Problem Set #4 - SOLUTIONS

PHY 300 Observational Astronomy

Throop / Booth

ASSIGNED: MONDAY 16-MAR-2015
DUE: MONDAY 23-MAR-2015, BEGINNING OF CLASS

**** BECAUSE OF THE UPCOMING QUARTER TEST ON 25-MAR, I WILL POST THE SOLUTION SET IMMEDIATELY AFTER CLASS ON THE DUE DATE. THEREFORE, NO LATE ASSIGNMENTS CAN BE ACCEPTED.**

1. **Telescope lengths**. You have a Galilean telescope with a 20-cm diameter primary and focal ratio f/10.

    a) Roughly how long is the telescope tube? You can ignore the eyepiece, which will add a few cm.

FOCAL LENGTH F = DIAMETER * FOCAL RATIO = 20 CM * 10 = 200 CM.

SINCE THIS IS A GALILEAN, THE TUBE LENGTH IS ROUGHLY EQUAL THE FOCAL LENGTH.

    b) Same problem as above, but for a Newtonian telescope?

IN A NEWTONIAN, THE FOLDED OPTICS ALLOW FOR A TUBE WHICH IS ROUGHLY HALF OR 2/3 THE LENGTH OF THE GALILEAN, SO ABOUT 100 - 130 CM.

    c) Same as above, but for a Cassegrain telescope?

ABOUT HALF THE LENGTH, SO ~100 CM — MAYBE LESS DEPENDING ON THE SECONDARY CURVATURE.

    d) What is the magnification in each one? You can assume you have the same eyepiece on each telescope (a 5-mm eyepiece). What happens if you then switch to a 15-mm eyepiece?

MAG = F_1 / F_2 = 200 CM / 0.5 CM = 400X, FOR ALL THREE DESIGNS.

    e) Roughly speaking, how does the brightness (that you see through the 5mm eyepiece) of each of these compare to each other?

CASSEGRAIN AND NEWTONIAN WILL BE A BIT FAINTER DUE TO THE SECONDARY OBSTRUCTING THE IMAGE SLIGHTLY, TYPICALLY 20-30%. THE DIFFERENCE MIGHT BE NOTICEABLE TO A TRAINED OBSERVER, THOUGH IT IS NOT LARGE.

2. **Eyepieces**. Why does a telescope need an eyepiece, while a magnifying glass does not? A diagram might be helpful to explain.

YOUR REQUIRES INCOMING RAYS TO BE PARALLEL, OR NEARLY SO. FOR AN OBJECT VIEWED AT A LARGE DISTANCE THROUGH A TELESCOPE, THE RAYS MUST BE BENT BACK TO PARALLEL USING AN EYEPIECE. BUT FOR A

MAGNIFYING GLASS, THE OBJECT IS MUCH CLOSER, SO THE RAYS COME OUT MUCH CLOSER TO PARALLEL.

3. **Mirror Designs**. What are the pros and cons of parabolic vs. spherical optics?

PARABOLIC PRO: NO SPHERICAL ABERRATION
PARABOLIC CON: HARDER TO MAKE THAN SPHERICAL; ADDS COMA.
SPHERICAL PRO: HISTORICAL; EASY TO MANUFACTURE; NO COMA
SPHERICAL CON: SPHERICAL ABERRATION.

4. **Minister of Telescopes**. You are the science minister for the Republic of Slobovia, a little-known province outside of Malawi. Your country has asked you to lead the way to develop a new observatory to put Slobovia at the forefront of modern astronomy. The president asks you to design a telescope that meets the following criteria:

Wavelength:	100 nm - 1 micron
Resolving power:	Able to resolve a solar system to a resolution of 1 AU, for a system 500 ly from the Sun.
Sky Visible:	Able to images targets through the entire sky (northern and southern hemispheres).
Purpose:	General purpose optical astronomy (some wide-angle, some narrow-angle studies).

a) Describe the telescope that you propose she fund. Be sure to describe the diameter, the basic optical design and the rough focal ratio, and the location on Earth where it should be built. (You can ignore atmospheric effects — that is, assume that the telescope will resolve down to the diffraction limit.)

THE NECESSARY ANGULAR RESOLUTION IS

$\Theta = R/R = 1\ AU / 500\ LY = 3\ 10^{-8}\ RAD = 0.006''$.

TO ACHIEVE THIS, WE NEED A DIAMETER OF

$D = 1.22\ LAMBDA/\Theta = 1.22\ (1\ MICRON) / (3\ 10^{-8}\ RAD) = 38.6\ METERS.$

WHOA! NOTE THAT WE HAVE TAKEN A WAVELENGTH OF 1 MICRON, SINCE WE WILL EXCEED OUR REQUIREMENTS FOR SHORTER WAVELENGTHS — IT'S THE LONG ONE WE MUST DESIGN FOR.

I'D RECOMMEND A HIGH-ELEVATION SITE NEAR THE EQUATOR. IT WOULD BE IMPOSSIBLE TO BUILD A REFRACTOR OF THIS SIZE… A REFLECTOR IS POSSIBLE, THOUGH STILL A CHALLENGE!

b) Telescope construction cost scales roughly with the cube of the telescope diameter. Assuming it cost R1000 million to build the 10-meter Keck telescope, how much should you request for your telescope?

IT'S ABOUT FOUR TIMES THE DIAMETER OF KECK, SO IT WILL COST ROUGHLY 4^3 AS MUCH, OR R64 BILLION.

c) The minister comes back to you and says that she has located a 3-meter hyperbolic-surface mirror high in the mountains made by previous residents and abandoned. Is this of interest to you for use in this telescope? Why or why not?

IT'S OBVIOUSLY NOT LARGE ENOUGH TO USE AS THE SINGLE PRIMARY. BUT PERHAPS YOU COULD INVESTIGATE USING IT AS A SECONDARY, DEPENDING ON THE FOCAL LENGTH? OR MAYBE AS PART OF AN OPTICAL INTERFEROMETER, IN CASE THE BUDGET FOR THE MAIN TELESCOPE IS JUST TOO MUCH FOR SLOBOVIA TO AFFORD?

5. **Observational Organization**. You are observing with your new telescope in Pretoria (lat 25 deg S). The local time is midnight, and the sun will rise at 6h00 local time. You look at your sidereal clock, and it says 03h15.

   You'd like to observe each of the following objects.

Jupiter	RA 03h15, Dec -20°
Constellation Cassiopeia	RA 5h, Dec +62°
The Carina nebula	RA 11h, Dec -60°
Moon	RA 23h, Dec 0°

   For each of these, is it possible to observe tonight? If so, when should you do it? And where in the sky should you look? You don't need to be precise: "Look toward the north now" or "Look close to the zenith in two hours" is fine.

   ** The best time to observe something is typically when it is crossing the meridian, but for some of these that might not be possible due to the sun rising.

JUPITER: THE RA PUTS IT ON THE MERIDIAN NOW. JUPITER'S DECLINATION PUTS IT 5° NORTH OF THE ZENITH. OBSERVE IT NOW!

CASSIEOPEIA: AT DEC 62°, CASSIOPEIA IS 87 DEGREES NORTH OF YOU, AND JUST 3 DEGREES UP FROM THE HORIZON. BUY A PLANE TICKET TO TEXAS, BUT DON'T TRY TO OBSERVE IT FROM HERE.]

CARINA: DECLINATION WILL PUT IT 35° SOUTH OF THE ZENITH (THAT IS, 55° UP FROM THE HORIZON) — NOT IDEAL BUT CLEARLY VISIBLE. HOWEVER, THE RA MEANS THAT IT WILL CROSS THROUGH THE MERIDIAN 8 HOURS FROM NOW. IT WILL RISE A FEW HOURS BEFORE THAT. IT MIGHT BE VISIBLE OR MAYBE NOT — LOOK TOWARD THE SOUTHEAST JUST BEFORE SUNRISE TO GIVE IT A SHOT.

MOON: DECLINATION LOOKS OK: IT WILL BE 25° TO YOUR NORTH WHEN IT CROSSES THE MERIDIAN. SINCE THE RA IS 3H15 NOW, THE MOON CROSSED THE MERIDIAN 4H15 AGO. IT'S ABOUT TO SET WITHIN ANOTHER HOUR OR TWO, SO LOOK TOWARD THE NORTHWEST TO CATCH IT BEFORE IT SETS.

6. **Parallax Perspective**. You are observing your favorite distant star. You notice that its position changes slightly throughout the year, and you measure the amount of this shift as 0.1 arcseconds (0.1"). You assume (correctly) that this shift is due to parallax from the Earth's motion. How far away is your star?

BY DEFINITION, A STAR AT 1 PARSEC (1 PC = 3.26 LY) SHOWS A PARALLAX SHIFT OF 1". THIS SHOWS 1/10 THAT SHIFT, SO IT'S 10 TIME FURTHER AWAY, OR 10 PC.