SIERRA COLLEGE OBSERVATIONAL ASTRONOMY LABORATORY EXERCISE		
NUMBER III.Jb.	**TITLE: PLUTO AND CHARON (WORKSHEET)**	
DATE- **DAY-** **LOCATION**	**PRINT NAME/S AND INITIAL BELOW:**	**GROUP** ☐

Procedure
We will analyze light from the system, to learn Pluto's and Charon's sizes, and the mass of the system.

1) First, you must construct a "light curve," which is a history of the brightness of the system during an occultation event (similar to Figure 4 in the Introduction handout). The brightness changes (Δ magnitude), as compared to the typical brightness (m≈15), are given in Table 1. Plot these values as a function of Universal Time (UT); use the blank graph paper provided.

   Use a ruler to fit five line segments to your data, resulting in a graph similar to Figure 4 (In the Introduction handout).

Table 1: Pluto-Charon brightnesses

Time (UT)	Δ Magnitude	Time (UT)	Δ Magnitude
13:15	0.005	16:45	-0.219
13:30	-0.005	17:00	-0.220
13:45	-0.001	17:15	-0.199
14:00	0.012	17:30	-0.150
14:15	0.000	17:45	-0.130
14:30	-0.033	18:00	-0.092
14:45	-0.050	18:15	-0.049
15:00	-0.097	18:30	-0.024
15:15	-0.128	18:45	-0.005
15:30	-0.155	19:00	-0.006
15:45	-0.180	19:15	-0.002
16:00	-0.218	19:30	-0.001
16:15	-0.220	19:45	0.010
16:30	-0.221	20:00	-0.005

2) From the intersection points of your line segments, estimate the times of 1st, 2nd, 3rd, and 4th contact, in hours and minutes (ex: 17h 25m).

   1st: _____ 2nd: _____ 3rd : _____ 4th: _____

3) Convert the four contact times into decimal times, i.e. 14h 45m → 14.75h.

   1st: _____ 2nd: _____ 3rd : _____ 4th: _____

4) Calculate the decimal time intervals corresponding to when Charon moved from 1st to 2nd contact, and from 3rd to 4th contact, and the average of these two. (Notice that these time intervals estimate how long it takes for Charon to cover or uncover Pluto, and depend upon Charon's size.)

   1st — 2nd: _____ 3rd — 4th: _____ Average: _____ hours

   Convert the average value into seconds: Average: _____ sec

5) Calculate the decimal time intervals corresponding to when Charon moved from 1st to 3rd contact, and from 2nd to 4th contact, and the average of these two. (Notice that these time intervals estimate how long it takes for the leading or trailing edge of Charon to traverse Pluto, and depend upon Pluto's size.)

   1st — 3rd: _____ 2nd — 4th: _____ Average: _____ hours

   Convert the average value into seconds: Average: _____ sec

6) The radius (R) of Charon's orbit is estimated to be 17,500,000 m. Calculate the circumference (C) of Charon's orbit, using $C=2\pi R$.

   Circumference: _____ m

7) Charon's orbital period (P) is 6.387 days. Convert this period into seconds:

   Orbital period: _____ sec

8) Knowing that Charon travels its orbital circumference (C) in its period (P), calculate its orbital velocity ($v=C/P$) in m/sec:

   Orbital velocity: _____ m/sec

9) Multiply Charon's orbital velocity by the average time you calculated in step #4, to determine the diameter for Charon:

   Charon's diameter: _____ m

10) Multiply Charon's orbital velocity by the average time you calculated in step #5, to determine the diameter for Pluto:

   Pluto's diameter: _____ m

QUESTIONS

1. Kepler's third law, refined by Newton, tells us that the masses of two orbiting objects, such as Pluto and Charon, is given by

$$M_{System} = M_P + M_C = K\frac{R^3}{P^2}$$

where:
M_{System} = the mass of the entire system (in kg)
M_P, M_C = Pluto's and Charon's masses (in kg)
R, P = Charon's orbital radius (in m) and orbital period (in sec)
$K = 5.92\times10^{11}\ m^{-3}\ kg\ s^2$

   Use this equation to calculate the mass of the Pluto/Charon system:

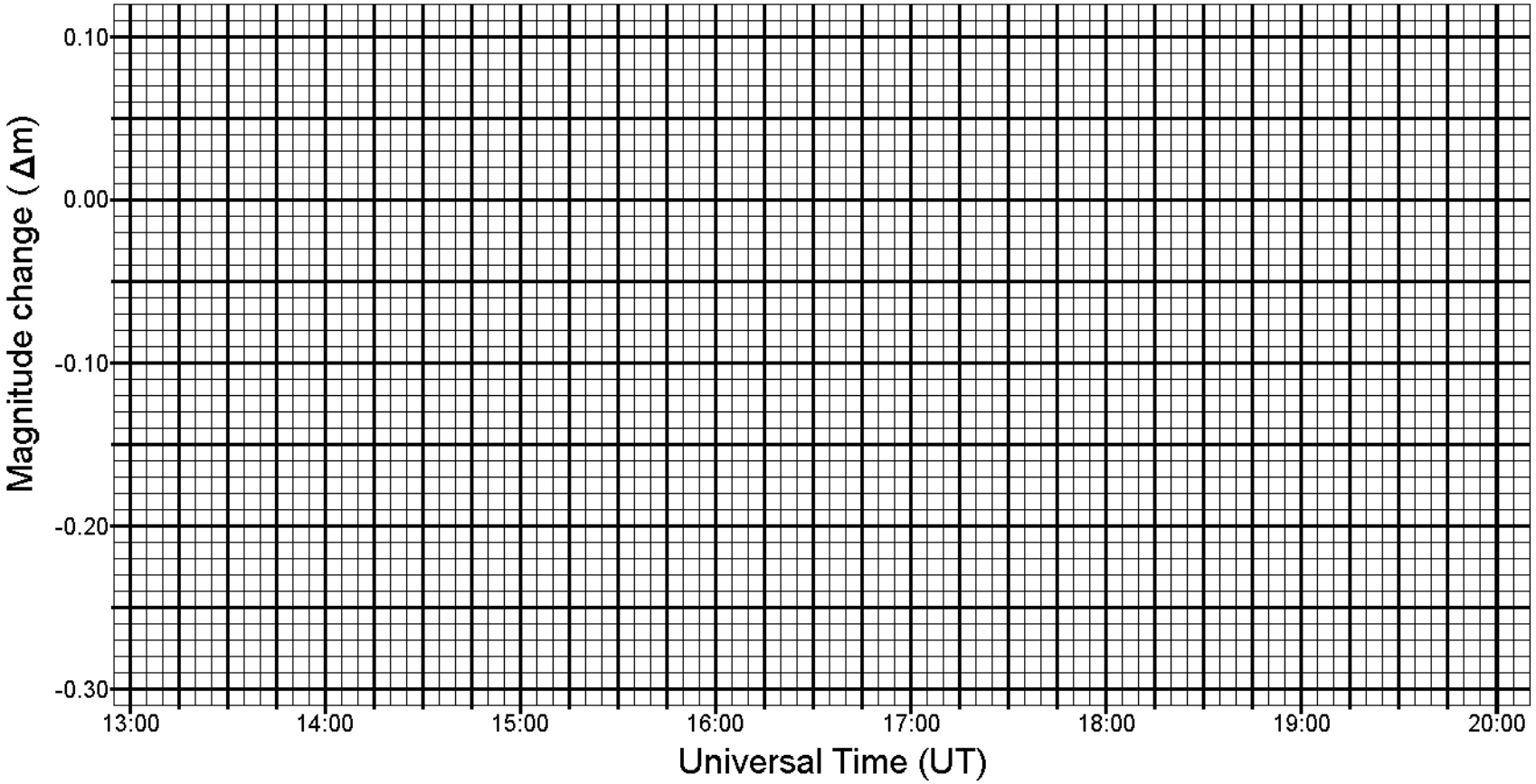
   M_{System}: _____ kg

2. What are some possible sources of error in this experiment?

3. When Charon occults Pluto, the light we receive from the system drops. But when Pluto occults Charon, the system gets fainter but not by as much. Why might this be the case. (Hint: consider that in both cases, the total amount of reflective surface we see of the Pluto-Charon system decreases by an area equal to Charon's apparent surface area.)

4. How would observations of occultations by a space telescope (such as the Hubble) would improve our knowledge of Pluto and Charon?

5. If Pluto or Charon had extensive atmospheres, how would the occultation graph change shape? How would this changed shape complicate the kind of calculations we did in this lab?


0.10
0.00
-0.10
-0.20
-0.30
Magnitude change (Δm)
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
Universal Time (UT)