Name: ___________________________
Partner(s): ________________________
1102 or 3311: ______
Desk # ____________
Date: _____________

Messier Catalog

Purpose

- Train your eyes to recognize different kinds of astronomical objects.
- Determine where star clusters are located in our galaxy.

Equipment

- Constellation chart
- Spreadsheet
- Coloured markers or pencil crayons

Introduction and Theory: In this lab, you will be using the Messier Catalog: a catalog of nebulae. In Latin, the word Nebula (plural Nebulae) means cloud. The term originally applied to any extended object, i.e. any object that looked like a fuzzy cloud. Charles Messier published his catalog between 1771 and 1784. Since Messier's time, telescopes have greatly improved and we've discovered that his catalog was actually dealing with different kinds of objects: galaxies, globular clusters, open clusters, planetary nebula, supernova remnants and clouds of gas. These days, the name *nebula* is only used to describe clouds of gas. The table below gives a definition for each of these celestial objects.

Object	Definition
Galaxy	Gas and millions of stars held together by gravity. All that you can see in the sky (with a very few exceptions) belongs to our Galaxy. These exceptions are other galaxies.
Globular cluster	Tightly bound, roughly spherical collection of hundreds of thousands of stars, spanning about 50 parsecs. Stars are bound by gravity.
Open cluster	Loosely bound collection of tens to hundreds of stars, a few parsecs across. Stars are bound by gravity.
Nebula	A wide, spread out, irregularly shaped cloud of gas.
Planetary nebula	A shell of ejected glowing gas surrounding a star.
Supernova Remnant	The scattered glowing remains from a supernova that occurred in the past. The Crab Nebula is one of the best-studied supernova remnants.

Question 1: Build your own catalog. You are a graduate student trying to determine where all the objects in the Messier catalog are located. You work in collaboration with other observatories that sent you images of the Messier objects. You have now a complete database for the 110 Messier objects. ("The Messier Catalog" in Lab Brightspace or http://langaraphysics.com/Tyron/MessierCatalog.htm)

a) Sort the clusters and nebulae by category by looking carefully at each of the 110 images. Present your results in the table below.

Type of object	**Name in Messier Catalog**
Globular cluster	
Open cluster	
Nebula	
Galaxy	

b) Provide the rough ranges of distances for each category of object: galaxies, clusters and nebulae. Do you notice any trends?

c) Our galaxy, the Milky Way, has a diameter of roughly 100,000ly. Are the galaxies you observed inside the Milky Way, in its neighbourhood, or very far away? Comment.

Question 2: Distribution of star clusters. Your goal is now to investigate the location and distribution of globular and open star clusters in our Galaxy. Knowing the equatorial coordinates of each object (right ascension and declination), you can show their distribution on a map of the sky (constellation chart).

a) On the constellation chart, draw the position of the Milky Way (use its representation on a plastic celestial sphere) and the Galactic Center. The coordinates of the Galactic Center are: RA 17h45m40.04s, Dec -29º 00' 28.1" (J2000 epoch).

b) Draw the distribution of clusters using your catalog. Include a legend. Use a **red** pencil or marker for the globular clusters and a **green** one for the open clusters. For each cluster, indicate with a pencil its distance to the Earth.

c) Do you notice anything specific about each type of cluster? Do you think both types belong to the Milky Way? Do they belong to any particular zone of the Milky Way? Explain.

Question 3: Nebulae. Your goal is now to differentiate between a diffuse nebula, an emission nebula, a reflection nebula, a dark nebula, and a planetary nebula. You can Google the following terms to see pictures of each.

A **diffuse nebula** is a wide, spread-out, irregularly shaped cloud of gas (mostly hydrogen gas) in space that can be up to 100 light-years wide. The Orion Nebula is a molecular cloud, a mass of dust and turbulent gas that is one of the coldest places in the known universe.

An **emission nebula** is a nebula that glows; it emits light energy. The reddish light is produced when electrons and protons combine, forming hydrogen atoms. Emission nebulae are formed when energetic ultraviolet light from a very hot star excites a cloud of hydrogen gas: the UV radiation ionizes the hydrogen (stripping electrons from the hydrogen atoms). The free electrons then combine with protons, forming hydrogen and red light.

A **reflection nebula** is a nebula that glows as the dust in it reflects the light of nearby stars. These nebulae are frequently bluish in color because blue light reflects more efficiently than red light does. A reflection nebula surrounds the Pleiades star cluster.

A **dark nebula** is a cool cloud of dust and gas. Due to its low temperature, it does not emit light in visible region of spectrum so appears dark, often blocking out light from stars that are behind it. A great example is Barnard 68.

Combinations: the Horsehead Nebula is an example of a dark nebula in front of an emission nebula that illuminates the outline of the horsehead. The Trifid nebula exhibits the three kinds of diffuse nebulae.

A **planetary nebula** is a nebula formed from a shell of gas that was ejected from a certain kind of extremely hot star. As the giant star explodes, the core of the star is exposed. Planetary nebulae have nothing to do with planets. The Hourglass Nebula is a planetary nebula.

Now classify all the **nebulae** of the Messier catalog in one of the following categories: emission nebula, reflection nebula, dark nebula or planetary nebula/SN remnant. You do not need to differentiate between a planetary nebula and SN remnant.

Type of nebula	**Name in Messier Catalog**
Emission	
Reflection	
Dark	
Planetary SN remnant	

Question 4: The luminosity and size of globular clusters. Here, you will investigate **one** of two hypotheses using the data from the Messier Catalog file ("messier_catalog.csv" on Lab Brightspace or at http://langaraphysics.com/Tyron/messier_catalog.csv).

1. Do all globular clusters have roughly the same luminosity[1]?
2. Do they all have roughly the same size?

If one of these two hypotheses is true, globular clusters could be used as standard candles to measure distances in the Universe. That would be a significant discovery. Choose **one** of these two hypotheses and test it. Use Excel.

a) Open the file (http://langaraphysics.com/Tyron/MessierCatalog.htm), divide all objects into two groups: globular clusters and non-globular clusters.
b) In a new column, calculate the luminosity or the size of all objects. The equations are given below. Pay attention to the units! (1 arc min = 3.1416/10800 radians.)
   The luminosity (in solar units) = $(0.081) \times [\text{distance(ly)}]^2 \times 10^{(-0.4 \times \text{magnitude})}$
   The size (in ly) = apparent diameter in radians × distance(ly)
c) Plot the luminosity or the size of the objects. Use a different color for the globular clusters. You may have to blow up the vertical scale to see the distributions.
d) Comment and conclude (in a separate paper). If your answer (to Question 1 or 2) is positive, give a rough range for the luminosity or the size of the globular clusters.

[1] The luminosity in this question refers to the luminosity in the visual spectrum.