# 2.011 HW # 4

Due Tuesday March 21, 2006 In class

Problem 1: Review of dB and logarithms:

a) Explain in words what a decibel is a measure of.

b) Look up (Google, etc.) the relative *Source Levels* (in dB) for ***four (4)*** of the following sounds (cite your source)

   i. Jet Engine
   ii. Car
   iii. Whale (specify type of whale)
   iv. Underwater seismic activity
   v. A rock concert at the Fleet center or similar arena
   vi. A ships propeller (can be any ship, just specify)
   vii. A dolphin
   viii. Some other sound

c) Expand the following expressions:

   i. $10\log_{10}(A/B) =$ ii. $10\log_{10}(A+B) =$ iii. $10\log_{10}(A^B) =$

d) Given your math in part *e* and your understanding of the definition for a decibel, calculate the following quantities:

   i. $10\log_{10}(1)$ dB = ii. $10\log_{10}(10)$ dB =

   iii. $10\log_{10}(0.5)$ dB = iv. $10\log_{10}(4)$ dB =

   v. $10\log_{10}(16)$ dB =

Problem 2: Sound Wave properties

a) A sound wave is really a pressure wave traveling at the speed of _____(?)____.

b) Determine the frequency or wavelength of sound waves:

   i. If frequency, $f$ = 1.0 Hz , then $\lambda$ =_____m in air and $\lambda$ =____m in water.
   ii. If frequency, $f$ = 2.0 MHz , then $\lambda$ =_____m in air and $\lambda$ =____m in water.
   iii. If frequency, $f$ = 450 kHz , then $\lambda$ =_____m in air and $\lambda$ =____m in water.
   iv. If wavelength $\lambda$ = 10 m, then $f$ = _____Hz in air and $f$ = _____Hz in water.
   v. If wavelength $\lambda$ = 2 m, then $f$ = _____Hz in air and $f$ = _____Hz in water.
   vi. If wavelength $\lambda$ = 100 m, then $f$ = _____Hz in air and $f$ = _____Hz in water.

c) Which of the above waves will travel better (farther, with less attenuation) in each of the following media: Fresh Water, Air (dry, 20ºC), Steel. Explain Why?

Problem 3: Sonar Systems

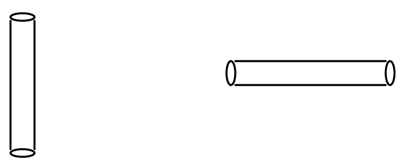
a) Explain the difference between active and passive sonar.

b) In the definition for source level (SL) given in Prof. Leonard's notes, what is typically used as $P_{ref}$ in the *general* SL equation?

c) What are the implications of directivity on the sound measured some distance away from a source?

d) If you used a line array versus a disc or a rectangular array what considerations are necessary when calculating the directivity index (DI)?

e) Roughly sketch the beam spread patterns for the following transducers:



Problem 4: Sound Reflection and Transmission

We know that the speed of sound is affected by water properties such as temperature, salinity and depth (pressure). Considering a region with salinity of 35‰, and a typical Temperature/depth profile with a well-mixed, warm layer down to 100 meters, and a thermocline down to 1500 meters, where cold bottom temperature is found, *discuss how sound waves would propagate within the upper, mixed layer and also the middle of the thermocline.*

a) Do you expect them to travel far or not so far?

b) Do you expect the sound to travel horizontally in a straight line (assume that it is a simple pressure wave moving horizontally near it's source).

Problem 5: Sines and Cosines

Given that the pressure wave in cylindrical coordinates is given by the following relationship:

$$p(r,t) = \frac{A}{r}\cos(kr - \omega t) = \mathrm{Re}\left\{\frac{A}{r}e^{-i(kr-\omega t)}\right\}$$

a) Show that the intensity is related to the RMS of the pressure:

$$I(r,\theta,\varphi) = \frac{1}{\rho c}\, p_{rms}^2$$

Power is the integral of the intensity:

$$P(r) = \int I(r,\theta,\varphi)\,d\Omega$$

where $\mathrm{d}\Omega = r\,\mathrm{d}\varphi\; r\cos\mathrm{d}\theta$ . The integral is evaluated over the range $\varphi = [-\pi,\pi]$ and $\theta = [-\pi/2, \pi/2]$ .

b) Determine (mathematically) the relationship between power (*P(r)*) and pressure (*p(r)*).

c) Using your equation from (b) evaluate the power (at r = 1m) at any given time and show how this can be related to source level.

d) Why do we determine SL at 1m from the object versus some other distance?

Note: RMS is the Root Mean Square of a function; for a function of time, *f(t)*, its RMS ($f_{rms}$) is the square root of temporal average of the square of the function:

$$f_{\mathrm{rms}} = \sqrt{\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} [f(t)]^2\, dt}$$