TOPICS, TERMS and FORMULAS, ASTR 503

General text shorthands…
a*b means a times b (the product of two terms multiplied together). Don't use "x" which can be a variable.
a/b means a divided by b
a**b means a raised to the b power; a**2 is a-squared, etc.
aEb means a times ten to the b power. Thus 4.3E4 is 43,000.
Note: this shows the number of significant figures at the same time!
Sqrt (a) means the square root of a. Same as a**.5 = $\sqrt{a}$
Sin (a), Cos (a), Tan (a) means sine, cosine, and tangent of the Angle a.
IF NO UNITS, assume the angle is measured in RADIANS (see below).
thet = greek theta = θ (usually a measure of angle)
lam = greek lambda = λ (latitude, or wavelength)
alph = greek alpha = α (usually a measure of angle)
~ means "approximately equal to"
deg = degrees (usual units, 360 deg = a circle)
pi = π = you know this one. Approximately 3.14159…. my favorite number ~ $\sqrt{10}$
R = the radius of a circle
Re = the radius of the Earth (generally the "e" is an UPPERCASE subscript) = 6378 km.
qv = means "quid videre" which means "go look it up" (it's defined elsewhere).
In the html version this will be a hot link.

Scientific notation: write as n.fff x 10^{e} where n is a number 1-9, .fff is the fraction (with the number of digits indicate how accurately we know the number), and e is the exponent (power of ten).

Thus, 1,000,000 = 1 x 10^{6} if you only know one significant digit
1,001,000 = 1.001 x 10^{6} since presumably that extra 1 means something, so four significant digits

PREFIXES IN SI (no prefix: plain unit, e.g. m = meters)

deci = d =	0.1 = 10^{-1}	deka = da =	10 = 10^{1}
centi = c =	0.01 = 10^{-2}	hecto = h =	100 = 10^{2}
milli = m =	0.001 = 10^{-3}	kilo = k =	1000. = 10^{3}
micro = mu =	E-6= 10^{-6}	Mega = M =	E6 = 10^{6}
nano = n =	E-9= 10^{-9}	Giga = G =	E9 = 10^{9}
pico = p =	E-12= 10^{-12}	Tera = T =	E12 = 10^{12}
femto = f =	E-15= 10^{-15}	Peta = P =	E15 = 10^{15}
atto = a =	E-18= 10^{-18}	Exa = E =	E18 = 10^{18}
zepto = z =	E-21= 10^{-21}	Zetta = Z =	E21 = 10^{21}
yocto = y =	E-24= 10^{-24}	Yotta = Y =	E24 = 10^{24}

constants you should know: speed of light 3 E5 km/s = 3 E8 m/s (186,000 miles per second)
Astronomical unit = AU = 1.5 E8 km (93 million miles) = distance from Earth to Sun
Light year = distance light travels in a year = c km/s * π x 10^{7} s/yr = 9.46 x 10^{12} km
(seconds in a year = 365.25 x 24 x 60 x 60 = 3.156 x 10^{7})
1 parsec / 1 AU = 1 radian / 1 arc sec = 57.3 deg/rad * 60 * 60 = 2.06 x 10^{5}
So, 1 parsec = 2.06 x 10^{5} * 1.5 x 10^{8} km = 3.09 x 10^{13} km = 3.27 LY

Introduction

1. Ask your students: what's in the sky? (answers might include stars, birds, clouds, the Sun)
Which things belong to earth and which are outside the earth?
Birds: you know they are of earth because they might land beside you

Clouds: you know they are of earth because they are sometimes below you (when you're on a mountaintop, or in a plane)
What about the Sun? How do we know it's not in our atmosphere? The Moon? Stars? Harder… meteors… how do we know those are in our atmosphere and not in the sky? (Occasionally folks see them actually hit the ground. From the shuttle they can look down on them). No obvious parallax for sun, moon, and stars, (although you can tell parallax for the moon… later..) Planets – wandering stars; comets – hairy stars; meteors – shooting stars.

2. Generally, when you look in the sky you see angular size and angular motion… you don't know how close so how large it is. If someone says a UFO was traveling 500 mph, they really don't know.. they just saw its angular position change across the sky.

3. **Rule of "thumb":** one thumb at arm's length is about 2 degrees; one fist at arm's length is about 10 degrees; a "hook-em" is 15 degrees. (Generally people with big fists have long arms – check it yourself by measuring "fists" from the horizon to the zenith.

4. **Intensity of energy, light**, etc… is amount of energy (or particles) per unit area.
As the distance from an object gets larger, the surface area of the sphere of radius R enclosing it gets larger $A = 4 \pi R^2$. So the energy PER unit area gets smaller as $1 / R^2$.

5. **Change units**: multiply by "1" to cancel units. 1.609 km / 1 mi = 1 = 1 kg / 2.2 lb , etc.

6. **Flux of Energy** = Energy per unit area PER unit time. 1 W/m^2 is one Joule per second (=1 Watt) crossing an area of one square meter.
Energy from Sun at Earth = 1.4E3 W/m^2. (actually 1387 W/m^2)
How many kilowatts on average do you use? (KWH used in a month divided by the hours in a month). (Most people around 2 kW, more in summer). How big an area of solar cells do you need? (include day/night; ~10% efficiency; tilt)

7. **Total energy output of Sun** = 1.387E3 W/m^2* (4 π * 1AU * 1AU) = 1.74 E 4 $(1 AU/m)^2$
1.5E11 m = 1 AU so 1 = 1.5E11 m / AU
So Sun's energy output = **solar luminosity** = 1.74 E4 * 1.5 E11 * 1.5E11 = 3.9 E26 W

8. **components of the galaxy**:
galaxy: a collection of hundreds of *billions* of stars, orbiting around a center of mass. (some galaxies are smaller)
nebulas: cloudy looking balls of gas. Can be birth or death shrouds of stars (some that were called nebulas in the past are actually galaxies on their own – "Island Universes". Thus, the Andromeda nebula is now called Andromeda galaxy).
milky way: the mass of stars in the galaxy our Sun belongs to. A spiral.
stars: hot dense balls of gas, that radiate energy from nuclear fusion

Light

9. **Light is an electromagnetic wave**, with properties wavelength λ (m/cyc), speed v (m/s) and frequency f (cyc/sec). Changing magnetic field causes the electric field and a changing electric field causes the magnetic field so it DOES NOT REQUIRE a medium to propagate.

10. **speed of light:** 3.00 E5 km/s (186,000 miles per second). The two extra zeros mean that, yes, it is good to three significant digits (actually 2.99792….).
light slows down when it is in a medium. So, yes, it is possible that particles can travel faster in a medium than light does *in that same medium* (but not faster than the speed of light in vacuum). If they do, they emit "Cerenkov" radiation.

11. **wavelength of light:** depends on the frequency. Lambda = $\lambda = c / f$ (watch units!)
(meters / cycle = (meters / s) / (cycles / s)
Unit of measure of **frequency** = Hertz (Hz) = f, cycles per second (contrast radians/s below)

12. **energy of a photon of light**: $E = h f$ where h = Planck's constant = 6.626 E-34 J-s
So, blue and ultraviolet light are more energetic than red or infrared light.

13. **angle measured in radians**: the arc length of an angle (the portion of the circumference that the angle subtends) divided by the total circumference ($2 \pi R$). One radian is about 57.3 degrees. A full circle is 2π radians; 90 degrees is pi/2 radians, etc.

14. **frequency** measured in radians/s (generally lower case greek 'omega') $\omega = 2 \pi f$
So, if a particular color has a frequency 1 MHz, then its frequency in radians/s = 6.3 Mrad/s
1 rad/s = 2π (rad/osc) * f (osc/sec)

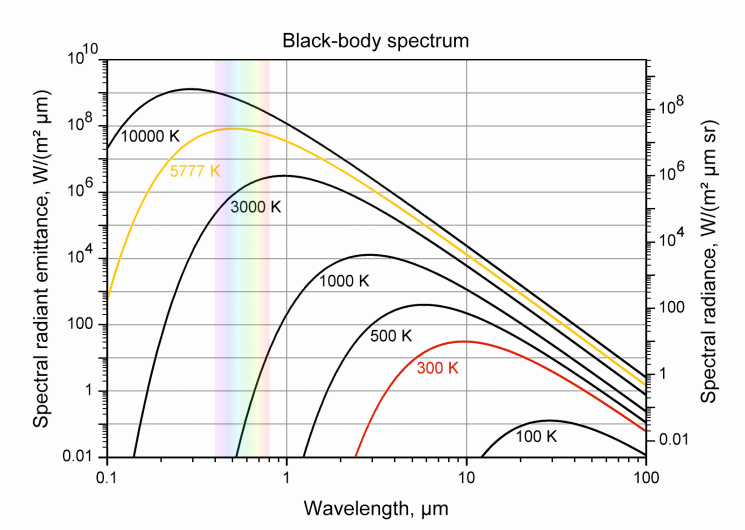
15. **spectrum:** the light from a source spread out so that the intensity at each wavelength can be measured separately.

16. **continuous spectrum:** a spectrum that has light smoothly varying over a large band of wavelengths. (light from a black body or incandescent bulb looks this way) (rainbow)

17. **line emission**: discrete lines of light emission, from a thin gas. Each element has a unique fingerprint of line emissions, from steps in their electron energy levels. (no electrons, no lines, so ionized Hydrogen is invisible)

18. **absorption spectrum**: a continuous spectrum with narrow dark lines (light from a black body passing through a thin gas)

19. **blackbody spectrum:** a continuous spectrum from a heated solid (an empty box makes a good blackbody too!). Has a peak energy and falls off steeply at high frequency (short wavelength) and slowly at low frequency (long wavelength).



20. **Wien's law:** shows how the wavelength of the peak of a blackbody spectrum changes with temperature. Hotter stars are bluer.
Lambda = .3 cm / (T/1K)
where T is measured in Kelvins (from absolute zero)

21. **Stefan-Boltzmann law:** shows how the total energy flux (energy radiated per m^2 per sec) of a black body changes with temperature:

    $JE = \sigma * T^4$ (the fourth power of the temperature)

    Where σ (sigma) is the Stefan-Boltzmann constant = 5.67 E-8 $J/(s * m^2 K^4)$

22. **More massive stars are bluer.** Why? More mass means more compression in the core, more nuclear fusion since can overcome the electrostatic repulsion of the protons… Gives more energy so has to become hotter to get rid of all that energy.

23. **know the electromagnetic spectrum in order of energy:** radio then infrared then visible (red to blue) then ultraviolet then X-ray then gamma ray. The higher the energy, the more damage it can do. Gamma rays can disrupt nuclei; x-rays can ionize atoms; UV can dissociate atoms and ionize outlying electrons; visible can break molecular bonds (photosynthesis); infrared can only heat. Microwaves heat food by making water or fat molecules vibrate.

24. **Doppler shift:** if an object emitting sound or light is traveling with the respect to the receiver, the apparent frequency and wavelength will change based on the line of sight velocity V and the speed of the wave C. (Cs = speed of sound; C = speed of light).

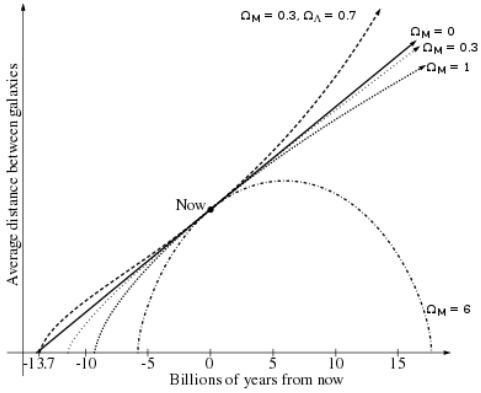
    Delta f / f = $(f - f_0) / f$ = -delta λ / λ = $(\lambda_0 - \lambda) / \lambda$ = V/C

    Frequency INCREASES if the V is towards you but wavelength DECREASES

    Relativistic version: (delta λ)/ λ= -1 + SQRT ((1 + v/c)/(1 - v/c)).

25. **Hubble Constant:** Galaxies farther away are moving faster from us. No real "center" of the universe (looks the same to all). **H = 71 km/s / Mpc**
    (so a Galaxy 1 Mpc away is typically moving 71 km/s away from us).

26. **Age of the Universe:** = 1/H if the universe is expanding at a constant rate. = 13.8 BY bp . Zero time = **"Big Bang"** (universe all together and very small and hot, then particles condensed, then stars, galaxies, etc).



27. **Dark Matter** = real matter which is hard to see (might be brown dwarfs, black dwarfs, black holes, etc..) (about 27% of the total energy in the Universe, or about 85% if you exclude dark energy). (Inferred from the rotation of galaxies – outer parts of galaxies rotate faster than they should if all the mass were visible). "Regular" matter around 5%. Appears to be associated with normal matter. Most likely = WIMPS (Weakly Interactive Massive Particles, like Higgs bosons or other strange stuff), or MACHOs (MAssive Compact Halo Objects), like black holes, neutron stars, etc. Best estimate is MACHOS can be about 10% but the rest is probably WIMPS.

28. **Dark Energy** = energy that is causing the expansion of the Universe to accelerate. About 68% of the energy in the Universe (but is constantly INCREASING). Strange!! (and might even go away as we better measure the distances to very far away galaxies).
    Good website: http://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/