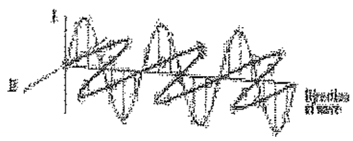
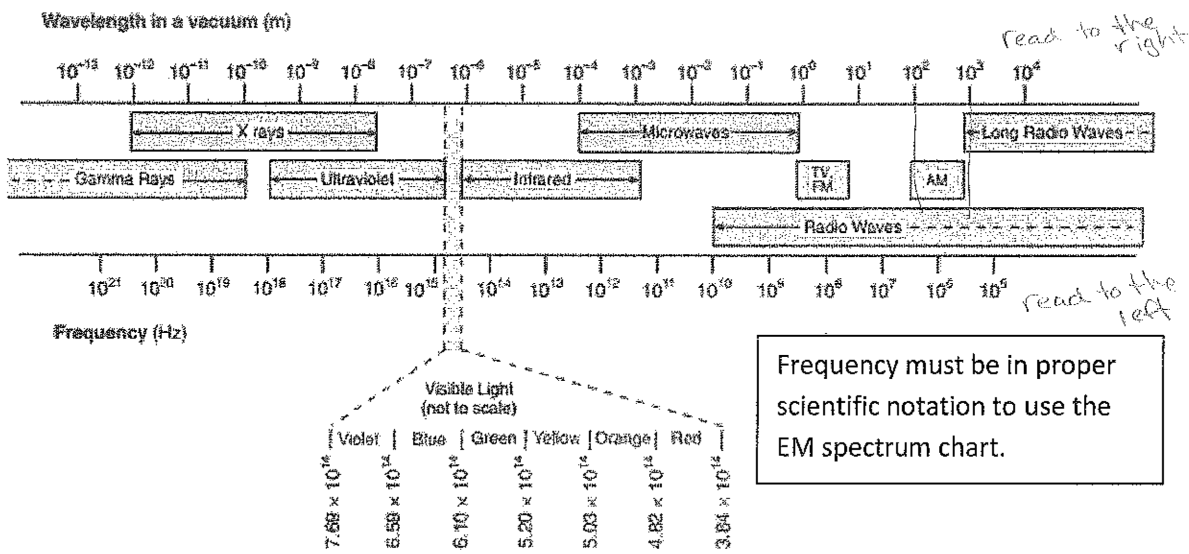
Skill 51: EM Waves

135. Electromagnetic (EM Wave)– produced by the acceleration (oscillation) of a charged particle. EM waves are able to travel through a Vacuum. (A PLACE WITHOUT MATTER.)



A moving charge has an electric field and also creates a perpendicular magnetic field. This in turn creates an electric field

136. EM SPECTRUM CHART FROM REFERENCE TABLE: VALUES GIVEN FOR A VACUUM, THEREFORE THE SPEED OF EVERY WAVE ON THIS CHART IS 3.0×10^{8} m/s known as "c". If you know wavelength and speed you can find frequency.



Frequency must be in proper scientific notation to use the EM spectrum chart.

137. When an EM wave enters a medium the speed of the wave will depend on the index of refraction "n" of the medium. The speed in the new medium can be calculated using the equation $n = c/v$ which means $v = c/n$

Index of refraction and speed of EM wave in a medium have a(n) inverse relationship.

138. The frequency of an EM does not change if it enters a new medium.

139. EM Waves are photons. They behave as both particles and waves.

140. A wave traveling through a vacuum has a wavelength of 100 nm. What type of wave is this?

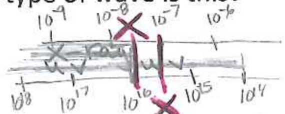
$\lambda = 100\,nm = 1\times10^{2}\times10^{-9}m = 1\times10^{-7}m$

$V = c = 3\times10^{8} m/s$

$V = f\lambda$

$f = V/\lambda = \frac{3\times10^{8} m/s}{1\times10^{-7} m} = 3\times10^{15} Hz$ (Ultraviolet)

141. A wave traveling through a vacuum has a wavelength of 4.70 x 10^{-8}m. What type of wave is this?



$\lambda = 4.7\times10^{-8} m$

$V = c = 3\times10^{8} m$

$f = ?$

$V = f\lambda$

$f = V/\lambda = \frac{3\times10^{8} m/s}{4\times10^{-8} Hz} = .75\times10^{16} Hz$

$= 7.5\times10^{15} Hz$ = ultraviolet

overlap of λ 10^{-8}m
& f 10^{15} Hz

142. A wave has a wavelength of 50 x 10^{-6}m. What type of wave is this?

$\lambda = 50\times10^{-6}m = 5.0\times10^{-5}m$ must be in correct SN

Infrared

143. An electromagnetic wave with a wavelength of 5 x 10^{-9} m is traveling through outer space.

a. What is the speed of this wave? $3\times10^{8} m/s$
(speed of light in a vacuum)

b. Determine the frequency of this wave

$f = V/\lambda = \frac{3\times10^{8} m/s}{5\times10^{-9} m} = .6\times10^{17} Hz = 6\times10^{16} Hz$

c. In what part of the electromagnetic spectrum is this wave found? UV or X-ray

144. An electromagnetic wave with a frequency of 6.2 x 10^{14} Hz is passing through unknown substance that has an index of refraction of 2.4

a. In what part of the electromagnetic spectrum is this wave found? Blue visible light

b. Determine the speed of the wave in this medium.

$n = c/v \qquad V = \frac{c}{n} = \frac{3\times10^{8} m/s}{2.4} = 1.25\times10^{8} m/s$

c. Calculate the wavelength of this wave in this medium.

$V = f\lambda$

$\lambda = V/f = \frac{1.25\times10^{8} m/s}{6.2\times10^{14} Hz} = .2\times10^{-6} m = 2\times10^{-7} m$

Frequency remains the same when mediums change
- Wavelengths do not

145. Bees have specially adapted eyes that can detect electromagnetic radiation outside of what humans refer to as 'visible light'. Some flowers that bees visit have colorations that are invisible to humans, and yet match this amazing evolutionary development in bees! Bees also use these specially adapted eyes to aid them in navigation when it is cloudy. This type of radiation has a somewhat higher frequency than that of visible light.

What part of the electromagnetic spectrum are these bee eyes able to see?
Ultraviolet

146. An electromagnetic wave traveling through a vacuum has a wavelength of 1.5×10^{-1} meter. What is the period of this electromagnetic wave?

(1) 5.0×10^{-10} s (2) 1.5×10^{-1} s (3) 4.5×10^{7} s (4) 2.0×10^{9} s

$v = \frac{\lambda}{T}$ $T = \lambda / v = \frac{1.5\times10^{-1} m}{3\times10^{8} m/s} = .5\times10^{-9} s = 5\times10^{-10} s$ OR $v = f\lambda$ $f = \frac{v}{\lambda} = \frac{3\times10^{8} m/s}{1.5\times10^{-1} m} = 2\times10^{9} Hz$ $T = 1/f = \frac{1}{2\times10^{9} Hz} = .5\times10^{-9} s = 5\times10^{-10} s$

147. The speed of a ray of light traveling through a substance having an absolute index of refraction of 1.1 is

(1) 1.1×10^{8} m/s (2) 2.7×10^{8} m/s ~~(3) 3.0×10^{8} m/s~~ ~~(4) 3.3×10^{8} m/s~~

$n = c/v$ $v = \frac{c}{n} = \frac{3\times10^{8} m/s}{1.1} = 2.7\times10^{8} m/s$

148. A microwave and an x-ray are traveling in a vacuum. Compared to the wavelength 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

$\lambda = \frac{v}{f}$ $f = \frac{1}{T}$

as λ decreases frequency increases; frequency and period are inverse; so λ & T are direct.

OR

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

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

$100\times10^{-9} m$ $1\times10^{-7} m$ | $100\times10^{-3} m$ $1\times10^{-1} m$ | $1\times10^{2} m$ | $1\times10^{2}\times10^{-6} m$ $1\times10^{-4} m$

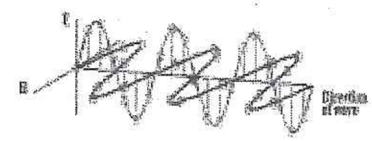
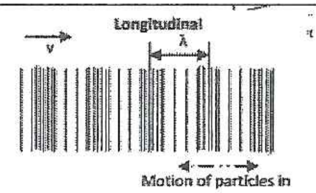
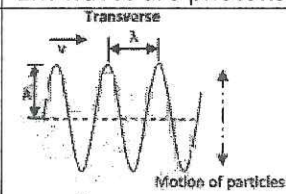
10^{-6} 10^{-5} 10^{-4} 10^{-3}

$v = \frac{\lambda}{T}$ $\lambda = vT$

150. To determine the type or category of a wave on the EM spectrum you can use either the wavelength or frequency if traveling in a Vacuum unless it is visible light. If the wave is traveling through a substance you must solve for frequency, because it does not change when an EM wave enters a new medium.

Radio waves are categorized as electromagnetic because they can travel through the vacuum of space. The type of particle vibration for radio waves is tranverse which means the particles move perpendicular to the motion of the wave. Visible light (such as Red, Orange..) is similar to a radio wave in type of wave and type of particle vibration but it has a higher energy, a smaller Wavelength and a higher frequency. In a vacuum the Speed of a radio wave and a visible light are the same (which is 3×10^{8} m/s).

Sound waves are categorized as mechanical because they cannot travel through a vacuum. The type of particle vibration for sound waves is longitudinal. Mechanical waves other than sound can also have transverse particle vibration. The speed of a sound wave in air at STP is 331 m/s. The speed of sound in air is less than water because the particles are less dense.

151. Fill in Blanks on Chart	**Sound Waves**	**Electromagnetic Waves**
What do they do?	Transfer energy not mass	Transfer energy not mass
Where do they come from?	Vibration within a medium. (Sound is a pressure wave)	Vibration (acceleration) of a charged particle. The motion of the charged particle causes the electric field to oscillate. The oscillation of the electric field causes the oscillation of the magnetic field.  EM waves are photons that behave as waves & particles.
Types of Vibration	 	
Speed	Speed of sound at STP: 331 m/s	Speed of light (EM waves) in a vacuum Equals 3×10^8 m/s equation in a medium $v = c/n$
How speed changes with medium	Can only move (propagate) through a medium. Speed up with density. CANNOT propagate through a vacuum	Move at 3×10^8 m/s in a vacuum (or air n=1) Speed in a medium is inversely related to index of refraction. $v=c/n$
Energy of a propagating wave is related to...	Amplitude Mechanical wave	Frequency
To compare the energy of two different types of wave consider	Amplitude	Frequency
Amplitude is related to...	Loudness	Brightness
Increasing frequency is related to....	Increasing pitch	Increasing energy (See EM spectrum)
Wavelength is the distance	Between two ..... compressions or rarefactions	Between two ....crests or troughs

Topic 6B: Electromagnetic Waves
Skill 51

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

A) blue
B) green 5.2 to 6.1×10^{14} Hz
C) orange
D) violet

$n=1$ so $v=c$
$v=f\lambda$
$f=v/\lambda=\frac{3\times10^{8}\,m/s}{5\times10^{-7}\,m}=.6\times10^{15}\,Hz=6\times10^{14}\,Hz$

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

A) 0.005 m 5×10^{-3} m
B) 5 m 5×10^{0} m
C) 500 m 5×10^{2} m
D) 5 000 000 m 5×10^{6} m

radio $10^{2}\rightarrow10^{3}$

154. 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

A) ~~longer~~ and a period that is shorter
B) ~~longer~~ and a period that is longer
C) shorter and a period that is longer
D) shorter and a period that is shorter

shorter λ, higher f, shorter T

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

A) 100 nm 1×10^{-7} m
B) 100 mm 1×10^{-1} m
C) 100 m 1×10^{2} m
D) 100 μm 1×10^{-4} m

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

A) infrared
B) orange
C) blue
D) ultraviolet

must find frequency

$f=\frac{v}{\lambda}=\frac{3\times10^{8}\,m/s}{1\times10^{-7}\,m}=3\times10^{15}\,Hz$

above violet

157. Radio waves are propagated through the interaction of

A) nuclear and electric fields
B) electric and magnetic fields
C) gravitational and magnetic fields
D) gravitational and electric fields

158. Compared to the period of a wave of red light the period of a wave of green light is

A) less
B) greater
C) the same

green has higher frequency than red
f is inverse to T
so
green has lower T than red

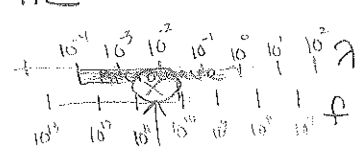
159. Which pair of terms best describes light waves traveling from the Sun to Earth?

A) electromagnetic and transverse
B) electromagnetic ~~and longitudinal~~
C) ~~mechanical~~ and transverse
D) ~~mechanical and longitudinal~~

160. Electrons oscillating with a frequency of 2.0×10^{10} hertz produce electromagnetic waves. These waves would be classified as

A) infrared
B) visible
C) microwave
D) x-ray

$f=2\times10^{10}\,Hz$



Topic 6B: Electromagnetic Waves

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

A) ultraviolet B) x-ray
C) infrared D) microwave

Energy of an EM wave is related to frequency

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

A) shorter B) longer
C) the same

163. A beam of green light may have a frequency of

A) ~~5.0×10^{-7} Hz~~ B) ~~1.5×10^{2} Hz~~
C) ~~3.0×10^{8} Hz~~ D) 6.0×10^{14} Hz

5.2 → 6.1×10^{14} Hz

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

A) yellow B) orange
C) violet D) blue

6.1 to 6.59 $\times 10^{14}$ Hz

165. Which electromagnetic radiation has the *shortest* wavelength?

A) infrared B) radio
C) gamma D) ultraviolet

166. Which of the following electromagnetic waves has the lowest frequency?

least energy

A) violet light B) green light
C) yellow light D) red light

167. Which of the following electromagnetic radiations has the shortest wavelength?

A) radio B) infrared
C) visible D) ultraviolet

168. Which is not in the electromagnetic spectrum?

A) light waves B) radio waves
C) sound waves D) x-rays

169. Which color of light has the greatest period?

lowest f
lowest E

A) violet B) green
C) orange D) red

170. To which part of the electromagnetic spectrum will a photon belong if its wavelength in a vacuum is 5.6×10^{-7} meters?

A) X-ray B) ultraviolet
C) visible light D) infrared

$f = v/\lambda = \frac{3.0 \times 10^{8} m/s}{5.6 \times 10^{-7} m} = .53 \times 10^{15}$ Hz

5.3×10^{14} Hz

Topic 6B: Electromagnetic Waves

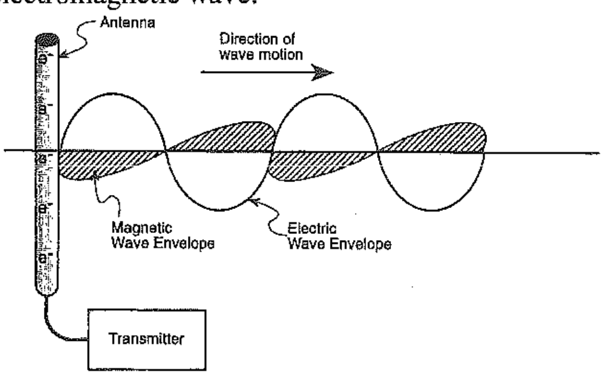
171. The color of visible light is determined by its

A) frequency B) amplitude
C) intensity D) speed

172. Which statement best describes a proton that is being accelerated?

A) It produces electromagnetic radiation.
B) The magnitude of its charge increases.
C) It absorbs a neutron to become an electron.
D) It is attracted to other protons.

173. The diagram below shows an antenna emitting an electromagnetic wave.



In what way did the electrons in the antenna produce the electromagnetic wave?

A) by remaining stationary
B) by moving at constant speed upward, only
C) by moving at constant speed downward, only
D) by accelerating alternately upward and downward

174. Electromagnetic waves can be generated by accelerating

A) a hydrogen atom B) photon
C) a neutron D) an electron

has a charge

175. An accelerating particle that does not generate electromagnetic waves could be

A) a neutron No charge B) a proton charged
C) an electron charge D) an alpha particle charged

176. When electrical charges are accelerated in a vacuum, they may generate

A) sound waves B) water waves
C) light waves D) torsional waves

EM waves

177. Radiations such as radio, light, and gamma are propagated by the interchange of energy between

A) magnetic fields, only
B) electric fields, only
C) electric and gravitational fields
D) electric and magnetic fields

178. Orange light has a frequency of 5.0×10^{14} hertz in a vacuum. What is the wavelength of this light?

A) 1.5×10^{23}m B) 1.7×10^{6}m
C) 6.0×10^{-7} m D) 2.0×10^{-15} m

$\lambda = \frac{v}{f} = \frac{3\times10^{8} m/s}{5\times10^{14} Hz} = .6\times10^{-6} m$
$= 6\times10^{-7} m$

Topic 6B: Electromagnetic Waves

179. What is the wavelength. of X-rays with a frequency 1.5×10^{18} hertz traveling in a vacuum?

A) 4.5×10^{26} m B) 2.0×10^{-10} m
C) 5.0×10^{-10} m D) 5.0×10^{9} m

$v = f\lambda$ $\lambda = \frac{v}{f} = \frac{3\times10^8 m/s}{1.5\times10^{18} Hz} = 2\times10^{-10} m$

high f small λ

180. The time required for light to travel a distance of 1.5×10^{11} meters is closest to

A) 5.0×10^{2} s B) 2.0×10^{-3} s
C) 5.0×10^{-1} s D) 4.5×10^{19} s

$v = d/t$ $t = \frac{d}{v} = \frac{1.5\times10^{11} m}{3\times10^8 m/s} = .5\times10^3 s$
$= 5\times10^2 s$

181. The distance from the Moon to Earth is 3.9×10^{8} meters. What is the time required for a light ray to travel from the Moon to Earth?

A) 0.65 s B) 1.3 s
C) 2.6 s D) 3.9 s

$d = 3.9\times10^8 m$
$t = ?$
$V = 3\times10^8 m/s$

$t = d/v = \frac{3.9\times10^8 m}{3\times10^8 m/s}$
$= 1.3\times10^0 s$
$= 1.3 s$

182. A typical microwave oven produces radiation at a frequency of 1.0×10^{10} hertz. What is the wavelength of this microwave radiation?

A) 3.0×10^{-1} m B) 3.0×10^{-2} m
C) 3.0×10^{10} m D) 3.0×10^{18} m

$f = 1\times10^{10} Hz$
$\lambda = ?$
$V = 3\times10^8 m/s$

$V = f\lambda$
$\lambda = \frac{V}{f} = \frac{3\times10^8 m/s}{1\times10^{10} Hz} = 3\times10^{-2} m$

183. How long will it take a light wave to travel a distance of 100. meters?

A) 3.00×10^{10} s B) 3.00×10^{8} s
C) 3.33×10^{-7} s D) 3.33×10^{7} s

$d = 100 m$
$t = ?$
$V = 3\times10^8 m/s$

$V = d/t$
$t = d/v = \frac{100 m}{3\times10^8 m/s} = 33.3\times10^{-8} s$
$3.33\times10^{-7} s$

184. When x-ray radiation and infrared radiation are traveling in a vacuum, they have the same

A) speed B) frequency
C) wavelength D) energy per photon

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

A) energy B) frequency
C) speed D) period

186. How much time does it take light from a flash camera to reach a subject 6.0 meters across a room?

A) 5.0×10^{-9} s B) 2.0×10^{-8} s
C) 5.0×10^{-8} s D) 2.0×10^{-7} s

$d = 6m$
$t = ?$
$V = 3\times10^8 m/s$

$V = d/t$ $t = d/v$
$t = \frac{6m}{3\times10^8 m/s} = 2\times10^{-8} s$

187. Base your answer to the following question on the information below.

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?

A) 4.11×10^{-3} s B) 2.43×10^{2} s
C) 2.19×10^{8} s D) 1.46×10^{17} s

$f = 2\times10^6 Hz$
$d = 7.3\times10^{10} m$
$V = 3\times10^8 m/s$
$t = ?$

$t = \frac{d}{V} = \frac{7.3\times10^{10} m}{3\times10^8 m/s}$
$= 243\times10^{2} s$

Topic 6B: Electromagnetic Waves

188. As the wavelength of a visible light beam is increased from violet to red, the speed of the light in a vacuum

A) decreases B) increases
C) remains the same

Speed in a vacuum is c 3×10^8 m/s for all EM waves

189. As the frequency of an electromagnetic wave increases, its speed in a vacuum

A) decreases B) increases
C) remains the same

Speed in a vacuum is c (3×10^8 m/s) for all EM waves

190. All frequencies of light have the same speed when traveling through

A) a vacuum B) glass
C) water D) alcohol

191. A change in the speed of a wave as it enters a new medium produces a change in

~~A) frequency~~ ~~B) period~~
C) wavelength D) phase

frequency comes from the source of the wave → it does not change after created

Period depend on frequency so it follows the same rules

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

A) ~~The frequency decreases~~ and the speed increases.
B) ~~The frequency increases~~ and the speed decreases.
C) The frequency remains the same and ~~the speed increases.~~
D) The frequency remains the same and the speed decreases.

frequency remains the same

$v = \frac{c}{n}$ n of air = 1 as n↑
n of glass = 1.52 or 1.66 v↓

193. What is the speed of light ($f = 5.09 \times 10^{14}$ Hz) in ethyl alcohol?

A) 4.53×10^{-9} m/s B) 2.43×10^{2} m/s
C) 1.24×10^{8} m/s D) 2.21×10^{8} m/s

$v = \frac{c}{n} = \frac{3 \times 10^8 \text{ m/s}}{1.36} =$

194. The wavelength of a wave doubles as it travels from medium *A* into medium *B*. Compared to the wave in medium *A*, the wave in medium *B* has

A) half the speed
B) twice the speed
~~C) half the frequency~~
~~D) twice the frequency~~

A	B
λ	2λ

frequency remains the same
$v = f\lambda$ direct so speed doubles

195. As a wave travels into a different medium with a change in direction, there will be a change in the wave's

A) speed ~~B) frequency~~
~~C) period~~ ~~D) phase~~

frequency and period are linked
frequency does not change

$v = c/n$

Topic 6B: Electromagnetic Waves

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

A) 1.81×10^8 m/s B) 1.97×10^8 m/s
~~C) 3.00×10^8 m/s~~ ~~D) 4.98×10^8 m/s~~

$V = \frac{c}{n} = \frac{3\times10^8 m/s}{1.66}$ Can't be greater than c

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

A) 1.54×10^8 m/s B) 1.95×10^8 m/s
~~C) 3.00×10^8 m/s~~ ~~D) 4.62×10^8 m/s~~

$V = \frac{c}{n} = \frac{3\times10^8 m/s}{1.54}$

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

A) wavelength of light in a vacuum
B) frequency of light in water
C) sine of the angle of incidence
D) speed of light in a vacuum

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

199. If the speed of light in a medium is 2.0×10^8 meters per second, the index of refraction for the medium is

A) 1.0 B) 2.0 C) 1.5 D) 0.67

$V = 2\times10^8 m/s$
$n = ?$
$c = 3\times10^8 m/s$

$n = \frac{c}{v} = \frac{3\times10^8 m/s}{2\times10^8 m/s}$

200. In which of the following materials is the speed of light the greatest?

A) quartz 1.46 B) alcohol 1.36
C) glycerol 1.47 D) lucite 1.50

$V = \frac{c}{n}$ inverse