

02 - Visual Photometry Project - Charts, Stars & Magnitudes

Perception & the Magnitude Scale

The capabilities of the eye far surpass those of the best camera. Your eye is so sensitive it can sense a single photon (packet of light energy) or accommodate the glare of the noonday Sun, some 100 billion times as intense. Since, a single photon generates one nano (one billionth) amp of current, shouldn't the brightest glare of the noon-day Sun, 100 billion times as intense, send 100 amps (100 billion nano amps) up your optic nerves into your brain?

Fortunately the eye is not a simple window through which the mind peers out at the universe. The eye is an extension of the brain, a pre-processor which reduces the flood of visual stimulus (brightness; the amount of light coming into your eye) to a rivulet of sensation (magnitudes; the information that flows from eye along the optic nerve to the brain) that the mind can accommodate. It is magnitude which the mind perceives.

For example, when you watch a light become 10,000 *times brighter*, poking 10,000 times as much light into your eyes, your eyes only produce a 10 *magnitude difference* in sensation. — The equations that describe what the eye does in converting brightness to magnitude is:

$$\text{magnitude difference} = -2.5 * \log_{10}(\text{brightness ratio})$$

Note that the equation generates magnitude differences from brightness ratios ... people compare stars one to another. And going the other way:

$$\text{brightness ratio} = 10^{\left(\frac{\text{magnitude difference}}{-2.5}\right)}$$

10 is raised the exponent of magnitude difference divided by -2.5, not 10 times magnitude difference divided by -2.5. Be careful with this calculation. The -2.5 in the exponent tweaks the equations to match Hipparchus' original visual magnitude scale with smaller magnitude being brighter and larger magnitude being fainter.

Another way to visualize the relationship between brightness ratio and magnitude difference is to convert the equations to a picture (Figure 1). A *negative* magnitude difference implies comparing a *brighter* star to a *fainter* star, a *plus* magnitude difference implies comparing a *fainter* star to a *brighter* star. Note that the choice of brighter or fainter implies two ways of comparing stars that result in the same answer. The order of comparison, revealed by the sign of the magnitude difference, is important in using the table correctly.

For example, star A is magnitude 10 while star B is magnitude 15. What is the brightness ratio of the two stars? Start by figuring which order you're going to compare them: star A to star B or star B to star A.

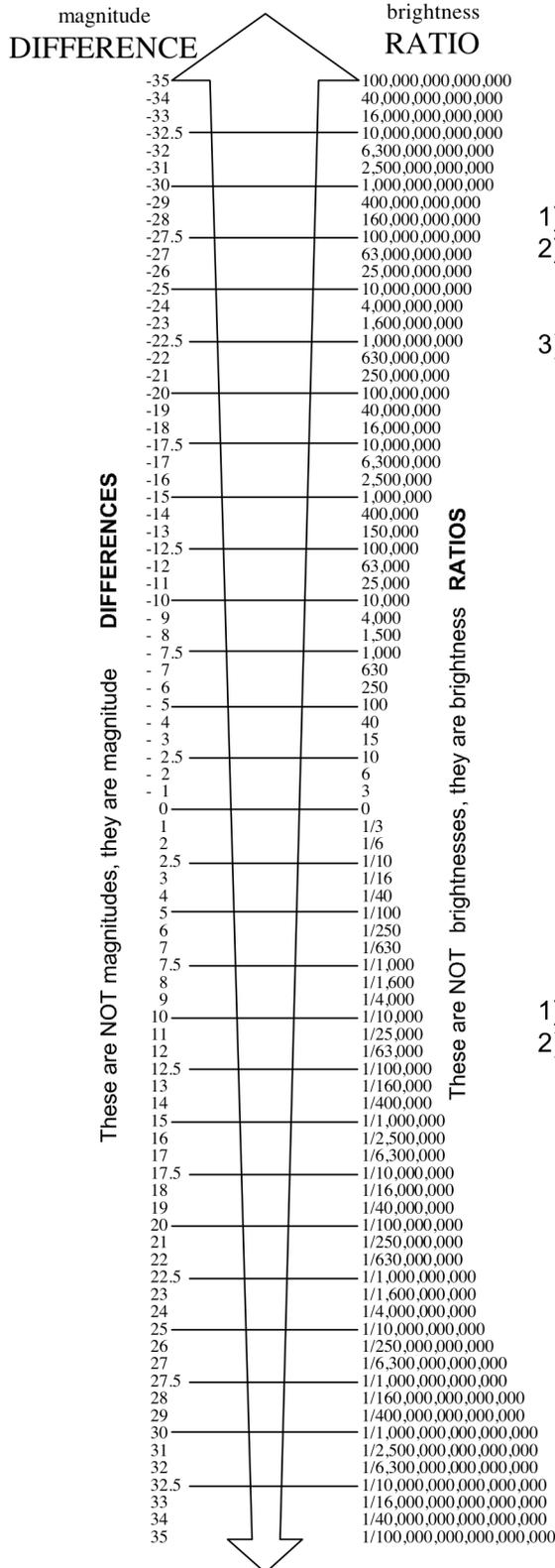
Comparing star A to B, you would subtract 15 from 10 to get a magnitude difference of -5. The brightness ratio in the table that corresponds to a magnitude difference of -5 is 100; star A is 100 times brighter than star B.

Comparing star B to star A, you would subtract 10 from 15 to get a magnitude difference of +5. The brightness ratio in the table that corresponds to a magnitude difference of +5 is 1/100th; star B is 1/100th as bright (100 times fainter) than star A.

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Another example. Star C is 1000 times brighter than star D of magnitude 20. What is the visual magnitude of star C? Going to the table, a brightness ratio of 1000 corresponds to a magnitude difference of -7.5 magnitudes. Add the -7.5 to star D's visual magnitude of 20 and the visual magnitude of star C is 12.5.

Figure 1: Magnitude difference to brightness ratio converter



How to convert

a magnitude difference to a brightness ratio

- 1) You need magnitudes for 2 (TWO) stars
- 2) Subtract the magnitude of the second star from the first star to get the magnitude difference.
- 3) Find the magnitude difference on the left side, and read straight across to the corresponding brightness ratio

For Example....

Star A = magnitude is +8
Star B = magnitude is +13

subtract +13 from +8
magnitude difference is -5

find -5 on the left side and read straight across to the corresponding brightness ratio of 100

Star A is **100 times** brighter than star B

How to convert

a brightness ratio to a magnitude difference

- 1) You need a brightness ratio for 2 (TWO) stars
- 2) Find the brightness ratio on the right side, and read straight across to the corresponding magnitude difference

For Example....

Star A is 10 times brighter than star B

find **10** on the right side and read straight across to the corresponding magnitude difference of **-2.5**

Star A is **-2.5** magnitudes brighter than star B

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Procedure

Attached is a finding chart for the brighter stars in the open star cluster named M67 which lies in the constellation of Cancer. Its name indicates that it is the 67th object in the catalog compiled by Messier.

Visual photometry is the process of determining the brightnesses of an unknown star by comparing its brightnesses to nearby standard stars of known brightness. You make this comparison with your eye. The standard stars that match the unknown closest in brightness set limits on what the visual magnitude of the unknown star can be; if the unknown is fainter than standard A but is brighter than standard B, then its visual magnitude is somewhere between those of A and B.

For this exercise, you will work with the image of the star cluster M67 projected on the computer screen. The image is in color, which makes the project even more interesting. Attached is a sheet with standard stars and unknown stars for you to work with. The visual magnitudes for the standards are printed on the finding chart without decimal points (6.6 magnitude is printed as 66) to avoid confusing decimal points as stars.

Follow the process described below for the unknowns assigned by your instructor on the attached sheet. When you have finished all the unknowns, record your results in Tables 1 and 2. Be sure to list them from brightest to faintest (small mag to large mag) in Table 2.

Then review your results to see if they are internally consistent. That is, if you say unknown U is brighter than standard 1, but unknown V is fainter than standard 1, then your results should show unknown U brighter than unknown V. If not, you have problems.

Example

Suppose you want to determine the visual magnitude of star U (a fictional unknown star). First find U on your finding chart, then locate it on the slide. Next identify a standard that is near U on the slide and on your finding chart, for example 2.9. Compare the two. Which is brighter? Keep track of your observations by making notes like the following:

Unknown U is fainter than standard of V mag 2.9.

Since you know U is fainter than 2.9 magnitude, now compare it to a standard that is fainter than 2.9 magnitude, like 8.7 and record your results:

Unknown U is brighter than standard of V mag 8.7.

You have now narrowed U's magnitude down to somewhere between 2.9 and 8.7. Continue to work on narrowing it down. For example, compare it to standard 4.3.

Unknown U is brighter than standard of V mag 4.3.

You have now narrowed U's magnitude down to somewhere between 2.9 and 4.3. Now compare to standard 3.9.

Unknown U is slightly brighter than standard of V mag 3.9.

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So you now know U is somewhere between 2.9 and 3.9 in magnitude, but probably pretty close to 3.88. Pretty good so far, but the range is still too large. Now, find another standard slightly brighter than 3.9 and compare U to it.

Unknown U is slightly fainter than standard of V mag 3.6.

At this point, you should have narrowed the visual magnitude of U to the 3.6 to 3.9 magnitude range. Now recompare U to both of these stars. Which is it closer to in brightness? We could call it 3.75, if it appears halfway between, or 3.7, if it is closer to the 3.6 magnitude standard, or 3.8, if it is closer to the 3.9 magnitude standard. Such a train of thought looks like;

Unknown U is slightly fainter than standard of V mag 3.6.

Unknown U is slightly brighter than standard of V mag 3.9.

Unknown U is closer to standard of V mag 3.6.

I estimate Unknown U has a V magnitude of 3.7.

Tricks of the Trade

- 1) *Don't zero in on your star too fast by visually picking one that at first glance seems to match; you won't be that lucky at the telescope.*
- 2) *The last two standards that bracket each unknown should not differ by more than 0.5 magnitudes.*
- 3) *Look for small patterns of stars (triangles, squares, pentagons, etc.) to find your way around the slide.*
- 4) *The finding chart shows the stars photographed in blue light while the image on the computer is a color photo. That's why the sizes of a star image on the finding chart don't always match its image on the color photo — you are seeing the differences in the colors of stars in black and white.*
- 5) *Make your comparisons in the same order each time. Don't compare the unknown to the standard and then the next time compare the standard to the unknown. Yes, there is a subtle but significant difference.*
- 6) *Never treat an unknown as a standard — don't use an unknown to determine the magnitude of another unknown.*
- 7) *Magnitudes for standard stars are shown next to star with decimal point omitted (e.g., 101 = 10.1 magnitude)*

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Table 1: M 67 Unknowns Ordered by V Magnitude

Star #	V Magnitude
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	

Questions

- 1) What properties of the star images are you are using to estimate the visual magnitudes of stars on the slide?

Hint: What you are measuring is their visual magnitude, but what is it that you can see that differs from one star image to another on the slide?

Answer

- 2) List and discuss the at least three sources of error (things that give you trouble) in performing visual photometry.

Answer

1)

2)

3)

4)

5)

6)

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3) List the stars from Brightest (smallest magnitude) to faintest (largest magnitude) in Table 2.

Table 2: M67 Unknowns Ordered by V Magnitude

Star #	V Magnitude

4) What is the magnitude of the brightest star in Table 2? _____

5) What is the magnitude of the faintest star in Table 2? _____

6) What is the magnitude difference between them? _____

7) How many times brighter is the brightest unknown star than the faintest? _____

Hint: Use the magnitude difference vs brightness ratio chart in Figure 1 to convert magnitude difference to brightness ratio