Equations

Orbital period

$$p_1 = d_2 - d_1$$
$$p_2 = d_3 - d_2$$
$$p = \frac{(p_1 + p_2)}{2}$$

Note: you may see more or fewer than 3 transits. You want to calculate the average of all the periods you find. If you only see one transit, then you cannot find the orbital period.

Radius

$$Drop\ in\ Brightness = \frac{r^2}{R^2}$$

- *r* = radius of the planet (km)
- *R* = radius of the star (km)
- Earth radius ($r_{Earth} = 6378.1\ km$)

Mass

This can be estimated based on the size of the planet and its distance from its star.

- If $r < 6\ r_{Earth}$, then:
$$m = 0.9515 r^{3.1}$$
- If $6\ r_{Earth} \leq r < 10\ r_{Earth}$, then:
$$m = 1.7013 r^{2.0383}$$
- If $r \geq 10\ r_{Earth}$, then:
$$m = 0.6631 r^{2.4191}$$
- *r* = radius of planet (km)
- Earth mass ($m_{Earth} = 5.976 \times 10^{24}\ kg$)

For the planet types discussed in class, the masses would be approximately:

- **Hot Jupiter**: $1.90 \times 10^{27} kg = 317.8\ m_{Earth}$
- **Hot Neptune**: $1.03 \times 10^{26} kg = 17.23\ m_{Earth}$
- **Super-Earth**: $1.90 \times 10^{27} kg = 317.8\ m_{Earth}$
- **Exo Earth**: $5.976 \times 10^{24} kg = 1\ m_{Earth}$

Semi-major axis (the distance of the planet from the star)

Listen to your instructor as to which way they would like you to calculate this.

- *Kepler's Third Law graphs* from *Lesson 7: Creating and Interpreting Light Curves*
  - Using the orbital period, find the corresponding semi-major axis value on the line.
- Kepler's Third Law:
$$P^2 = \frac{4\pi^2}{G(m + M)} a^3$$
  - *P* = orbital period
  - *G* = gravitational constant ($6.67384 \times 10^{-11} m^3 kg^{-1} s^{-1}$)
  - *m* = mass of the planet
  - *M* = mass of the star
  - *a* = semi-major axis
  - For this equation, the units need to match up with those of the gravitational constant and would need to estimate the mass of the planet and star first.
- Approximation of Kepler's Third Law:

$$P^2 = a^3$$

- P = orbital period (yrs)
- a = semi-major axis (AU)
- 1 AU is equal to the distance between Earth and the Sun ($149597871\ km$).

Density

$$V = \tfrac{4}{3}\pi r^3$$
$$d = \frac{m}{V}$$

The units should be in kilograms per meter cubed, ($\frac{kg}{m^3}$).

Surface temperature

$$T_P = \left(\frac{L(1-A)}{16\pi\sigma a^2}\right)^{\frac{1}{4}} = \left(\frac{R^2 T_S^4 (1-A)}{4a^2}\right)^{\frac{1}{4}}$$

- T_P = surface temperature of the planet
- L = luminosity of the star ($L = 4\pi R^2 \sigma T^4$)
- a = semi-major axis
- T_S = temperature of the star
- σ = Stefan-Boltzmann constant ($5.670\times 10^{-8} W m^{-2} K^{-4}$)
- A = albedo of the planet

For the types of planets discussed in class the albedo would be:

- **Hot Jupiter**: $A = 0.52$
- **Hot Neptune**: $A = 0.35$
- **Super-Earth**: $A = 0.39$
- **Exo Earth**: $A = 0.39$