hInformation about the Final

The final is on Saturday, December 11, starting at 2:00. If you are ill or miss the test for any reason, contact me via email ecarlson@wfu.edu or by cell 336-407-6528.
PHY 310: Test is from 2:00 – 4:00 pm. If you have extra time you will have from 2:00–5:00 pm.
PHY 610: Test is from 2:00 – 4:20 pm

To the final, you should bring:

- Pen or pencil
- Calculator
- Paper (or you can borrow some from me)

Outline of the Final

This test consists of three parts. For the first two parts, you may write your answers directly on the exam, if you wish. For the other parts, use separate sheets of paper. Useful equations can be found at the end of part 4/start of part 5. The total test is worth 180 points for PHY 310, and 210 points for PHY 610.

Part I: Multiple Choice [40 points/40 points] (2 points each) (mostly new material)
For each question, choose the best answer
[questions 1-20]

Part II: Short answer [40 points/50 points] (10 points each) (4 new material, 1 review)
PHY 310: Choose four of the five following topics, and write 2-4 sentences discussing them
PHY 610: Answer all five of the following questions
[questions 21-25]

Part IV: Calculation [100 points/120 points] (20 points each) (5 new material, 1 review)
For each of the following problems, give the answer, explaining your work.
PHY 310: Choose five of the following six problems.
PHY 610: Do all six of the following problems
[questions 26-31]

Equations for the Final

The following should be memorized by you:

Units

$2\pi \text{ rad} = 360°$

$1° = 60'$

$1' = 60''$

$1'' = 1000 \text{ mas}$

$\frac{1 \text{ pc}}{1 \text{ rad}} = \frac{1 \text{ AU}}{1''}$

Metric

$\text{k} = 10^3$

$\text{M} = 10^6$

$\text{G} = 10^9$

$\text{m} = 10^{-3}$

$\mu = 10^{-6}$

$\text{n} = 10^{-9}$

Doppler Shift

$1 + z = \frac{\lambda_{\text{now}}}{\lambda_{\text{then}}} \approx 1 + \frac{v_r}{c}$

Scale Factors and Stuff

$\frac{a}{a_0} = \frac{\lambda_{\text{then}}}{\lambda_{\text{now}}} = \frac{d}{d_0} = \frac{1}{1+z} \approx \frac{T_0}{T}$

Hubble's Law

$v = H_0 d$

Approximate Cosmological Parameters

$\Omega = 1$

$\Omega_\Lambda \approx 0.69$

$\Omega_d \approx 0.26$

$\Omega_b \approx 0.05$

$H_0 \approx 68 \text{ km/s/Mpc}$

$T_0 \approx 2.7 \text{ K}$

$t_0 \approx 14 \text{ Gyr}$

Degrees of Freedom

$g_{\text{eff}} = g_b + \frac{7}{8} g_f$

Simple Orbits

$\mathbf{F} = -\frac{GMm\hat{\mathbf{r}}}{r^2}$

$v^2 = \frac{GM}{R}$

Scaling

$\rho_m \sim a^{-3}$

$\rho_r \sim a^{-4}$

$\rho_\Lambda \sim a^0$

EM waves

$c = 3 \times 10^8 \text{ m/s}$

$\omega = ck$

$k\lambda = 2\pi$

$\nu = 1/T$

$\omega = 2\pi\nu$

$c = \lambda\nu$

Photons

$E = h\nu$

$E = \hbar\omega$

Collision Rates

$\Gamma = n\sigma(\Delta v)$

Eras

$1 < z < 3000$	matter
$3000 < z$	radiation
$k_B T < 1 \text{ eV}$	matter
$k_B T > 1 \text{ eV}$	radiation

Size of horizon at time *t*

$d \approx ct$

Luminosity/Brightness

$L = 4\pi R^2 \sigma T^4$

Average Energy

$\bar{E} = 3k_B T$

Size/Angular Size

$\alpha = s/d$

You should be able to use the following equations, but you are not expected to memorize them:

Units

$1 \text{ AU} = 1.496 \times 10^{11} \text{ m}$

$1 \text{ pc} = 3.086 \times 10^{16} \text{ m}$

$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$

$1 \text{ y} = 3.155 \times 10^7 \text{ s}$

$R_\odot = 6.955 \times 10^8 \text{ m}$

$M_\odot = 1.989 \times 10^{30} \text{ kg}$

$L_\odot = 3.828 \times 10^{26} \text{ W}$

$T_\odot = 5777 \text{ K}$

Physical Constant

$k_B = 1.381 \times 10^{-23} \text{ J/K}$

$k_B = 8.617 \times 10^{-5} \text{ eV/K}$

$\sigma = 5.670 \times 10^{-8} \text{ W/m}^2/\text{K}^4$

$\hbar = 1.055 \times 10^{-34} \text{ J} \cdot \text{s}$

$\hbar = 6.582 \times 10^{-16} \text{ eV} \cdot \text{s}$

$G = 6.673 \times 10^{-11} \text{m}^3/\text{kg/s}^2$

Magnitude/Distance

$m - M = 5 \log d - 5$

$d = 10^{1 + \frac{m-M}{5}} \text{ pc}$

Mass Density

$\rho = g_{\text{eff}} \frac{\pi^2 (k_B T)^4}{30 (\hbar c)^3 c^2}$

$g_{\text{eff},0} = 3.36$

Age of Universe

Matter

$t = \frac{17.3 \text{ Gyr}}{(z+1)^{3/2}}$

$= \frac{62.2 \text{ kyr}}{(k_B T/\text{eV})^{3/2}}$

Radiation

$t = \frac{2.42 \text{ s}}{\sqrt{g_{\text{eff}}}} \left(\frac{\text{MeV}}{k_B T} \right)^2$

Brightness/Magnitude

$F = 2.518 \times 10^{-8} \text{W/m}^2 \left(10^{-\frac{2}{5} m}\right)$

Friedman Equation (*k* = 0)

$H^2 = \frac{\dot{a}^2}{a^2} = \frac{8}{3} \pi G \rho$

Doppler Shift

$1 + z = \frac{\lambda}{\lambda_0} = \sqrt{\frac{1 + v_r/c}{1 - v_r/c}}$

Definition of Ω_i

$H^2 \Omega_i = \frac{8}{3} \pi G \rho_i$