**Your Name______________________________Section______**

# HOMEWORK #13 - 8.01 MIT - Prof. Kowalski

## Due 4:00PM Thursday Dec. 4, 2003

**Topics: Harmonic Oscillators and Relative Motion**

Any following problems designated with a bold number indicate problems from Young and Freedman 11th edition.

**1. Vibration Isolation System**

A heavy table of mass M is vibrationally isolated by being hung from the ceiling by springs so that its period of vertical oscillation is $\omega_0$ (take $\omega_0$ to be $2\pi$/sec, a typical value). Assume now that the ceiling vibrates vertically with amplitude A at frequency $\omega$, i.e. yc(t) = A*cos($\omega$*t).

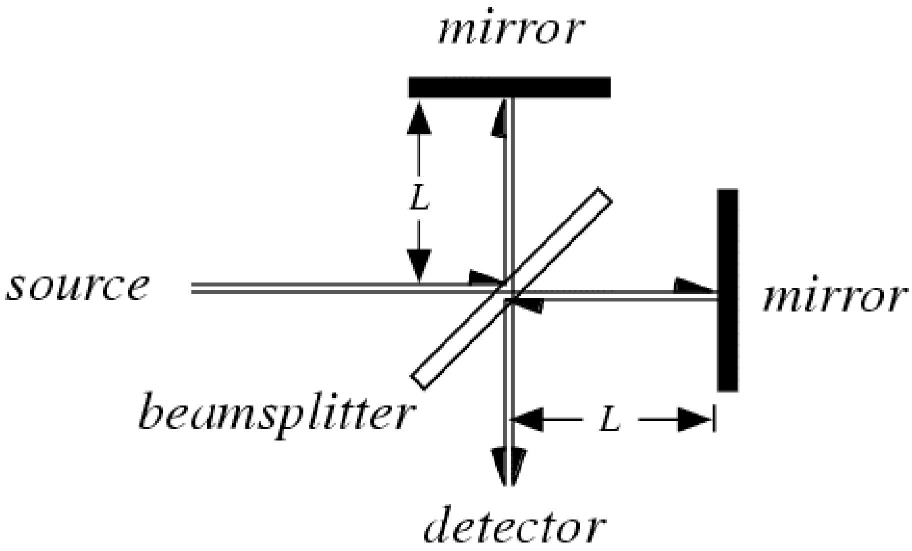
1. Write down the dynamical equation that relates the acceleration of the table a(t) to its position y(t), and the position of the ceiling. Although M and k will appear in this equation, you should be able to replace them with $\omega_0$. Show that the equation you get this way is the same as if a force proportional to cos($\omega$*t) were acting on the mass – spring system.

This system is referred to as a **driven harmonic oscillator**. Its steady state solution is y(t) = C($\omega$)*cos($\omega$*t). NOTE that it responds solely at the drive frequency $\omega$, not at the natural frequency of the oscillator $\omega_0$. (Actually there is also a transient at $\omega_0$ that fades away with time in a real system due to damping.)

2. By substituting the above expression for y(t) (and the a(t) that results from this) in your equation from part a, you should be able to obtain and solve a simple equation for C($\omega$).
3. With what amplitude, yt, will the table oscillate if the building (i.e. ceiling) oscillates with amplitude 0.01 cm at a (typical) frequency of 15 Hz? This ratio is called the isolation factor at $\omega$.

**2. 13.88**

**3. 37.1** A double lightening bolt strikes opposite ends of a passenger car that is moving with speed v, lighting up the ends of the car simultaneously from the perspective of a rider in the middle of the car. Which bolt appears to have come earlier to an observer on the ground, or do they appear simultaneous to him?




**4. Michelson-Morley Experiment with ether.** Michelson, and later Michelson and Morley used a Michelson interferometer mounted on a round granite block that floated on mercury in a surrounding tub. Their experiment is shown above (drawing from http://hyperphysics.phy-astr.gsu.edu/hbase/relativ/mmhist.html). Michelson and most physicists of his generation imagined that light propagates through a transparent nearly massless but quite stiff (so the speed of the light relative to the ether is c=3*10^8 m/s) medium called the "ether". He thought his experiment would detect the motion of the earth through this ether.

**a.** If this experiment is moving to the right at speed v, find the time difference for the light to traverse back and forth through the distance L in *both* the horizontal and vertical direction. *Hint: neither time is 2*L/c*

**b.** In the Michelson-Morley experiment, the light bounced back and forth several times for a total distance L=11m, and the travel time difference was measured as a shift of the interference pattern (where one fringe was 0.25 um). What was the expected fringe shift when the apparatus was rotated through 90 degrees assuming that v is the velocity of the earth in its orbit? (The observed fringe shift was less than 0.01 of a fringe.)