Due at NPB 2079 (or in my mailbox) by 1:00pm on Friday, April 24. Half credit will not be available for late homework. The solutions will be posted on Saturday, April 25.

It is in your interests to attempt all questions. It always helps to write your answers neatly. In your own mind, clearly identify all your collaborators on this assignment. To gain maximum benefit you should be prepared to explain your reasoning and show all working.

1. A seismograph records the signals arriving from a distant earthquake.
   a) If the S waves arrive 12 minutes after the P waves, how far away was the earthquake? Use $c_{\text{long}} \approx 5.25 \text{ km/s}$ and $c_{\text{trans}} \approx 3.00 \text{ km/s}$.

2. The equation of motion for an inviscid fluid is:
   \[ \rho \frac{dv}{dt} = \rho g - \nabla p. \]
   a) Assuming that $g$ is uniform and $\rho$ is constant (independent of $r$), prove the well-known result from introductory physics that the pressure difference between two points $r_1$ and $r_2$ in a static fluid is just $\Delta p = \rho gh$, where $h$ is the vertical difference in elevations of $r_1$ and $r_2$.

3. a) Prove the equivalence of:
   \[ \frac{d\rho}{dt} + \rho \nabla \cdot v = 0 \quad \text{and} \quad \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho v) = 0. \]

4. A crucial step in showing that the waves in a fluid are necessarily longitudinal was establishing that:
   \[ \int f'(n \cdot r - ct) dt = -\frac{1}{c} f(n \cdot r - ct). \]
   For an arbitrary function $f(\xi)$, with derivative $f'(\xi)$, prove this.

5. To find the speed of sound in air using the result $c = \sqrt{BM/\rho_0}$, requires a little care. (Even the great Newton got this one wrong!) The trouble is to decide on the correct value of the bulk modulus of air. Because the vibrations are so rapid, there is no time for heat transfer and the air expands and contracts adiabatically, so that $pV^\gamma = \text{constant}$, where $\gamma$ is the so-called “ratio of specific heats,” $\gamma = 1.4$ for air.
   a) Show that the bulk modulus is $BM = \gamma p$. 
b) Use the ideal gas law, $pV = nRT$ to show that the density is $\rho_0 = \frac{pM}{RT}$, where $M$ is the average molecular mass of air ($M \approx 29$ grams/mole).

c) Put these results together to show that the speed of sound is $c = \sqrt{\frac{\gamma RT}{M}}$. Find the speed of sound at $0^\circ$C, and compare with the accepted value of 331 m/s.