Planets — problems (F. Bagenal)

1. **Minimum Mass Solar Nebular**

   (a) Estimate the amount of material needed to make a solar system.

   (b) Mass is not everything — check you have enough:
   - Rock/metal to make the terrestrial planets
   - Hydrogen to make Jupiter
   - water/ammonia/methane to make Uranus & Neptune

   (c) Estimate the mass density of the nebular

2. **Collapse time**

   Make a rough estimate of the minimum time to collapse the solar nebula.
   Hint: Think of a parcel of gas as an object orbiting the Sun on a very eccentric orbit. Think Kepler's $3^{\rm rd}$ *Law.*

3. **Mass accretion**

   (a) Think of a sphere orbiting the Sun and accreting solar solar nebular mass. Show how the mass accretion coule be approximated

   $$\frac{dM}{dt} \sim \pi R^2 v_{\rm orbit}\, \rho_{\rm nebula} \quad .$$

   (b) Integrate to derive the time to accrete to radius R

   $$T \sim \frac{4R}{v_{\rm orbit}} \left(\frac{\rho_{\rm planet}}{\rho_{\rm nebula}} \right) \quad .$$

   (c) Use the following to compute the time required to accrete a 1000 km object.
   - $v_{\rm orbit} \sim 30$ km/s at 1 AU
   - $\rho_{\rm nebula} \sim 10^{-7}\,{\rm kg\,m^{-3}}$.
   - $\rho_{\rm planet} \sim 3000\,{\rm kg\,m^{-3}}$.

4. **Heating & Cooling Planets**
   sketch profiles of interior temperature of a terrestrial planet that

   (a) accreted quickly with no radioactivity.

   (b) only had radioactive heating

   (c) accreted very slowly.

   Hint: think of conducting heat from the interior, and cooling from the surface (via radiation).