PH 222 Activity 6

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Problems 2 through 5 are borrowed/adapted from Chapter 16 of the *Student Workbook* for *Physics for Scientists and Engineers*. Numerical values for gravitational acceleration on Venus come from <https://phys.org/news/2016-01-strong-gravity-planets.html>.

Activity 1

On Venus, gravitational acceleration is about $g_{♀} = 8.87\ \mathrm{m/s^2}$, or $0.904g$. How does the period $T_{♀}$ of a simple pendulum on Venus compare to the period T of a pendulum on Earth? How long would the string of the pendulum have to be to make the periods differ by an entire second?

The period of a simple pendulum is $T = 2\pi\sqrt{L/g}$. Comparing the period on Earth to the period on Venus, we find

$$\frac{T_{♀}}{T} = \sqrt{\frac{g}{g_{♀}}} = \sqrt{\frac{1}{0.904}} \approx 1.05.$$

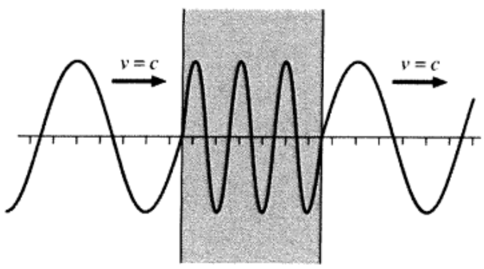
As such, the period of the pendulum becomes about $0.05T$ longer when it is on Venus. If we want this change to be equal to 1 second, then it must be that $T = 20$ s on Earth. Solving the period equation for length, we find

$$L = g\left(\frac{T}{2\pi}\right)^2 = (9.8\ \mathrm{m/s^2})\left(\frac{20\ \mathrm{s}}{2\pi}\right)^2 \approx 99.3\ \mathrm{m}.$$

We would need a pendulum approximately 99.3 meters in length to see such a large change.

Activity 2

(a) A light wave travels from vacuum, through a transparent material, and back to vacuum. What is the index of refraction of this material? Explain.



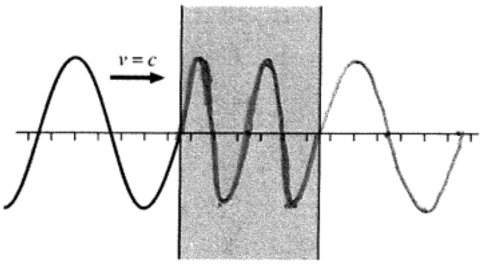
Frequency is a property of the source, and thus remains constant as the wave travels from one medium to another. The wavelength in vacuum is λ, and in the medium, we can see that $\lambda' = \frac{\lambda}{3}$.

We know that the speed of light in the medium is $v' = \frac{c}{n}$, where n is the medium's index of refraction. The speed is can also be expressed as a product of wavelength and frequency:

$$v' = \lambda' f = \frac{\lambda}{3} f = \frac{c}{3}.$$

This suggests that $n = 3$.

(b) A light wave travels from vacuum, through a transparent material whose index of refraction is $n = 2.0$, and back to vacuum. Finish drawing the snapshot graph of the light wave at this instant.



From our previous work, we can see that $\lambda' = \frac{\lambda}{n}$, so the wave should have half of its original wavelength while within the medium. Once it leaves, it returns to its original wavelength.

Activity 3

A laser beam has intensity I_0.

(a) What is the intensity, in terms of I_0, if a lens focuses the laser beam to $\frac{1}{10}$ its initial diameter?

Intensity $I = \frac{P}{A}$, and the cross-sectional area of the light beam is $A = \pi r^2$. Therefore, $I \propto \frac{1}{r^2}$. When the diameter is reduced to a tenth its original size, so is the radius. Let r_1 be the reduced radius, and let r_0 be the original (thus $r_1 = r_0/10$). By comparison:

$$\frac{I_1}{I_0} = \frac{r_0^2}{r_1^2} = \frac{r_0^2}{(r_0/10)^2} = 100.$$

Thus, $I_1 = 100I_0$.

(b) What is the intensity, in terms of I_0, if a lens defocuses the laser beam to 10 times its initial diameter?

In this case, $r_1 = 10r_0$. As such,

$$\frac{I_1}{I_0} = \frac{r_0^2}{r_1^2} = \frac{r_0^2}{(10r_0)^2} = \frac{1}{100}.$$

Thus, $I_1 = \frac{I_0}{100}$.

Activity 4

Sound wave A delivers 2 J of energy in 2 s. Sound wave B delivers 10 J of energy in 5 s. Sound wave C delivers 2 mJ of energy in 1 ms. Rank in order, from largest to smallest, the sound powers P_A, P_B, and P_C of these three sound waves.

Order: $P_C = P_B > P_A$
Power is the rate at which energy is delivered.

$$P_A = \frac{2\text{ J}}{2\text{ s}} = 1\text{ W}, \qquad P_B = \frac{10\text{ J}}{5\text{ s}} = 2\text{ W}, \qquad P_C = \frac{2\text{ mJ}}{1\text{ ms}} = 2\text{ W}.$$

Activity 5

A giant chorus of 1000 male vocalists is singing the same note. Suddenly, 999 vocalists stop, leaving one soloist. By how many decibels does the sound intensity level decrease? Explain.

Let I be the intensity from 1000 singers. Assuming they all sing at the same level, then the intensity drops to $I/1000$, or $I/10^3$. The decrease in sound intensity level is $\Delta\beta = \beta_f - \beta_i$, so

$$\begin{aligned}
\Delta\beta &= (10\text{ dB})\log_{10}\left(\frac{I/10^3}{I_0}\right) - (10\text{ dB})\log_{10}\left(\frac{I}{I_0}\right) \\
&= (10\text{ dB})\log_{10}\left(\frac{I/10^3}{I}\right) \\
&= (10\text{ dB})\log_{10}\left(\frac{1}{10^3}\right) \\
&= -30\text{ dB}.
\end{aligned}$$

The sound intensity level decreases 30 dB.