Names: ______________________ ______________________

______________________ ______________________

Teamwork (5)	Discussion (5)	Correctness (5)	Explanations (5)	Total (20)

Exoplanet Discovery

A house of wood in a hidden place,

Built without nails or glue.

High above the earthen ground,

It holds pale gems of blue.

What is it?

____

Pre-Lab Quiz

Record you team's answers as well as your reasoning and explanations.

1.
2.
3.
4.

Part 1: Detecting Exoplanets

1. Sketch a graph of the output from the photometer used in the transit demonstration. Label the axis and indicate where the planet

   a) is not in front of the star

   b) is traveling over the limb (edge) of the star

   c) is completely in front of the star

2. If a sphere with half the diameter of the first is passed in front of the light source, how will this affect the light curve? Explain your prediction below and try to quantify it.

3. Did the second demo verify your reasoning? What does this mean for the kind of exoplanets that are likely to be discovered using the transit method?

4. In this problem we're going to derive the relationship between the radius of the planet r_p, the radius of the star $r_\star$, and the dip in the star's brightness ΔB. Partnering with another group, on a white board work though the following steps:

1. The star's normal brightness $B_\star$ is given by the area that we see (a circle with radius $r_\star$) multiplied by the star's surface brightness density, which we'll call $S_\star$. Write down the equation for the brightness $B_\star$ in terms of $r_\star$ and $S_\star$.

2. When the planet is completely in front of the star, the surface area that we see is the cross-sectional area of the star $A_\star = \pi r_\star^2$ minus the area blocked by the planet $A_p = \pi r_p^2$. Write down the equation for the brightness B when the planet is completely in front of the star in terms of r_p, $r_\star$, and $S_\star$.

3. The relative brightness of the dip to the star's normal brightness is $B/B_\star$. Write down this ratio and use your expressions from (1) and (2) to form an equality. Simplify the expression by canceling common terms in the fraction.

4. You should now have the expression $B/B_\star = (r_\star^2 - r_p^2)/r_\star^2$. Split the right side into two parts to remove the radius of the star in the numerator. Then solve for the ratio $r_p/r_\star$.

5. When dealing with light curves, astronomers usually normalize the brightness of the star so that $B_\star = 1$. Apply this normalization to derive the relationship between $r_p/r_\star$ and the change in brightness $\Delta B = 1 - B$.

Go over your work with your TA and have them mark below once complete. Record the relationship between $r_p/r_\star$ and B as we'll be using it in part 2.

TA	

Part 2: Exploring the Trappist-1 System

1. What is the Trappist-1 system and why is it important?

2. Determine the radius and mass of the star Trappist-1a given that these are 11.4% and 8% of the solar radius ($r_{sun} \approx 110 \cdot r_{earth}$) and mass ($m_{sun} \approx 330,000 \cdot m_{earth}$) respectively. Show your work and use values relative to Earth.

3. How does the size and mass of the star compare to Jupiter? **Note**: *Wolfram Alpha* might prove useful: for example, try typing "jupiter radius in earth radii".

4. Using the light curve, record the brightness of the star when the indicated exoplanet is completely in front of the star. Then use the relationship you derived to find the radius of each exoplanet relative to the host star. Use **Python** for your calculations.

Exoplanet	Brightness (B)	$r_{exo}\ /\ r_{\star}$
1b		
1c		
1d		
1e		
1f		
1g		
1h		

Python Programming

Open an *Anaconda Prompt*, type *jupyter qtconsole* and press return. One way we can compute the relative radius of each exoplanet is as follows:

```
In [1]:  from math import sqrt                   # Import sqrt from Math library
In [2]:  b = [0.995, 0.991, 0.978, 0.965]  # Example list of brightness
In [3]:  for x in b:                             # Iterate through each value in b
             print sqrt(1 - x)                   # Print sqrt(1 - x) to terminal
                                                 # Return again to complete loop
```

Another way is to use the Numerical Python (NumPy) library, which allows us to operate on an entire array of values at once:

```
In [1]:  from numpy import sqrt, array
In [2]:  b = array([0.995, 0.991, 0.978, 0.965])
In [3]:  print sqrt(1 - b)
```

5. Using the host star's radius from problem 2, what are the sizes of the Trappist-1 exoplanets relative to Earth?

Hint: How can you use Python to compute the values? Note that * indicates to multiply two things in Python.

Exoplanet	r_{exo} (Earth Radii)	Exoplanet	r_{exo} (Earth Radii)
1b		1f	
1c		1g	
1d		1h	
1e			

6. Explain the "Mystery Light Curve" for Trappist-1a on the website by draw a sketch of the light curve and indicating what is responsible for the changes in brightness.

Part 3: Observing the Night Sky

1. Find the following objects in the night sky and point them out to your TA.

Object	Type	TA
Aurvandil's Toe (Corona Borealis)	Norse Constellation	
Boötes	Constellation	
Cassiopeia	Constellation	
Draco	Constellation	
Hercules	Constellation	
Lyra	Consellation	
Maui's Hook (Scorpius)	Hawaiian Starline (Constellation)	
Sagittarius	Constellation	
Ursa Minor	Constellation	