Astronomy 3020: Cosmology
Samples for Exam 4

Chapter 6

1. The Copernican Principle is
   a) There is nothing special or unique about Earth.
   b) Earth is at the center of the universe.
   c) The Sun is at the center of the universe.
   d) The universe is infinite and has no center.

2. The weak anthropic principle states
   a) The conditions in the universe exists because we are here.
   b) The conditions in the universe are compatible with our existence.
   c) The conditions in the universe are incompatible with our existence.

3. The strong anthropic principle states
   a) The conditions in the universe exists because we are here.
   b) The conditions in the universe are compatible with our existence.
   c) The conditions in the universe are incompatible with our existence.

4. Something is isotropic if it is
   a) the same everywhere.
   b) not the same everywhere.
   c) the same in all directions.
   d) not the same in all directions.

5. Something is homogeneous if it is
   a) the same everywhere.
   b) not the same everywhere.
   c) the same in all directions.
   d) not the same in all directions.

6. If you could be instantaneously transported 13 billion lightyears away from Earth, you would see
   a) the same kinds of stars and galaxies you see here, just different patterns.
   b) the region around you filled with glowing hot gas from the Big Bang.
   c) nothing if you looked in the direction opposite the Earth since you would be at the edge of the universe.
   d) stars and galaxies unlike any we see around Earth.

7. An inertial frame of reference is one in which a particle will undergo
   a) straight line uniform motion when a net force is applied to it.
   b) straight line accelerated motion when no force is applied to it.
   c) straight line uniform motion when there is no net force acting on it.
   d) curved motion when a net force acts on it.

8. The cosmological principle states that the universe
   a) is isotropic and homogeneous and the laws of physics are the same everywhere.
   b) Is isotropic but not homogeneous because the laws of physics are not the same everywhere.
   c) is homogeneous but not isotropic because the plane of the Milky Way defines a preferred direction.
   d) is isotropic and homogeneous in space but not in time since the laws of physics have evolved in time.

9. Which of the following is a manifestation of the surface of the Earth being a non-inertial reference frame?
   a) The Coriolis Effect
   b) The Doppler Effect
   c) The Butterfly Effect
   d) The Crystal Effect.

10. Which of the following is **not** an inertial reference frame?
    a) A spacecraft moving at constant speed in deep space.
    b) A rock undergoing freefall near the surface of a non-rotating planet.
    c) A person standing still on the surface of the Earth.

11. Which of the following quantities requires a Galilean transformation from one inertial reference frame to another?
    a) The velocity of an object
    b) The mass of an object
    c) The acceleration of an object
    d) The force acting on an object

12. The Michelson-Morley experiment
    a) proved that the luminiferous ether exists.
    b) proved that the speed of light was the same in all directions.
    c) proved that light behaved differently than mechanical objects.
    d) proved that the Earth was a preferred reference frame.

13. Which of the following papers was **not** published by Albert Einstein in 1905?
    a) A paper on Brownian motion
    b) A paper on the photoelectric effect
    c) A paper on the electrodynamics of moving bodies
    d) The General Theory of Relativity.

Chapter 7

1. One of the basic principles of Einstein's Special Relativity is
   a) The speed of light depends on the relative speed between the source and the observer.
   b) It is always possible determine who is moving and who is stationary.
   c) The observed laws of physics are the same regardless of any constant velocity at which you move.
   d) It is possible to move at speeds greater than the speed of light.
   e) All of the above.

2. If an observer is stationary on the surface of the Earth and watches a spacecraft moving past at $^{9}/_{10}$ the speed of light he sees
   a) the stationary observer sees the moving clock as running fast.
   b) the stationary observer sees the moving clock as running the same speed as his clock.
   c) the stationary observer sees the moving clock as running slow.

3. Others had proposed a Lorentz transformation to solve the problem of the speed of light before Einstein. Most scientists were reluctant to accept this because it
   a) seemed too arbitrary and there was no physical explanation for it.
   b) violated Newtonian absolute space and time.
   c) only applied to electromagnetic systems and not mechanical systems.
   d) did not give the same answer as ordinary Galilean transformations when the relative speed was small as compared to the speed of light.
   e) None of the above, the Lorentz transformation was widely accepted even before Einstein published his special theory of relativity.

4. An observer on a moving train sees two flashes of lightning strike the front and rear of his train car simultaneously. An observer on a platform watching the train move past sees
   a) the two flashes of lightning strike the ends of the train simultaneously.
   b) one flash striking the rear of the train first then a second flash strike the front of the train later.
   c) one flash strike the front of the train first and then a second flash strike the rear of the train later.

5. In Special Relativity, if I see your clock as running slow, you will see
   a) your clock as running slower than my clock.
   b) my clock as running slower than your clock.
   c) your clock as running faster than my clock.
   d) both our clock as running at the same speed.

6. Proper time is the time
   a) measured by a clock that is stationary with respect to inertial observer.
   b) that is measured by a clock that is stationary with respect to the luminiferous ether.
   c) measured by a clock that is moving at the speed of light with respect to the observer.
   d) that is measured by any clock that is moving are an arbitrary speed with respect to the observer.

7. If the spacetime interval between two events in spacetime is an imaginary number, they are said to have a
   a) a time-like separation.
   b) imaginary separation.
   c) space-like separation.
   d) no separation.

8. In the twin paradox where one twin takes a voyage to Alpha Centauri at close to the speed of light while the other stays at home, the twin that takes the voyage is the younger at the end because
   a) She observed her stay-at-home brother's clock to be running fast during the entire time of her trip
   b) He observed his travelling sister's clock to be running very slow as she was acceleration away from Earth, turning around at Alpha Centauri and slowing down as she approached Earth but running slightly fast for the rest of her trip.
   c) She observed her stay-at-home brother's clock to be running fast as she accelerated away from Earth, slowing down approaching Alpha Centauri, accelerated away from Alpha Centauri and slowing down approaching Earth but running slow for the rest of her trip.
   d) None of the above, they are both younger and that is the paradox.

9. An observer on the Earth sees a spaceship moving east at 0.8c and another moving west at 0.9c. If a passenger on the spaceship moving west shines a laser at the spaceship moving east, which of the following is **not** possible?
   a) A passenger on the spaceship moving east measures the speed of the laser to be exactly $2.998\times10^8\ ^m/_s$.
   b) The observer on the Earth measures the speed of the laser to be exactly $2.998\times10^8\ ^m/_s$.
   c) A passenger on the spaceship moving west observes clocks aboard the spaceship moving east to be running fast.
   d) The observer on the Earth observes clocks on both spaceships to be running slow but at different rates.

Chapter 8

1. General Relativity is
   a) a theory of the relative brightness of stars.
   b) a theory on the relative distance to various galaxies.
   c) a theory that explains gravity.
   d) a theory that explains how things change as relative velocities approach the speed of light.

2. The basic postulate of general relativity is
   a) it is impossible to determine absolute velocity, only relative velocity.
   b) gravity and acceleration are indistinguishable.
   c) the speed of light is the same for all observers, regardless of any relative velocity between the source and the observer.
   d) objects with mass distort spacetime.

3. Which of the following was ***not*** something that called for a new theory of gravity?
   a) Newton's form of gravity used an inverse square of distance in the force law.
   b) Newton's gravity did not give a propagation speed.
   c) The perihelion of the orbit of Mercury precessed by an amount that could not be explained by Newtonian gravity.
   d) The orbit of the Sun around the center of the Milky Way could not be explained by Newtonian gravity.

4. Objects in freefall are
   a) not in an inertial reference frame.
   b) are in an inertial reference frame.
   c) may or may not be in an inertial reference frame depending on whether you are inside the freely falling frame or viewing it from outside.

5. An inertial reference frame is one in which
   a) objects move according to Newton's 1^{st} Law.
   b) objects move according to Newton's 2^{nd} Law.
   c) objects are fixed in place and do not move.

6. Which of the following is ***not*** a consequence of general relativity?
   a) The path of light can be bent by gravity from a massive object.
   b) Orbits are the motion of objects following the curvature of spacetime.
   c) The wavelength of light coming from a massive object is blueshifted by gravity.
   d) A clock deep in a gravity well will run slower than one higher up.

7. Which of the following is not a geometry used in general relativity?
   a) Spherical
   b) Cubical
   c) Hyperbolic
   d) Euclidian

8. In spherical geometry
   a) the sum of the angles around a triangle is always 180°
   b) the shortest distance between two points is a straight line.
   c) parallel lines converge.
   d) The circumference of a circle is always $2\pi r$.

9. The metric is
   a) the shortest distance between two points.
   b) the shortest distance between two points.
   c) the shortest spacetime interval between two events.

10. The geometry Einstein used for general relativity is
    a) Riemannian geometry.
    b) Euclidian geometry.
    c) Hyperbolic geometry.
    d) Minkowskian geometry.

11. Tidal forces are the result of
    a) the strength of the gravitational force acting on an object.
    b) the curvature of spacetime.
    c) flat spacetime.
    d) spherical spacetime.

12. Which of the following has ***not*** been a verification of general relativity?
    a) The explanation of the anomalous precession of the perihelion of Mercury.
    b) The deflection of light by the Sun measured by Arthur Eddington during the 1919 total eclipse.
    c) The observation of gravity lenses by galaxy clusters like Abell 2218.
    d) The observed time dilation of objects moving at close to the speed of light.

13. The LIGO observatory observes
    a) gravity waves.
    b) the gravitational distortion of spacetime by the Sun.
    c) x-rays and gamma rays coming from quasars.
    d) Nothing, it has never succeeded in detecting anything.

Chapter 9

1. The first person to solve the equations of general relativity for a massive object was
   a) Karl Schwarzschild.
   b) Roy Kerr.
   c) Albert Einstein.
   d) Albert Michelson.

2. A Schwarzschild black hole is a
    a) rotating charged black hole.
    b) non-rotating charged black hole.
    c) non-rotating uncharged black hole.
    d) rotating uncharged black hole.

3. The Schwarzschild metric describes spacetime
    a) only near the event horizon of a black hole.
    b) only inside the event horizon of a black hole.
    c) inside, outside and near the event horizon of a black hole.
    d) at the event horizon of a black hole.

4. The escape velocity from the event horizon of a black hole is
    a) the speed of light.
    b) greater than the speed of light.
    c) less than the speed of light.

5. The Schwarzschild radius of a black hole is
    a) the radius measured from the singularity to the event horizon.
    b) the radius measured by determining the diameter through the black hole from one side of the event horizon to the other and dividing by two.
    c) the reduced circumference of the event horizon.

6. An observer on a probe falling toward a black hole
    a) would be smashed by a physical barrier at the event horizon.
    b) would pass through the event horizon without any noticeable barrier.
    c) would gradually come to a stop at the event horizon.
    d) would never reach the event horizon.

7. According to the Schwarzschild metric, inside the event horizon
    a) the sign of the coefficient of the spatial term and temporal term reverse.
    b) the temporal term becomes infinite and the spatial term goes to zero.
    c) the sign of the coefficient of the spatial term and temporal term remain the same.
    d) the spatial term goes to infinity and the temporal term goes to zero.

8. Which of the following statements is ***<u>false</u>***?
    a) It is possible for photons to orbit a black hole outside the event horizon.
    b) No physical object can orbit a black hole closer than three times the Schwarzschild radius.
    c) Objects at the event horizon can orbit the black hole without falling in.
    d) The event horizon of a black hole is the point of no return. Anything inside it is doomed to fall to the singularity.

9. A Kerr black hole is
   a) rotating charged black hole.
   b) non-rotating charged black hole.
   c) non-rotating uncharged black hole.
   d) rotating uncharged black hole.

10. The first solution for a rotating black hole was published in
    a) 1916.
    b) 1963.
    c) 1928.
    d) 2001.

11. Spacetime near a rotating black hole
    a) is static.
    b) rotates around in the same direction the black hole rotates.
    c) rotates around in the direction opposite the rotation of the black hole.
    d) spirals in toward the event horizon but does not move.

12. Hawking radiation is the result of
    a) particles escaping from within the event horizon of a black hole.
    b) radiation escaping from within the event horizon of a black hole.
    c) virtual particles being created very near but outside the event horizon of a black hole and one of them falling in while the other escapes.

13. All black holes in the universe today are
    a) Schwarzschild black holes.
    b) Kerr black holes.
    c) charged black holes.
    d) None of the above, black holes are theoretical and do not exist in reality.

14. Which of the following is ***not*** observational evidence of the existence of black holes in the universe today?
    a) The image of the M87 supermassive black hole taken by the Event Horizon Telescope.
    b) Orbital observations of stars near Sag A*.
    c) X-ray observations of Cygnus X-1.
    d) Observations of quasars.
    e) All the above are observational evidence for the existence of black holes.

Chapter 10

1. The Great Debate of 1920 was about
   a) the size and shape of the Milky Way.
   b) the distance to the nearest stars.
   c) the size of the universe and the nature of the spiral nebulae.
   d) the energy source of the stars.

2. The Doppler effect is
   a) the change in observed wavelength of a wave when the source is moving with respect to the observer.
   b) the change in the observed intensity of a wave when the source is moving with respect to the observer.
   c) the change in the observed speed of light when the source is moving with respect to the observer.
   d) the change in the observed position of a star due to the relative motion of the earth around the sun.

3. The relativistic Doppler Effect is
   a) the same as the classical Doppler Effect.
   b) affects the observed wavelength even if the motion is perpendicular to the line-of-sight.
   c) always gives a z less than 1.
   d) always gives a z greater than 1.

4. The person most responsible for the first accurate determination of the size of the Milky Way was
   a) Edwin Hubble.
   b) Harlow Shapley.
   c) William Herschel.
   d) Albert Einstein.

5. The cosmic distance ladder is
   a) different methods of measuring the distance to celestial objects that are all at the same distance away from Earth.
   b) different methods of measuring the distance to celestial objects that range from close to extremely distant with no overlapping so objects can only be measured with one method.
   c) different methods of measuring the distance to celestial objects with the methods overlapping allowing some objects to be measured with multiple methods.

6. Stellar parallax
   a) can be accurately measured for stars less that 300 light-years away.
   b) does not exist because the earth does not move in the heavens.
   c) increases with the distance to the star.
   d) is too small to measure even with the largest telescopes and the closest stars.

7. The parsec is defined as
   a) the distance at which a star shows a parallax of one arcsecond.
   b) the average distance between the earth and the sun.
   c) the distance to the nearest star.
   d) the distance light travels in one year.

8. Cepheid variable stars make good “standard candles” because
   a) they are main sequence stars so they are very luminous and can be seen from far away.
   b) their period of pulsation is related to their average luminosity.
   c) their period of pulsation is constant regardless of their distance from Earth.
   d) they are constantly changing their period in a way that is directly related to their size.

9. Type Ia supernovae make good “standard candles” because
   a) they always occur for the same size red supergiant so the explosion always reaches the same maximum luminosity.
   b) they always occur for a white dwarf that exceeds the Chandrasekhar limit so the explosion always reaches the same peak luminosity.
   c) they always occur when two neutron stars merge so the explosion always reaches the same maximum luminosity.

10. The first galaxy that Edwin Hubble determined the distance to was
   a) the Whirlpool galaxy, M51.
   b) the Andromeda galaxy, M31.
   c) the Pinwheel galaxy, M101
   d) The Large Magellanic Cloud.

11. A Hubble Diagram is a plot of
   a) luminosity versus distance for galaxies
   b) recessional velocity versus distance for galaxies.
   c) mass versus luminosity for galaxies.

12. Einstein’s greatest blunder was
   a) his prediction that the universe is expanding almost a decade before Hubble discovered it.
   b) his assigning a value to the cosmological constant in his equations of general relativity that would keep the universe static.
   c) his mistake in using Minkowskian geometry instead of Riemannian geometry on his first attempt at general relativity.
   d) his inability to resolve the conflict between general relativity and quantum mechanics.

13. The Robertson-Walker metric is
   a) a metric that describes spacetime for the universe that includes a curvature constant.
   b) a metric that describes the curvature of the universe as flat.
   c) a metric that describes the curvature of spacetime around a charged rotating black hole.
   d) a metric for a flat, non-expanding universe.

14. The Hubble time is
    a) the age of the universe regardless of any change in the expansion rate.
    b) the age of the universe for an expansion rate that is exponentially increasing.
    c) the age of the universe for an expansion rate that is decreasing.
    d) the age of the universe for an expansion rate that is constant.

15. The de Sitter model of the universe is for
    a) an empty universe with only a cosmological constant, no matter or energy.
    b) a universe with a uniform distribution of matter and no cosmological constant but no energy.
    c) a universe with a uniform distribution of energy and a cosmological constant but no matter.
    d) a universe with a uniform distribution of matter and energy and a cosmological constant.

Chapter 11

1. In the simplest model of the universe that contains matter but no cosmological constant, if E_∞ is less than zero the universe will
    a) expand forever, decreasing to zero expansion at infinite time.
    b) expand forever, never slowing to zero even at infinite time.
    c) collapse in a Big Crunch.

2. All the "Standard Models"
    a) include a non-zero cosmological constant.
    b) do not include a cosmological constant.
    c) expand forever at an accelerating rate.
    d) collapse after a long period of expansion.

3. The Hubble constant is
    a) always the same.
    b) increasing or decreasing depending on how the expansion rate is changing.
    c) always increasing.
    d) always decreasing.

4. In the standard models, the curvature constant of the Robertson-Walker metric depends on
    a) the mass density and the Hubble constant now.
    b) the cosmological constant and the Hubble constant.
    c) the density of dark matter.
    d) the density of dark energy.

5. The critical density is defined as
    a) the total density required to make the universe hyperbolic.
    b) the total density required to make the universe spherical.
    c) the total density required to make the universe flat.

6. A universe obeying a standard model with hyperbolic geometry will
   a) expand forever, decreasing to zero expansion at infinite time.
   b) expand forever, never slowing to zero even at infinite time.
   c) collapse in a Big Crunch.

7. A universe with a positive cosmological constant will
   a) expand forever with a decreasing but always positive rate of expansion regardless of geometry.
   b) expand forever with an increasing rate of expansion, regardless of geometry.
   c) expand for a while with a slowing expansion rate then collapse regardless of geometry.
   d) remain static forever with no expansion.

8. The Lemaître model has
   a) a negative cosmological constant and a flat geometry.
   b) a positive cosmological constant and a flat geometry.
   c) a positive cosmological constant and a spherical geometry.
   d) no cosmological constant and a flat geometry.

9. The best observational evidence suggests that the universe is
   a) flat with a positive cosmological constant.
   b) spherical with a positive cosmological constant.
   c) flat with a negative cosmological constant.
   d) flat with no cosmological constant.

10. The best observational evidence suggests that the universe consists of
   a) 73% matter, both dark and luminous, and 27% dark energy.
   b) 73% dark energy and 27% matter, both dark and luminous.
   c) 73% dark matter and 27% luminous matter.
   d) 73% dark energy and 27% luminous matter.

Chapter 12

1. The individuals most responsible for the discovery of the cosmic background radiation were
   a) Edwin Hubble and Vesto Slipher
   b) Albert Einstein and Willem de Sitter.
   c) Arno Penzias and Robert Wilson
   d) James Peebles and David Wilkerson.

2. The cosmic background radiation is mostly
   a) radio wave and microwave.
   b) microwave and infrared.
   c) visible and infrared.
   d) ultraviolet and visible.

3. Early theories for the origin of the elements proposed
   a) only protons were created in the Big Bang and all other elements were produced by fusion in stars.
   b) only neutrons were created in the Big Bang and they decayed into protons which then fused into the heavier elements before stars formed.
   c) super massive nuclei formed in the Big Bang and they underwent fission to form all the lighter elements.

4. The “stability gap is
   a) the low amount of elements heavier than Xenon in the universe.
   b) the instability of the carbon nucleus.
   c) the instability of the beryllium nucleus.
   d) the instability of the helium-3 nucleus.

5. The modern theory of nucleosynthesis predicts
   a) only hydrogen and helium formed within the first few minutes of the universe and all other elements formed by fusion in stars and supernovae.
   b) hydrogen, helium and elements up to carbon formed in the first few minutes of the universe and all other elements form by fusion in stars and supernovae.
   c) only hydrogen was formed in the first few minutes of the universe and all other elements form by fusion in stars and supernovae.

6. For the first few thousand years, the universe was dominated by
   a) matter, both dark and luminous.
   b) energy but not dark energy.
   c) matter but only luminous matter.
   d) dark energy.

7. In an energy dominated universe, the expansion rate goes as
   a) the square of time.
   b) the square root of time.
   c) linearly with time.
   d) exponentially with time.

8. The matter in the universe came from
   a) particle-antiparticle pair production.
   b) particle only baryon number violating processes.
   c) particle only baryon number conserving processes.
   d) anti-particle baryon number violating processes.

9. The earliest epoch of the universe is known as the
   a) Quark Epoch.
   b) Unified Epoch.
   c) Planck Epoch.
   d) Hadron Epoch.

10. During the period of inflation the universe
    a) expanded at an extremely high but subluminal rate.
    b) expanded at a rate of as much as 10^{26} times the speed of light.
    c) expanded at a rate of around the speed of light.
    d) contracted rapidly from the size of the Milky Way to the size of a pea.

11. Spontaneous symmetry breaking is
    a) events that change the density of matter or energy without changing its character.
    b) events similar to phase changes where the character of matter or energy are changed.
    c) events where the matter is converted into energy or energy into matter.
    d) events that result in the creation of matter or energy from nothing.

The four essay questions you will see on Exam 4 will be drawn from the 14 questions listed here.

Essay Questions

1. Describe the Michelson-Morley experiment. What did they attempt to measure and how did they measure it? What were their results? What was the significance of their results?
2. Briefly discuss Einstein's Special Theory of Relativity. What are the basic assumptions of the theory? What are some of the consequences of the theory on objects that are moving at speeds close to the speed of light?
3. Briefly discuss Einstein's General Theory of Relativity. What is the difference between General Relativity and Special Relativity? What is the basic principle of General Relativity? What are some of the consequences of General Relativity?
4. Discuss why it is necessary to use geometry to describe general relativity. What is meant by the "metric" and what is the general metric for space-time? What is a geodesic and why is it important? What types of geometries are important for general relativity and what property do they have in common?
5. Describe a rotating black hole. What three quantities completely describe such a black hole? Give the metric for a Kerr black hole. Describe the photon spheres, the ergosphere, the event horizons and the singularity of a Kerr black hole. Describe the effect on space-time as each event is crossed.
6. Describe how a black hole can evaporate. What is Hawking Radiation and how is it related to the evaporation of a black hole? How long would it take a ten trillion kilogram (10^{10} kg) black hole to evaporate? How long would it take for a 5 solar
7. What is the cosmological constant, who first proposed it and how does it influence the evolution of the universe? What is the current best estimate for the ratio of its density factor to the critical density?
8. Describe the cosmic distance ladder. What are several of the "rungs" of the distance ladder (explain how they work)? Why is it necessary for multiple rungs?
9. What is cosmological redshift? How is it different from normal Doppler redshift? How is it different from gravitational redshift? What is the cause of cosmological redshift? Is it possible to have a cosmological redshift greater than 1? How?

10. Describe the Einstein-de Sitter model. What are the values of k, q, Ω and Λ? What is the eventual fate of an Einstein-de Sitter universe? How does the scale factor R change in an Einstein-de Sitter universe?
11. Describe the Lemaître model. What are the values of k, q, Ω and Λ? What is the eventual fate of a Lemaître universe? How does the scale factor R change in a Lemaître universe?
12. Describe how and when most of the helium in the universe was made. Why wasn't it made earlier or later? What other elements or isotopes were made at the same time? How were all the other elements made?
13. Discuss the way in which energy and temperature changed during the earliest times when the universe was radiation dominated. How were they related to the scale factor R? How did the scale factor R change during this time? In the Friedmann equation, what term dominates during this time?
14. Describe the conditions in the universe during the Unified Epoch. What was the time scale for this epoch? What forces dominated during this epoch? What significant events occurred during this epoch?