Outline

- Hand in, go over homework problem 2.4
- Free fall time of Sun – dimensional analysis
- Hydrostatic equilibrium

Free Fall Time of the Sun

- Do via dimensional analysis

- Book does integration and gives answer:

$$\tau_{ff} = \left(\frac{3\pi}{32 G \bar{\rho}} \right)^{1/2}$$

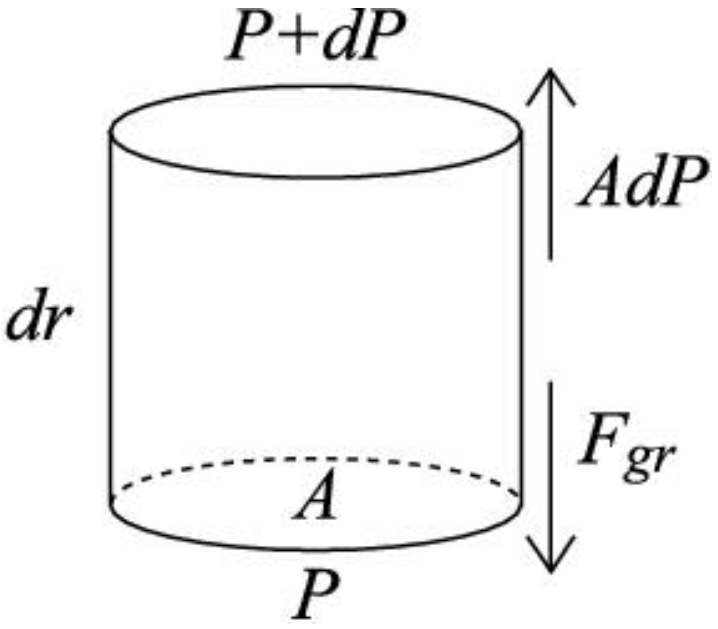
Virial Theorem

- Consider a system of particles. There is a force acting on the particles that produces a potential energy V between any pair of particle separated by a distance r so that $V(r) \propto r^n$.
  - Note that the energy goes to zero for particles with very large separations, so negative total energy means the system is bound, zero total energy means marginally unstable, positive means unbound.
- Then the average kinetic energy of the particles $\langle E_k \rangle$ is related to the average potential energy of the particles $\langle E_p \rangle$ as

$$\langle E_k \rangle = (n/2) \langle E_p \rangle$$

- If the force is gravity, then $n = -1$ hence $\langle E_k \rangle = -\frac{1}{2} \langle E_{gr} \rangle$.

Hydrostatic Equilibrium



- Consider forces on an element of gas in the gas.
- Upward force due to pressure (AdP) must equal downward force due to gravity (F_{gr}).

$$\frac{-GM(r)\,dm}{r^2} - A\,dP = 0$$

$$dm = \rho(r)\,A\,dr$$

$$\frac{dP(r)}{dr} = \frac{-GM(r)\rho(r)}{r^2}$$

Note dP/dr is negative = lower pressures as r increases towards the surface.

Hydrostatic Equilibrium

- Work out average pressure, total thermal energy, relation to virial theorem, whether or not the system is bound.

- Calculate the virial temperature and average pressure assuming constant density.

Homework

- For next class:
  - Use dimensional analysis to estimate the dependence of the oscillation period of a pendulum on the length of the string (l), the mass of the weight (m), and the acceleration of gravity at the surface of the Earth (g).
  - Problem 3-1