Solution Set

ASTRONOMY 5
Final Exam Spring 2001
(Edited for questions relevant to Astronomy 5 2007 Midterm)

Follow the directions in each section. Write all answers on this examination paper. Feel free to ask for clarification of any question. You may utilize the textbook, lecture notes, your notes, homework solutions, and any handouts that we have passed out. However, the exam must be written in your own words. Direct quotes from the texts or lecture notes will not be given credit.

Write neatly please. Keep answers short and to the point. Credit is given for the quality of ideas, not the number of words on the page.

The first two sections are graded in difficulty from easy to hard. If you are having trouble with the ends of these sections, skip them and go on to the rest of the exam.

TRUE-FALSE: Do all. One point each.

1. We know the Universe is not contracting because the light from galaxies is not blueshifted. — T

4. The HR diagram of a star cluster can be used to estimate its age. — T

7. Black holes are discovered at the centers of galaxies by observing very high velocities for stars orbiting close to the center. — T

15. Older stellar populations look bluer because massive red stars evolve quickly away. — F
⟶ Older stellar populations look redder because massive blue stars evolve quickly away.

18. Light paths when viewed from within curved space always appear straight. — F
They are curved. This can be thought of as a definition of "curved space."

21. A rough estimate of the age of the Universe can be gotten from the velocities of galaxies, assuming that their speeds of separation have remained roughly constant over time. — T
⟶ Using the Hubble constant: age ≈ $1/H_0$

23. Olber's Paradox is resolved by the fact that the Universe is finite in size. — T

24. Hubble's law is valid even if a universe expands at very different rates in different places. — F
Hubble's law assumes the Universe expands at the same rate everywhere.

25. A galaxy's location along the Hubble sequence reflects the importance of major mergers in its formation history. — T

MULTIPLE-CHOICE: Do all. Two points each.

26. Atomic spectral lines are produced because: C
    a) Atoms collide with other atoms.
    b) There are only a finite number of elements in the periodic table.
    c) Electrons in upper energy levels of atoms fall to lower energy levels, producing photons.
    d) There are an integral number of neutrons and protons in an atomic nucleus.
    e) Matter and anit-matter annihilate, producing photons.

30. What characteristic most determines how stars differ in luminosity? b
    a) Their composition.
    b) Their mass.
    c) The time they are formed.
    d) Where they are formed.
    e) Their color when they are formed.

31. The formula for Hubble's law is: b

$$v = H_0 r.$$

"radial velocity" means velocity along the line of sight.

Which of the following statements about Hubble's law is true?
    a) The symbol v is the total velocity of a galaxy, and the symbol r is its distance from us.
    b) The symbol v is the radial velocity of a galaxy, and the symbol r is its distance from us.
    c) The symbol v is the radial velocity of a galaxy, and the symbol r is its radius.
    d) The symbol v is the rotation velocity of a galaxy, and the symbol r is its radius.
    e) The symbol v is the velocity of a galaxy sideways to the line of sight, and the symbol r is its distance.

32. Which statement is true about the lifetimes of stars? a
    a) Little stars live longer because they don't burn energy very rapidly.
    b) Little stars live shorter because they have less fuel.
    c) Massive stars have more fuel, but they also burn it more rapidly, so they end up having the same lifetimes as little stars.
    d) Stars begin life at the top of the main sequence and evolve down it as they run out of fuel, become dimmer, and cool.
    e) Stars begin life as giants and contract to the main sequence just before they die.

33. By measuring the redshift of a galaxy we could NOT learn: d

a) Roughly how far away it is.
b) Roughly how long it took for the light to get from it to us.
c) How big the Universe was when the light left the galaxy compared to how big it is now.
d) How fast the galaxy is moving perpendicular to the line of sight.
e) How fast the galaxy is moving along the line of sight.

34. The disk of our Galaxy does NOT contain: c

a) Gas that is still forming young stars.
b) Material that fell into the Galaxy after the last major merger.
c) Stars that had formed before the last major merger. → major mergers disrupt the disks in galaxies
d) Objects that are moving in circular, co-planar orbits.
e) Other planetary systems.

36. The energy released in quasars comes from: e

a) Matter-antimatter annihilation near a black hole.
b) Black hole evaporation.
c) Nuclear reactions in an accretion disk around a black hole.
d) Energy emerging through a wormhole.
e) Heat generated via friction in an accretion disk around a black hole.

37. What is the strongest evidence that 90% of the mass of the Galaxy is in the form of dark matter? a

a) The orbital speeds of stars far from the Galactic center are surprisingly high, suggesting that these stars are feeling gravitational effects from unseen matter.
b) Although dark matter emits no visible light, it can be seen with radio telescopes, and such observations confirm that the halo of our Galaxy is full of this material.
c) Theoretical models of galaxy formation suggest that a galaxy cannot form unless it has at least 10 times as much matter as we see in the Milky Way, suggesting that the halo must be full of dark matter.
d) Our view of distant galaxies shows them to be full of obscuring, dark patches,
and we assume that our Galaxy must be full of similar dark patches also.

39. Our horizon is a surface that surrounds us on all sides. Which one of the following statements about it is NOT true? c

a) Our horizon encloses the part of the Universe that we can see.
b) Our horizon will encompass more matter in the future.
c) Our horizon surface is the same horizon surface seen by all observers in the Universe.
d) Our horizon is about 14 billion light-years in radius.
e) Our horizon has a lookback time equal to the age of the Universe.

40. Consider a distant galaxy one billion light years away. Its trajectory with respect to our Galaxy so far can best be described as: C

a) A circular orbit, with period equal to the age of the Universe.
b) An elliptical orbit, with period equal to the age of the Universe.
c) A straight line directed away from our Galaxy.
d) A straight line oriented sideways to the line joining our two galaxies.
e) A straight line directed towards our Galaxy.

SHORT DEFINITIONS: Do 5 out of 8. Four points each.

54. Schwarzschild radius

The Schwarzschild radius is the radius around a mass at which the escape velocity is the speed of light, which means that nothing inside this radius can escape — not even light! The Schwarzschild radius of a black hole is also called the "event horizon."

56. Hubble sequence — a galaxy classification system.

The Hubble sequence is: E-S0-Sa-Sb-Sc-Sd-Irr
"E" stands for elliptical galaxy. These have spheroidal shapes, scrambled stellar orbits, no gas, and no young stars. "Sa, Sb, Sc, Sd" are spiral galaxies with flattened rotating disks, spiral arms, gas, and young stars. The letters a–d go from the least gas and young stars to the most gas and young stars. "Irr" are irregular galaxies, which have the most gas and young stars, but no orderly disks

QUANTITATIVE QUESTIONS: Do all of these. Point totals vary and are marked at the end of each problem. Put answer in the blank. If you show your work, you are more likely to be given partial credit even if the answer is wrong. .

59. The formula for the Schwarzschild radius of a black hole is: _____

$$R_{Schwarz} = 2GM/c^2.$$

The Earth has a mass of about 10^{28} g and a Schwarzschild radius of about 1 cm. A massive star might have a mass as large as 10^{35} g. What is the Schwarzschild radius of such a star, in cm? Hint: get the factor that is the mass ratio, decide

whether the star's value is smaller or larger than the Earth's, and multiply the Earth's value appropriately. (5 points)

$$\frac{R_{sch,\,star}}{R_{sch,\,Earth}} = \frac{\frac{2G M_{star}}{c^2}}{\frac{2G M_{Earth}}{c^2}} \Rightarrow \frac{R_{sch,\,star}}{R_{sch,\,Earth}} = \frac{M_{star}}{M_{Earth}}$$

$$R_{sch,\,star} = \frac{M_{star}}{M_{Earth}} \times R_{sch,\,Earth} = \frac{10^{35}\ g}{10^{28}\ g} \times 1\ cm = 10^7 \times 1\ cm$$

$$\boxed{R_{sch,\,star} = 10^7\ cm = 100\ km}$$

61. The formula for the Hubble law is:

$$v = H_0\, r,$$

where the value of H_0 is 70 km/s/Mpc or 21 km/s/million light years. A distant galaxy has a radial velocity of 4200 km/s. How long does it take light to travel from it to us? Hint: Think about which value of the Hubble constant is better to use. (7 points)

question: light travel time ⟶ use units of lightyears!

$v_{galaxy} = 4200$ km/s, $H_0 = 21$ km/s/million ly

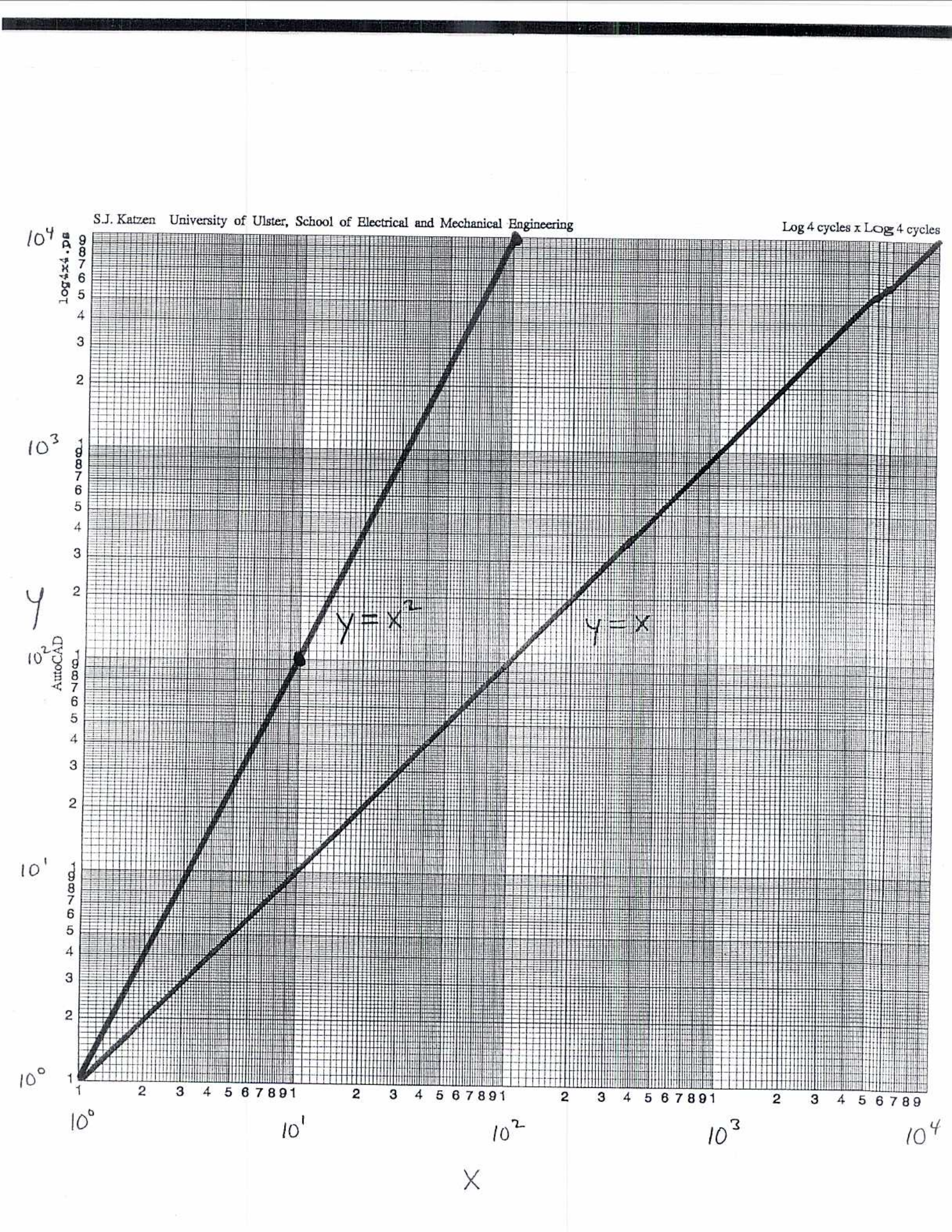
Hubble law: $v_{galaxy} = H_0\, r_{galaxy} \Rightarrow r_{galaxy} = \frac{v_{galaxy}}{H_0}$

$$r_{galaxy} = \frac{4200\ km/s}{\frac{21\ km/s}{million\ ly}} = \frac{4200\ km/s}{21\ km/s} \times (million\ ly) = 200\ million\ ly$$

distance to galaxy = 200 million ly, so it takes light

200 million years to travel from it to us.

62. The graph below uses logarithmic axes to plot the relationship $y = x$. On the same axes, plot the relationship $y = x^2$. (6 points)


S.J. Katzen University of Ulster, School of Electrical and Mechanical Engineering
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log4x4.ps
AutoCAD
$y = x^2$
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10^4
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