1. Temperatures of planets (45 points)
We can compute the equilibrium temperature of the Earth can be calculated by assuming
that it absorbs all the energy it receives from the Sun, and re-radiates it as a blackbody.
This implies that the mean temperature at the planet surface, $T_p$, can be related to $d$, the
planet’s distance from the star, the star’s temperature, $T_\ast$ and the star’s radius, $R_\ast$

$$T_p = T_\ast \sqrt{\frac{R_\ast}{2d}}$$

In this problem, you will derive the surface temperature of several planets. The data for
the planets can be found on the web site: http://exoplanet.eu/catalog-transit.php The
planets you should consider are:

- Kepler 9b
- HAT-P-2
- Kepler 33-f
- Corot-9b

Note that you will need to click on the planet name to get more information.

(a) Using the data on the web site above, calculate the equilibrium surface temperature for
each of the planets listed above. You may ignore the effects of albedo and greenhouse
effect on these planets (after all, we know absolutely nothing about their atmospheres!).

(25 points)

(b) Is it possible that liquid water can exist on the surface of any of these planets, assuming
that they have an atmospheric pressure similar to that of the surface of the Earth? Discuss.

(10 points)

(c) Some of the planets have very eccentric orbits (i.e., with eccentricity more than 0.2).
Discuss what effect this might have on any life that might exist on them, and the
presence of liquid water. *Hint: The eccentricity of an orbit refers to how squashed it
is. A perfect circle has an eccentricity of 0; the most flattened ellipse has an eccentricity
of 1.*

(10 points)

2. Inferring the Properties of a Transiting Planet (55 Points)
You read in next month’s New York Times that Kepler has detected a planet around
a Solar-type star (assume its mass, temperature and radius is the same as the Sun). The
eclipses have a 300 day period and the maximum eclipse depth is $10^{-4}$ times the average
flux. Follow-up observations find that the star’s radial velocity, $v_{\text{star}} = 1 \text{ cm/s}$. 
(a) Estimate the radius of the planet (10 points)
(b) Estimate its distance from the star (10 points)
(c) Estimate the mass of the planet (15 points). Recall that for a circular orbit
\[ v_{planet}^2 = \frac{GM_{star}}{r} \]
where \( r \) is the distance from the star and that conservation of momentum implies
\[ M_{star} v_{star} = M_{planet} v_{planet} \]
(d) Estimate the mean density of the planet. Based on its mean density, speculate about
its composition (hydrogen gas dominated \([\text{density} \ll 1 \text{ gm/cm}^3]\), water \([\text{density} = 1 \text{ gm/cm}^3]\), Earth-like, or Mercury-like) (10 points)
(e) Estimate the mean temperature of the planet. (10 points)