser beam is directed at the surface of a smooth, calm pond as represented in the diagram below. Which organisms could be illuminated by the laser light?



(1) the bird and the fish
(2) the bird and the seaweed
(3) the crab and the seaweed
(4) the crab and the fish 11 ____

12. What happens to the frequency and the speed of an electromagnetic wave as it passes from air into glass?

(1) The frequency decreases and the speed increases.
(2) The frequency increases and the speed decreases.
(3) The frequency remains the same and the speed increases.
(4) The frequency remains the same and the speed decreases. 12 ____

13. The speed of light in a material is 2.50×10^8 meters per second. What is the absolute index of refraction of the material?

(1) 1.20 (3) 7.50
(2) 2.50 (4) 0.833 13 ____

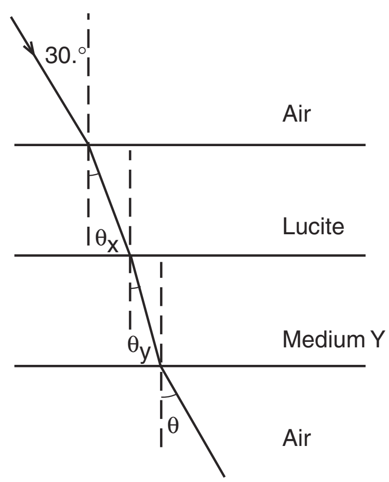
14. Which quantity is equivalent to the product of the absolute index of refraction of water and the speed of light in water?

(1) wavelength of light in a vacuum
(2) frequency of light in water
(3) sine of the angle of incidence
(4) speed of light in a vacuum 14 ____

15. What is the speed of light ($f = 5.09 \times 10^{14}$ Hz) in flint glass?

(1) 1.81×10^8 m/s
(2) 1.97×10^8 m/s
(3) 3.00×10^8 m/s
(4) 4.98×10^8 m/s 15 ____

16. The diagram below represents a light ray traveling from air to Lucite to medium *Y* and back into air.

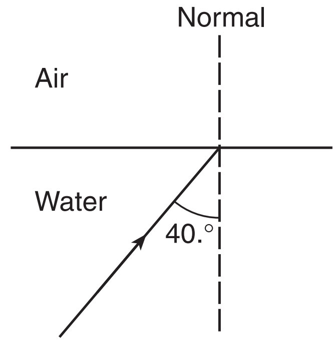


Light travels slowest in

(1) air, only
(2) Lucite, only
(3) medium *Y*, only
(4) air, Lucite, and medium *Y* 16 ____

Base your answers to questions 17*a* and *b* on the information and accompanying diagram.

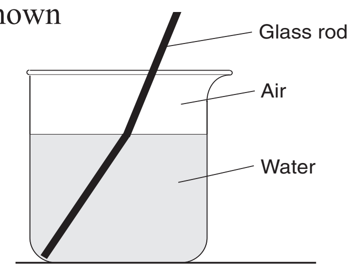
A ray of light of frequency 5.09×10^{14} hertz is incident on a water-air interface as shown in the accompanying diagram.



17. *a*) Calculate the angle of refraction of the light ray in air. [Show all work, including the equation and substitution with units.]

b) Calculate the speed of the light while in the water. [Show all work, including the equation and substitution with units.]

18. A straight glass rod appears to bend when placed in a beaker of water, as shown in the accompanying diagram. Give an explanation for this phenomenon?



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____

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19. A beam of monochromatic light has a wavelength of 5.89×10^{-7} meter in air. Calculate the wavelength of this light in zircon. [Show all work, including the equation and substitution with units.]

Refraction

Answers

Set 1

1. 4 Find the table of Absolute Indices of Refraction in the reference table. The index of diamond is 2.42. That of crown glass is 1.52. Under Waves, find the equation $n = c/v$. Solving for v, $v = c/n$. The value of c is a constant and is found on the List of Physical Constants. Since the light is entering a medium with a lower index of refraction, as shown by the equation for v, the speed of the light will increase.

2. 2 Refraction is defined as the change in direction of travel of a wave as it enters obliquely (at an angle of incidence other than 0°) a medium in which its speed changes.

3. 2 Under Waves, find the equation $n = c/v$. Since the absolute index of refraction of air is 1.00, the speed of light in air is equal to the speed of light in a vacuum (c). In the question, the speed of light in the transparent material (v) is 0.75 c. Substitution into the equation gives $n = \frac{c}{(0.75\text{ c})} = \frac{1}{0.75} = 1.3$.

4. 2 Under Waves, find the equation $n = c/v$. The value of the speed of light in a vacuum is given on the List of Physical Constants and the index of refraction of sodium chloride is found on the table of Absolute Indices of Refraction in the reference table. Substituting these values into the equation gives $1.54 = (3.00 \times 10^8\text{ m/s})/v$. Solving, $v = 1.95 \times 10^8$ m/s.

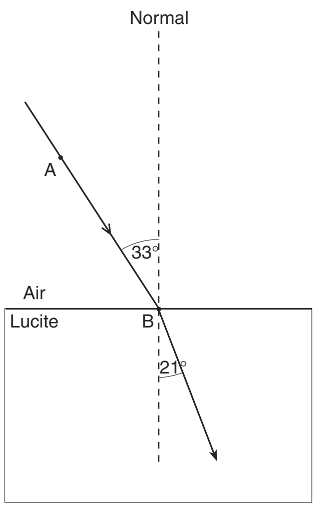
5. 3 Find the equation $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Snell's Law). The absolute index of refraction of air is found on the table of Absolute Indices of Refraction. Substitution gives $n_1(\sin 30°) = (1.00)(\sin 60°)$, where n_1 is the index of refraction of medium **X**. Solving, $n_1 = 1.73$.

6. 1 Find the equation $n_1 \sin\theta_1 = n_2 \sin\theta_2$. The absolute index of refraction of air and crown glass are found on the table of Absolute Indices of Refraction. Substitution gives $(1.00)(\sin 40°) = (1.52)(\sin\theta_2)$. Solving, $\sin\theta_2 = 0.422$ and $\theta_2 = 25°$.

7. *a*) $n_1 \sin\theta_1 = n_2 \sin\theta_2 \Rightarrow$ $(1.00)(\sin 33°) = (1.50)\sin\theta_2$ $\sin\theta_2 = 0.363$ $\theta_2 = 21°$

Explanation: Under Waves, find the equation $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Snell's Law). Using the table of Absolute Indices of Refraction in the reference table, find the index of refraction of air (1.00) and Lucite (1.50). Using $n_1 = 1.00$, $\theta_1 = 33°$ and $n_2 = 1.50$, substitute into the equation and solve for θ_2, the angle of refraction in Lucite.

b)



Explanation: From question 7*a*, the angle of refraction in Lucite is 21°. This is the angle between the refracted ray in Lucite and the normal.

8. *a*) The angle of incidence is 45° (±2°).
The angle of refraction is 26° (±2°).

Explanation: The angle of incidence is the angle between the incident ray and the normal. The angle of refraction is the angle between the refracted ray and the normal. They are not measured with respect to the boundary.

b)

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
$$n_2 = \frac{(1.00)(\sin 45°)}{\sin 26°}$$
$$n_2 = 1.61$$

Explanation: Under Waves, find the equation $n_1 \sin\theta_1 = n_2 \sin\theta_2$. Find the index of refraction of air on the Absolute Indices. Using $n_1 = 1.00$, θ_1 = your measured angle of incidence in question 8*a* and θ_2 = your measured angle of refraction in question 8*a*. Solve for n_2.

9. *a*) Answer: 17°

Explanation: The angle of incidence is the angle between the incident ray and the normal to the surface at the point of incidence. It must be within ±2°.

b) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$$\sin\theta_2 = \frac{n_1 \sin\theta_1}{n_2}$$

$$\sin\theta_2 = \frac{1.00 \sin 17°}{1.46}$$

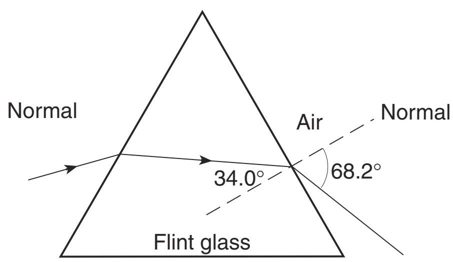
$\theta_2 = 12°$ *or* $11.6°$

Explanation: Under Waves, find the equation $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Snell's Law). Values of n_1 (absolute index of refraction of air) and n_2 (absolute index of refraction of fused quartz) are found on the table of Absolute Indices of Refraction. Use these values along with the angle of incidence (θ_1) measured in question 9*a* to calculate the angle refraction (θ_2).

10. *a*) $n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\quad \sin\theta_2 = \dfrac{n_1 \sin\theta_1}{n_2}$ $\quad \sin\theta_2 = \dfrac{(1.66)(\sin 34.0°)}{(1.00)}$ $\quad \theta_2 = 68.2°$ ***or*** $68°$

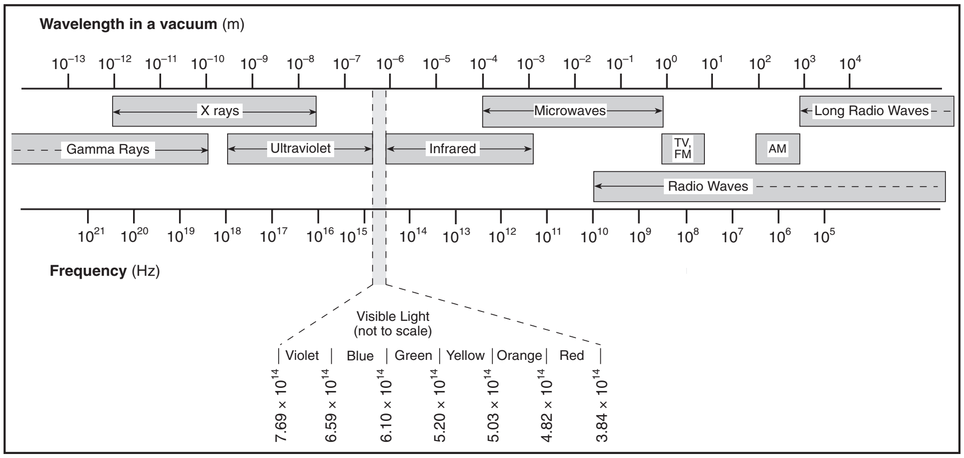
Explanation: Under Waves, find the equation $n_1 \sin\theta_1 = n_2 \sin\theta_2$. Use the table of Absolute Indices of Refraction in the reference table to find the indices of refraction of air (1.00) and flint glass (1.66), n_1 and n_2, respectively. Angle θ_1 is 34.0°. Substitute into the equation and calculate θ_2.

b)



Explanation: The angle of refraction is defined as the angle between the normal and the refracted ray. Measure the angle calculated in question 10*a* with respect to the normal in air. Draw in the refracted ray at this angle.

The Electromagnetic Spectrum



Overview:

Electromagnetic waves or radiation are transverse waves generated by accelerated charged particles. These waves consist of two transverse waves, one electric and the other magnetic, vibrating at a right angle to each other and to the direction of propagation.

The Electromagnetic Spectrum is a continuous range of electromagnetic waves or radiation ranging in frequency from about 10 to 10^{25} Hz. Wavelengths range from about 3×10^{7} to 3×10^{-17} m.

The Table:

The table lists the Names, Wavelength range and Frequency range of the families of the electromagnetic spectrum. The families of the electromagnetic spectrum differ only in the frequency of the waves and their source. There is no sharp boundary between the families.

Additional Information:

- In an electromagnetic wave, the changing electric wave induces a changing magnetic wave and vice versa. Therefore, electromagnetic waves do not require a medium for transmission.
- In a vacuum (or air), all electromagnetic waves travel with a speed of 3.00×10^{8} m/s. This is known as the speed of light (c). See the List of Physical Constants.
- The human eye is sensitive to only a very small range of electromagnetic waves known a visible light. This range is referred to as the visible spectrum, consisting the six spectral colors that are listed on the chart.
- As the frequency of the electromagnetic wave increases, the wavelength decreases.
- As the frequency of the electromagnetic waves increases, the wave nature of the radiation decreases and the particle nature increases.
- The infrared family is also known as heat waves. The ultraviolet family is referred to as black light.
- X-rays are used as diagnostic tools in medicine.
- Gamma rays are high energy rays emitted by radioactive elements.
- Microwaves cook the food in microwave ovens.
- Radio waves include TV, AM and FM signals.

Set 1 — The Electromagnetic Spectrum

1. Compared to the speed of a sound wave in air, the speed of a radio wave in air is

   (1) less
   (2) greater
   (3) the same 1 _____

2. Electromagnetic radiation having a wavelength of 1.3×10^{-7} meter would be classified as

   (1) infrared (3) blue
   (2) orange (4) ultraviolet 2 _____

3. Which pair of terms best describes light waves traveling from the Sun to Earth?

   (1) electromagnetic and transverse
   (2) electromagnetic and longitudinal
   (3) mechanical and transverse
   (4) mechanical and longitudinal 3 _____

4. Which wave characteristic is the same for all types of electromagnetic radiation traveling in a vacuum?

   (1) speed (3) period
   (2) wavelength (4) frequency 4 _____

5. A photon of which electromagnetic radiation has the most energy?

   (1) ultraviolet (3) infrared
   (2) x ray (4) microwave 5 _____

Base your answers to question 6 on the data table below. The data table lists the energy and corresponding frequency of five photons.

Photon	**Energy** (J)	**Frequency** (Hz)
A	6.63×10^{-15}	1.00×10^{19}
B	1.99×10^{-17}	3.00×10^{16}
C	3.49×10^{-19}	5.26×10^{14}
D	1.33×10^{-20}	2.00×10^{13}
E	6.63×10^{-26}	1.00×10^{8}

6. In which part of the electromagnetic spectrum would photon *D* be found?

   (1) infrared (3) ultraviolet
   (2) visible (4) *x* ray 6 _____

7. An electromagnetic AM-band radio wave could have a wavelength of

   (1) 0.005 m (3) 500 m
   (2) 5 m (4) 5 000 000 m 7 _____

8. A microwave and an *x* ray are traveling in a vacuum. Compared to the wavelength and period of the microwave, the *x* ray has a wavelength that is

   (1) longer and a period that is shorter
   (2) longer and a period that is longer
   (3) shorter and a period that is longer
   (4) shorter and a period that is shorter

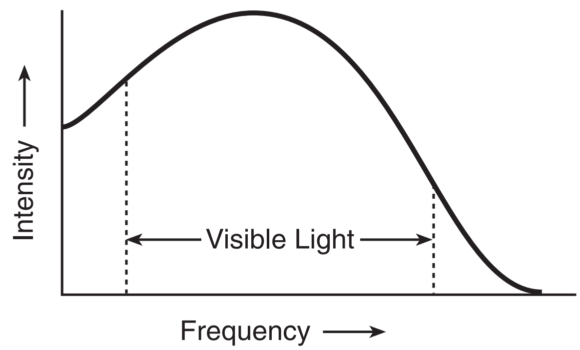
   8 _____

9. A monochromatic beam of light has a frequency of 6.5×10^{14} hertz. What color is the light?

   (1) yellow (3) violet
   (2) orange (4) blue 9 _____

Base your answers to questions 10 *a* and *b* on the information below and the accompanying graph.

Sunlight is composed of various intensities of all frequencies of visible light. The graph represents the relationship between light intensity and frequency.



10. *a*) Based on the graph, which color of visible light has the lowest intensity?

____

b) It has been suggested that fire trucks be painted yellow green instead of red. Using information from the graph, explain the advantage of using yellow-green paint.

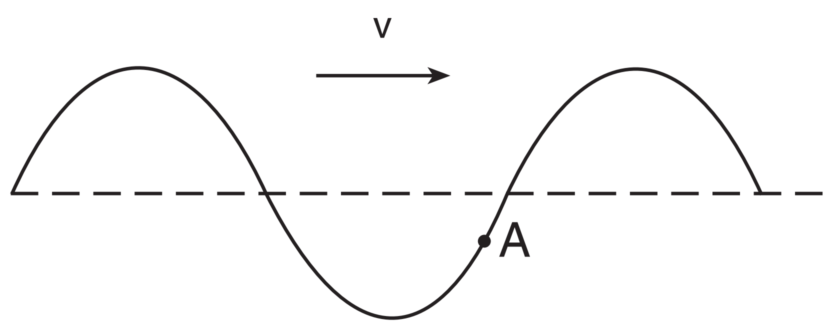
____

____

____

____

11. The accompanying diagram represents a transverse wave traveling to the right through a medium. Point *A* represents a particle of the medium. At position *A* draw an arrow showing the direction that particle *A* will move in the next instant of time?



Set 2 — The Electromagnetic Spectrum

12. Which type of wave requires a material medium through which to travel?

    (1) radio wave
    (2) microwave
    (3) light wave
    (4) mechanical wave 12 ____

13. Which characteristic is the same for every color of light in a vacuum?

    (1) energy (3) speed
    (2) frequency (4) period 13 ____

14. Which wavelength is in the infrared range of the electromagnetic spectrum?

    (1) 100 nm (3) 100 m
    (2) 100 mm (4) 100 µm 14 ____

15. What is the speed of a radio wave in a vacuum?

    (1) 0 m/s
    (2) 3.31×10^2 m/s
    (3) 1.13×10^3 m/s
    (4) 3.00×10^8 m/s 15 ____

16. Compared to the wavelength of red light, the wavelength of yellow light is

    (1) shorter
    (2) longer
    (3) the same 16 ____

17. As a transverse wave travels through a medium,the individual particles of the medium move

    (1) perpendicular to the direction of wave travel
    (2) parallel to the direction of wave travel
    (3) in circles
    (4) in ellipses 17 ____

Note: Question 18 has only three choices.

18. Compared to the speed of microwaves in a vacuum, the speed of *x*-rays in a vacuum is

    (1) less (2) greater (3) the same 18 ___

19. Which color of light has a wavelength of 5.0×10^{-7} meter in air?

    (1) blue (3) orange
    (2) green (4) violet 19 ____

---

20. Give the properties of a transverse wave.

____

____

The Electromagnetic Spectrum
Answers
Set 1

1. 2 Both light and radio waves are part of the electromagnetic spectrum and have the same speed in air (which is the same speed in a vacuum). Both speeds are found in the List of Physical Constants. Here it shows that electromagnetic waves are much faster than the speed of sound.

2. 4 On The Electromagnetic Spectrum chart a wavelength of 1.3×10^{-7} m places this radiation in the ultraviolet family.

3. 1 Light is a part of the electromagnetic spectrum (see The Electromagnetic Spectrum). All electromagnetic waves are transverse waves.

4. 1 The speed of all electromagnetic waves traveling in a vacuum is the same (the speed of light, c). As seen on The Electromagnetic Spectrum chart, the families of electromagnetic waves differ in frequency and wavelength.

5. 2 The higher the frequency, the greater the energy of the photon. Referring to The Electromagnetic Spectrum chart, *x*-ray radiation has the highest frequency of the choices given.

6. 1 Find the chart of The Electromagnetic Spectrum. The frequency of photon D falls in the infrared (IR) portion of the spectrum.

7. 3 Open to The Electromagnetic Spectrum chart. The AM-band radio waves have a wavelength range of 10^2 to 10^3 m.

8. 4 Find The Electromagnetic Spectrum chart. The wavelength of an *x*-ray is shown to be shorter than the wavelength of a microwave. The frequency of the *x*-ray is higher than the frequency of the microwave. Under Waves, find the equation $T = 1/f$. This indicates that the higher the frequency, the shorter the period.

9. 4 In The Electromagnetic Spectrum, the light spectrum is enlarged. Here it shows that a light beam having a frequency of 6.5×10^{-14} Hz is located in the blue area.

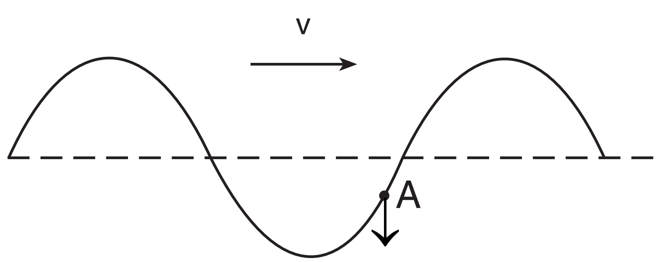
10. *a*) violet **or** the one with the greatest frequency

Explanation: According to the graph, the color of visible light with the lowest intensity is the color with the highest frequency. Referring to The Electromagnetic Spectrum chart, the color of visible light with the highest frequency is violet.

b) Yellow green has a higher intensity. **or** Yellow green is brighter than red.

Explanation: According to the graph, the color of visible light with the greatest intensity is in the middle of the frequency range of visible light. From The Electromagnetic Spectrum chart, this is in the yellow-green region.

11.



Point *A* moves up and down as the wave passes. It does not move along with the wave. As the wave moves to the right, the bottom of a trough is approaching point *A*. Therefore, point *A* is moving down.