PHY 310/610 Midterm Exam Name _____

October 8, 2025

This test consists of three parts. For the first and second parts, you may write your answers directly on the exam, if you wish. For the other parts, use separate sheets of paper.

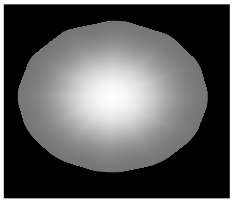
Part I: Multiple Choice [2 points each] Everyone: Answer all questions.
For each question, choose the best answer

1. Which spectral class of stars would be the hottest?
   A) F2 B) F7 C) K4 D) K6 E) M5

2. Which of the following elements counts towards the metallicity of a star, according to astronomers?
   A) Iron (only)
   B) Iron and calcium, but not silicon
   C) Iron, calcium, and silicon, but not oxygen
   D) Iron, calcium, silicon, and oxygen, but not helium
   E) Iron, calcium, silicon, oxygen, and helium

3. Sometimes behind a galaxy cluster we will see multiple galaxies with remarkably similar spectra. Why does this happen?
   A) It shows that there are very distant galaxies that form in clusters of identical galaxies
   B) There is one giant galaxy behind them, but dust blocks all but a few holes where the spectrum comes through
   C) One very bright galaxy is reflecting off of clouds that are orbiting it
   D) The galaxy is moving so fast it appears to be at several locations at once
   E) It is just a single galaxy with multiple images caused by gravitational lensing

4. The galaxy classification of the cartoon galaxy at right is approximately
   A) SAb B) SBc C) E2 D) E7 E) Im



5. Black holes are not supposed to allow any light to escape, and yet we see X-rays coming from many AGN's. How is this possible?
   A) X-rays are actually coming from the accretion disk near the black hole
   B) X-rays are produced by Hawking radiation from black holes
   C) The jets from the center smash into the intergalactic medium, producing X-rays
   D) The black holes have attracted numerous O and B stars, which produce X-rays
   E) X-rays are not the same thing as light; they CAN escape from black holes

6. Which of the following would by itself give you an estimate of the temperature of a star?
   A) Luminosity B) Brightness C) Mass D) Color E) Age

7. We are approximately what distance from the center of our galaxy?
   A) 8.3 pc B) 83 pc C) 8.3 kpc D) 8.3 Mpc E) 83 Mpc

8. MACHOS (massive compact halo objects) sometimes pass between us and a distant star, causing the star behind it to
   A) Be dimmed or blocked by the obscuring intervening object
   B) Be made temporarily brighter, due to gravitational lensing
   C) Be gravitationally **red**-shifted due to the MACHO
   D) Be gravitationally **blue**-shifted due to the MACHO
   E) Gain extra absorption lines as the light passes through the foreground object

9. The way you can tell how old a cluster of stars is is by
   A) Measuring the metallicity of the cluster
   B) Counting the number of living vs. dead stars
   C) Measuring the amount of dust that dying stars have ejected
   D) Studying the concentration of helium vs. hydrogen in a typical star
   E) Looking at the Hertzsprung-Russell diagram and seeing where the turn off point is

10. Spectroscopic parallax is somewhat unreliable, even when applied to main sequence stars, because
    A) It is often difficult to determine the spectral class of a star
    B) The luminosity of main sequence stars varies somewhat based on age
    C) Stars that are red- or blue-shifted will have their spectral class apparently shifted
    D) Many stars are surrounded by clouds of gas that hide their true luminosity
    E) Most stars are binaries or multiples, and it is impossible to disentangle their spectra

11. The name of the nearest large galaxy (not ours) to ours is
    A) Andromeda B) Virgo C) Milky Way D) Laniakea E) Coma

12. Central dominant galaxies (cD galaxies) are giant elliptical galaxies normally found where?
    A) The center of small galaxy groups
    B) The edge of small galaxy groups
    C) The center of large galaxy clusters
    D) The edge of large galaxy clusters
    E) Isolated, with no other galaxies nearby

13. Which of the following objects would you likely use radar distancing to find the distance to?
    A) Andromeda galaxy, M31 (only)
    B) Venus (only)
    C) The Coma cluster (only)
    D) All of the above
    E) None of the above

14. Approximately what fraction of a typical galaxy cluster's mass is in the form of dark matter?
    A) 2% B) 15% C) 50% D) 85% E) 98%

15. The amount of light coming from a black body at temperature T is proportional to
    A) $T^{1/4}$ B) $T^{1/2}$ C) T D) T^2 E) T^4

Part II: Short Answer PHY 310: Choose three of the four questions PHY 610: Answer all four questions. Write 2-4 sentences about each of the following [10 points each]

PHY 310: You may skip one question

16. Measuring the kinetic energy of a typical star in a galaxy is easy. Measuring the potential energy is hard. Explain how the virial theorem allows us to estimate the potential energy/gravitational potential, using at least one equation. When will the virial theorem tend to apply?

17. We would like to accurately know the distance to the Andromeda Galaxy (M31). Explain why using Hubble's Law or Type Ia supernovae are probably not the methods we use.

18. What is the main reason that we believe typical spiral and barred spiral galaxies have dark matter in them? Explain qualitatively how this is measured and how it shows dark matter.

19. In automobile crashes, it is worse if you collide with a more massive car and if you collide at high velocity. Of course, if you miss, even by a tiny amount, it has no consequences. Explain how galaxy collisions are like or unlike car crashes.

Physical Constants	Units	Brightness/Magnitude	Galactic Orbits
$k_B = 1.381\times10^{-23}$ J/K	$\text{pc} = 3.086\times10^{16}$ m	$F = 2.518\times10^{-8}\,\text{W/m}^2\left(10^{-\frac{2}{5}m}\right)$	$\Omega = \dfrac{V_0}{R_0}$
$\hbar = 1.055\times10^{-34}$ J·s	$\text{M}_\odot = 1.989\times10^{30}$ kg	**Cepheid Period/Luminosity**	$\nu = \sqrt{4\pi G\rho_0}$
$h = 6.626\times10^{-34}$ J·s	$\text{yr} = 3.156\times10^{7}$ s	$M = -2.43\log(P) - 1.62$	**Distance/Magnitude**
$G = 6.674\times10^{-11}\,\text{m}^3/\text{kg/s}^2$	$1'' = 4.848\times10^{-6}$ rad		$d = 10^{1+\frac{m-M}{5}}$ pc
			$m - M = 5\log(d) - 5$

Part III: Calculation: [20 points each]
PHY 310: Choose four of the five problems; PHY 610: Do all five problems.
For each of the following problems, find the answer, explaining your work.

PHY 310: You may skip one question on this page or the next

20. Star *X* has apparent magnitude $m = 8.40$. Suddenly it brightens and becomes magnitude $m = 6.89$
    (a) By approximately what factor has its flux increased?
    (b) Maybe the star got brighter by somehow increasing its radius, while leaving its temperature the same. By what factor must its radius have increased?
    (c) Maybe the star got brighter by somehow increasing its temperature, while leaving its radius the same. By what factor must its temperature have increased?
    (d) Assuming one of the two assumptions (a) or (b) is right, what observations could tell you which is correct?

21. The star Vega has a parallax of 0.1302″, a proper motion of 0.326″/yr, and the K-line spectral line normally at 393.366 nm occurs instead at 393.348 nm.
    (a) Whas it the distance to Vega in pc?
    (b) What is the radial velocity of Vega, in km/s? It it moving towards us or away from us?
    (c) What is the transverse velocity of Vega, in km/s?
    (d) What is the speed of Vega relative to the Sun, in km/s?

22. At right is an image of a spiral galaxy, exactly edge on to us. The atomic spectral feature normally at a wavelength of 21.206 cm on Earth has a wavelength of $\lambda_A = 21.283$ cm on the right side and $\lambda_B = 21.247$ cm on the left.

    (a) Find the radial velocity relative to us at points A and B.
    (b) Find the average velocity of the galaxy and the rotational velocity around its center. Which side is rotating towards us?
    (c) The radius of this galaxy 12.0 kpc. Find the mass of the galaxy within the region *AB* using this information.

23. An alien race in a distant galaxy has determined that they are currently at a distance $R = 9.70$ kpc from the center of their galaxy, and $z_0 = 85.0$ pc above the plane of their galaxy. They are orbiting the center at $V_0 = 247$ km/s. The local density of their plane is $\rho = 0.081\,M_\odot\text{pc}^{-3}$.
    (a) Find the frequency Ω for their motion around the center and their orbital period in Myr.
    (b) Find their frequency for vertical oscillations ν and the period for this motion in Myr.
    (c) The aliens find that their star currently has no vertical motion, $v_{z0} = 0$. We said in class that the formula for their vertical motion would be $z = z_0\sin(\nu t)$. Explain how this isn't exactly right and how to fix it.

PHY 310: You may skip this question or one on the previous page

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Brightness/Magnitude

$$F = 2.518\times10^{-8}\,\mathrm{W/m^2}\left(10^{-\frac{2}{5}m}\right)$$

Cepheid Period/Luminosity

$$M = -2.43\log(P) - 1.62$$

Galactic Orbits

$$\Omega = \frac{V_0}{R_0}$$

$$\nu = \sqrt{4\pi G\rho_0}$$

Distance/Magnitude

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

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

24. Three galaxies each are found to have a Cepheid variable start with a period of $P = 67$ days. The apparent magnitudes of each of these is measured, denoted m (CV).
    (a) What is the absolute magnitude of these Cepheid Variable stars?
    (b) What is the distance in kpc of each of these galaxies?
    (c) For the same three galaxies, the brightest red giant's magnitude is also measured. In each case, estimate the absolute magnitude of the brightest red giant.
    (d) Argue based on your previous computations that the brightest red giant is or is not a good standard candle.

Gal.	m (CV)	m (RG)	d (kpc)	M (RG)
A	16.97	18.93		
B	18.51	20.47		
C	22.68	24.63		