12 A distant star is traveling directly toward Earth with a speed of 36,500 km/s.

(1) Are the wavelengths of this star's spectrum greater, less than, or the same as compared to a rest measurement.

(2) By what fraction are the wavelengths shifted?

Solution (1)

observed frequency increases over rest measurement $f' = f\left(1 + \frac{v}{c}\right)$

$c = f\lambda \quad \lambda = \frac{c}{f} \rightarrow$ $\boxed{\text{observed } \lambda \text{ decreases}}$

Solution (2)

$$\Delta f_{factor} \quad \left(1 + \frac{36{,}500\text{ E}3\text{ m/s}}{3.00\text{ E}8\text{ m/s}}\right) = \boxed{1.12}$$

$$\Delta\lambda_{factor} = \frac{1}{\Delta f_{factor}} = \frac{1}{1.12} = \boxed{0.893}$$

How fast must a motorist move relative to a traffic light to observe a yellow ($\lambda = 590\text{ nm}$) light as green ($\lambda = 550\text{ nm}$) due to Doppler shift?

$\lambda' = 550\text{ nm} \qquad \lambda = 590\text{ nm}$

$f' = f\left(1 \pm \frac{u}{c}\right) \qquad f = \frac{c}{\lambda}$

motorist must <u>approach</u> $\quad \uparrow f \Rightarrow \downarrow \lambda$

$f' = f\left(1 + \frac{u}{c}\right)$

$f' - f = \left(\frac{f}{c}\right) u$

$$\frac{f' - f}{\frac{f}{c}} = u = \frac{\frac{c}{\lambda'} - \frac{c}{\lambda}}{\frac{\cancel{c}/\lambda}{\cancel{c}}} = c\lambda\left(\frac{1}{\lambda'} - \frac{1}{\lambda}\right)$$

$$= \boxed{2.18\text{E}7 \text{ m/s}}$$

Which color of light has a higher frequency, red or violet? Calculate each frequency if $\lambda_{red} = 680\,nm$ and $\lambda_{\cancel{blue}\ violet} = 470\,nm$.

$\uparrow f \Rightarrow \downarrow \lambda$ therefore ~~blue~~ violet has the highest frequency

$$f = \frac{c}{\lambda}$$

$$f_{violet} = \frac{3.0E8\,m/s}{470E{-9}\,m} = 6.38E14\,Hz$$

$$\boxed{6.4E14\,Hz}$$

$$f_{red} = \frac{3.0E8\,m/s}{680E{-9}\,m} = 4.41E14\,Hz$$

$$\boxed{4.4E14\,Hz}$$

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Which EM wave has the greater intensity?

Wave 1 $\quad E_0 = 52 \frac{V}{m}$

Wave 2 $\quad B_0 = 1.5 \mu T$

$$I = c \varepsilon_0 E^2 = \frac{c}{\mu_0} B^2$$

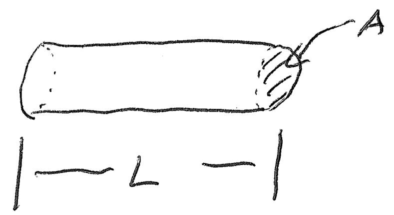
$$I_1 = \left(3E8 \, m/s\right)\left(8.85E{-12} \frac{C^2}{Nm^2}\right)\left(52 \frac{V}{m}\right)^2 = 7.18 \frac{W}{m^2}$$

$$I_2 = \frac{3E8 \, m/s}{1.26E{-6} \frac{Tm}{A}} \left(1.5E{-6} \, T\right)^2 = 5.36E2 \frac{W}{m^2}$$

$$\boxed{\text{Wave 2 has a larger intensity}}$$

52 What length of a 5.0 mW laser beam will contain 8.5 mJ of energy?

$P = \frac{\Delta E}{\Delta t}$ $\qquad$ $L = c\Delta t$



$d = vt$

$$L = c\left(\frac{\Delta E}{P}\right) = 3E8\,\text{m/s}\left(\frac{8.5E\text{-}3\ \text{J}}{5.0E\text{-}3\ \text{W}}\right)$$

$$= \boxed{5.1E8\ \text{m}}$$