First of the Three Astronomy Exams

April 9, 2021

Standard prefixes:

k = kilo = 10^3
M = mega = 10^6
G = giga = 10^9
T = tera = 10^{12}
c = centi = 10^{-2} (but do not confuse it this with the speed of light which is also c)
m = milli = 10^{-3}
μ = micro = 10^{-6}
n = nano = 10^{-9}
p = pico = 10^{-12}

Common unit abbreviations:

m is the usual abbreviation for meters (but also for milli!, so millimeters is mm)
s is the usual abbreviation for seconds
Hz is for Hertz which is $\frac{1}{\text{second}}$

Declination and Right Ascension

1. Declination

The declination of Polaris (The North Star) is about? HINT: The latitude of the North Pole is?

2. Declination

If you are out at night in Pucon, Chile, which has latitude -39°, and you look straight up, you will see stars with what declination?

3. Right Ascension

Right ascension is measured with a sidereal clock that like a regular clock marks out 24 hours of time. Circle one or more true statements

* The sidereal clock needs to run a little slow, to match each revolution of the stars.
* The sidereal clock needs to run a little fast, to match each revolution of the stars.
* Was calibrated to show 0h when the First Point of Aries passed across Tycho Brahe's observing slit.

4. Right Ascension

The “First Point of Aries” has moved in the greater than 2000 years since Hipparchus set the system up. Today, the “First Point of Aries” is in (circle one):

* Ursa Major
* Orion
* Pisces
* Sagittarius

5. Right Ascension

If you look through a slit in the roof and something with Right Ascension 13h goes across it, and you keep still and looking through the same slit, then whatever comes into view after (approximately) one hour has:

(A) Right Ascension of 12h
(B) Right Ascension of 13h
(C) Right Ascension of 14h
(D) Right Ascension of 15h

Apparent Magnitude (or just “Magnitude”)

6. Apparent Magnitude

In the modern system, five steps (e.g., mag 6 → 1) is about 2.5x2.5x2.5x2.5x2.5 times brighter. But this is only an approximation, and the exact answer for and the definition for five steps of apparent magnitude is:

(A) 12.5 times brighter
(B) 10 times brighter
(C) 100 times brighter

Wave Speed, Period, and Frequency

The definition for frequency in terms of period is

$f = \frac{1}{P}$

The main formula for waves of light is

$c = \frac{\lambda}{P}$ where the speed of light $c = 3 \times 10^8$m/s

From this and the definition of frequency, you can also get $c = \lambda f$, and then from that you can also get,

$\lambda = \frac{c}{f}$ and $f = \frac{c}{\lambda}$

7. Frequency and Period

The redline on a typical car engine is about 6000 rpm. In revolutions per second, that is 100 $\frac{\text{rev}}{\text{sec}}$ or we could just write 100 Hz.
What period corresponds to 100 Hz?

Comment: That’s just amazing mechanics (that in that little time the engine makes a complete revolution).

8. Wavelength from Frequency

We command nuclear submarines to come to the surface using ultra-low frequency waves. The frequency $f = 10$ Hz. These waves have wavelength:

(A) 3 x 10^4 m
(B) 3 x 10^4 km
(C) 3 x 10^7 km
(D) 3 x 10^8m

Blackbody Radiation, Wien’s Law, and the Stefan-Boltzmann Formula

For an object that is radiating electromagnetic waves the radiated light has a peak in the spectrum, and the location for the peak is:

$$\lambda_{\text{peak}} = \frac{2.9\ x\ 10^6\ \text{nm Kelvin}}{T}$$

The area of a star with radius R is

$$A = 4\,\pi R^2$$

The Stefan-Boltzmann formula says that the power emitted per unit area of a blackbody (its intensity) is:

$$I = \sigma T^4$$

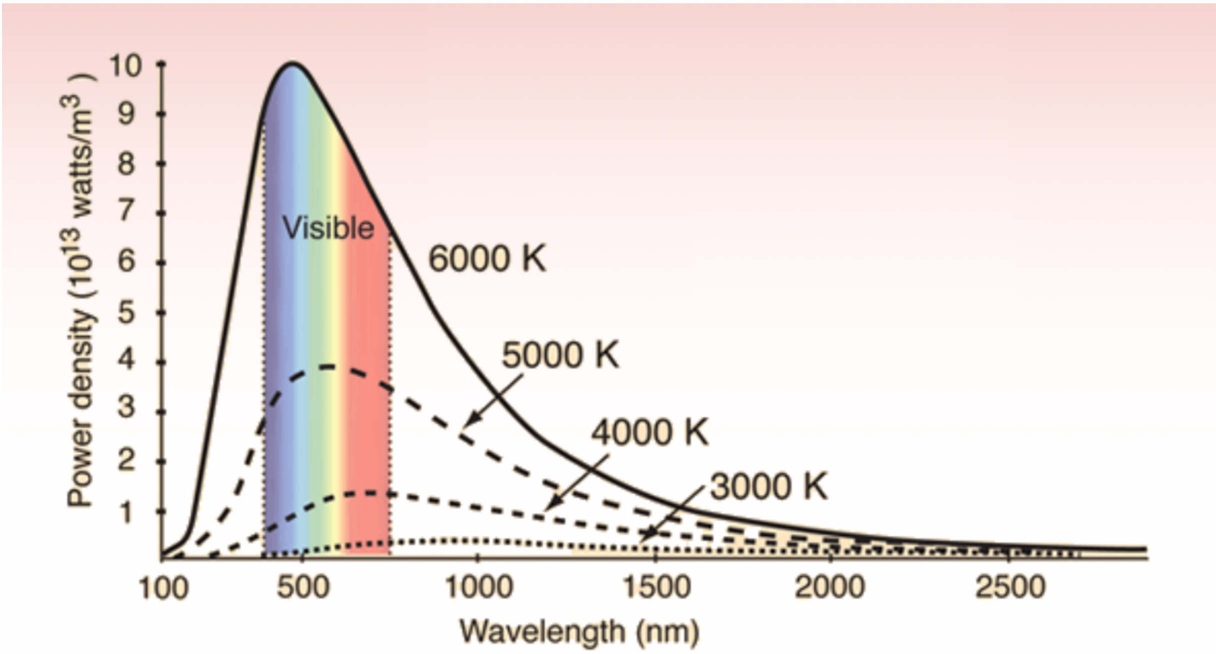
The preceding two formulas can be combined to get the total power emitted by a star (its luminosity) using

power = power per unit area x area

$$L = I\,A$$

9. Blackbody radiation

The graph below shows black-body radiation curves for stars of various temperatures:



In the graph on the previous page, study the dashed curve for the 4000K star. The peak wavelength for such a star is about:

(A) 100 nm
(B) 400 nm
(C) 700 nm
(D) 900 nm

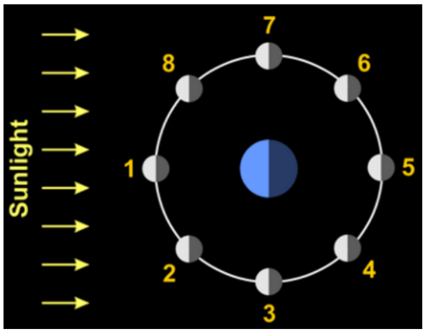
You could use Wien's Law and a calculator, but it is easier to read the graph. Fun fact: such a star looks reddish and an example is Betelgeuse which has temperature 3500K.

10. Blackbody radiation

Study the dashed curves for the 4000K, 5000K and 6000K stars. Write a short paragraph that describes:

* What color in the spectrum the three stars shines brightest at.
* What the overall impression of the three stars would be.
* Martha Evans Martin describes Arcturus as "Yellow" and "a little tinged with red". Include an estimate of the temperature of Arcturus in your paragraph.

Moon’s Phases and Eclipses



In the diagram, you are looking down on the North pole and the Moon is going counterclockwise.

11. Moon’s Phases

The phase numbered 8 is:

(A) Waxing crescent

(B) Waning crescent

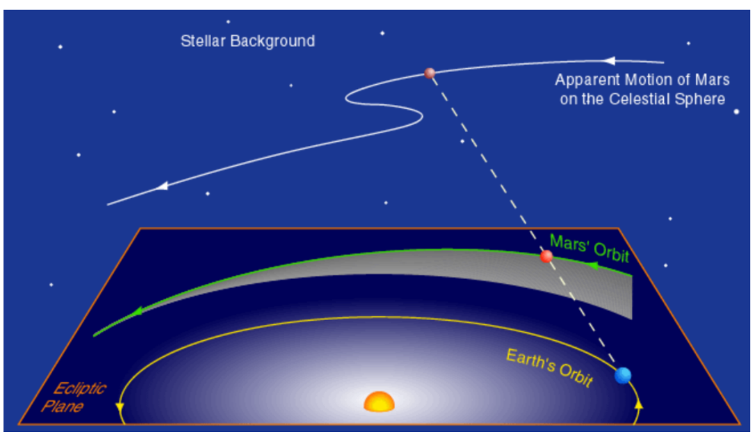
(C) Waxing gibbous

(D) Waning gibbous

(E) Full Moon

Prograde and Retrograde Motion

Mars has an apparent path through the stars. Below is the modern (Copernican) explanation of this:



Consult this diagram for the next two problems.

12. Prograde and Retrograde Motion

In the position of Mars as shown, it appears to be traveling:

(A) **Eastward** through the stars and this is called **prograde** motion.
(B) **Westward** through the stars and this is called **prograde** motion.
(C) **Eastward** through the stars and this is called **retrograde** motion.
(D) **Westward** through the stars and this is called **retrograde** motion.

13. Prograde and Retrograde Motion

A little later than shown in the picture, Mars will appear to be going the other way through the stars.

(A) This is called **prograde** motion, and Mars will be going **westward** through the stars.
(B) This is called **retrograde** motion, and Mars will be going **westward** through the stars.
(C) This is called **prograde** motion, and we now know it is caused by epicycles.
(D) This is called **retrograde** motion, and we now know it is caused by epicycles.

Using the “Pie Crust” Formula

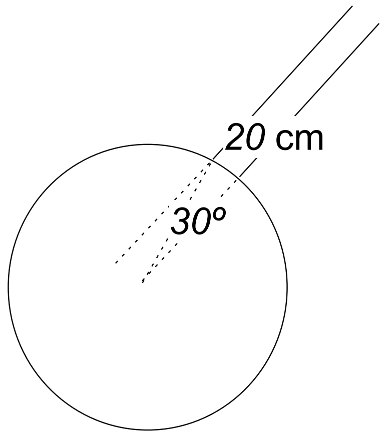
When Aristarchus estimated the size of the Moon he used this formula, which is handy for all sorts of calculations:

$$\frac{s}{2\,\pi\,r} = \frac{\text{angle in degrees}}{360\,^{\circ}}$$

For example, Eratosthenes is the person that estimated the size of the Earth using this formula. He knew of a well far south of Alexandria in which light fell straight down on the solstice, and he knew the angle of the Sun in Alexandria on the solstice. Using the formula, he got 252,000 stadia for the circumference of Earth. This turns out to be incredibly close. We don’t know quite how close because we don’t know the unit of the stadium. It is between 155 and 160 meters.

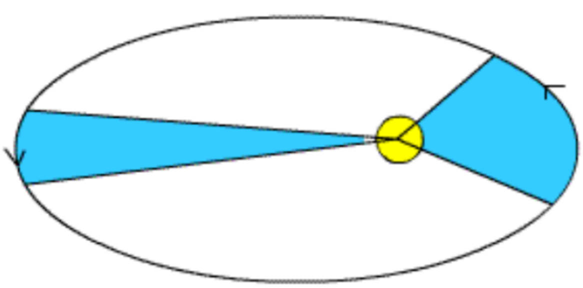
14. Eratosthenes and the Beach Ball

Imagine that Eratosthenes is looking at a beach ball in the sand on a sunny day. He can see that the sunlight is falling straight down on one part of the beach ball. 20cm away on the beach ball, the sunlight is coming down with an angle of 30°. The circumference of the beach ball is?



Ellipses and Kepler's Laws

15. Kepler's 2nd Law



In the drawing above the shaded wedges *are supposed to have the same area*. Circle one or more statements that are true:

* That the amount of **time elapsed** as the **right** wedge was traced out was longer.
* That the amount of **time elapsed** as the **left** wedge was traced out was longer.
* That the object is **moving faster** in the **left** wedge.
* That the object is **moving faster** in the **right** wedge.