Astronomy 25 Frontiers in Astronomy **Exam Test Bank #2**

9: PARTICLE PHYSICS AND COSMIC FORCES

9.01. Which of the following is a boson?
A) proton
B) photon
C) electron
D) quark
E) positron

9.02. Which force is mediated by photons?
A) weak
B) electromagnetism
C) color
D) gravity
E) strong

9.03. The color force is transmitted by what particle?
A) photons
B) gravitons
C) gluons
D) Z, W^+, W^- bosons
E) neutrinos

9.04. The carrier of the weak atomic force is the
A) photon
B) neutrinos
C) graviton
D) Higgs particle
E) W and Z particle

9.05. The carrier of the gravitational force is the
A) photon
B) W and Z particle
C) graviton
D) Higgs particle
E) neutrinos

9.06. The Heisenberg Uncertainty Principle tells us that there is a limit to how well you can simultaneously know a particle's position and its
A) momentum
B) energy
C) time interval for an interaction
D) charge
E) mass

9.07. The Heisenberg Uncertainty Principle, written in terms of $\Delta E \Delta t$, tells us that over very short time intervals, a particle can fluctuate in terms of its
A) momentum
B) energy
C) position
D) charge
E) size

9.08. The Standard Model of particle physics says that there are
A) three main families of particles; most of the matter we interact with is from Family 1
B) 14 types of quarks, including color forms with parity and nonparity.
C) massive photons with momenta exceeding critical values
D) tiny but potent strings at the core of every particle
E) enormous amounts of dark matter and dark energy in the Universe

9.09. Up, down, strange, charm, top, bottom are all
A) leptons
B) quarks
C) names of dwarves that hang with Snow White
D) bosons
E) types of photons

9.10. How many kinds of quarks are there? (Include antiquarks in your count!)
A) 1
B) 3
C) 6
D) 12
E) 17

9.11. The LHC is
A) a baryonic particle predicted by the Standard Model
B) a small irregular galaxy orbiting around the Milky Way galaxy
C) a consequence of symmetry-breaking in the GUTs era
D) the theory that all matter can be described as waves
E) the name of a huge accelerator in Switzerland and France

9.12. One consequence of the Higgs field is that particles that resist it
A) become bosons
B) have mass
C) are tachyonic
D) emit high energy photons
E) generate electrical charges

9.13. What characterizes a lepton?
A) they all are positively charged
B) they are a class of mostly low mass particles
C) they are all negatively charged
D) they are all high mass particles
E) they are all made out of antimatter

9.14. What characterizes a baryon?
A) they all are positively charged
B) they are all negatively charged
C) they are all low mass particles
D) they are a class of high mass particles
E) they are all made out of antimatter

9.15. Virtual particles (and virtual photons) are ones which
A) are produced by neutron stars
B) have wavelengths in accordance with de Broglie's equation
C) are both alive and dead, in the box, in accordance with the Schrödinger wave equation
D) orbit the atoms in quantized orbits, in accordance with Bohr's postulates
E) wink in and out of existence, in accordance with Heisenberg's Uncertainty Principle

9.16. In Quantum Chromodynamics, what is NOT true about color
A) different quarks literally have different colors—if you looked at a green quark it would look green!
B) color is a quantity that we use to track how quarks interact with each other
C) colored quarks always combine so that the resulting particle has no net color
D) in addition to the three colors, there are three anti-colors
E) red+blue+green= no color

9.17. The Standard Model of particle physics predicted the existence of Higgs Boson…
A) but despite long searches, it has not yet been found
B) and it was (almost certainly) detected in 2012 by the LHC
C) but while it should be detectable, we have never funded a program to look for it
D) but to detect it would require a device completely beyond human technology
E) and it was detected by Anderson in 1932

10: THE BIG BANG

10.01. Olber's Paradox notes that in an infinitely large and old universe,
A) the sky, even at night, should be infinitely bright
B) the universe is expanding, despite what you might think
C) light travelling through space become tired, hence redshifted
D) the universe should be equal parts matter and antimatter
E) the amount of dark energy cannot bring the universe to critical density

10.02. If the scale of the Universe increased by a factor of 5, the matter density and the energy density would
A) decrease by a factor of 125 and 625, respectively
B) increase by a factor of 125 and 625, respectively
C) decrease by a factor of 625 and 125, respectively
D) increase by a factor of 625 and 125, respectively
E) stay the same

10.03 As the Universe aged, from an early state to its current state,
A) it changed from matter dominated to energy dominated
B) it changed from energy dominated to matter dominated
C) the energy and matter densities did not change
D) the energy and matter densities both increased
E) the energy and matter densities both decreased, but the matter density decreased more rapidly

10.04 Nucleosynthesis in the standard Big Bang theory predicts
A) the existence of the cosmic background radiation
B) the relative amounts of hydrogen, helium, and other elements
C) the total mass of the universe
D) both dark mass and dark energy
E) the age of the Universe

10.05 The steady state hypothesis lost to the Big Bang with the discovery of
A) dark energy
B) dark matter
C) inflation
D) cosmic microwave background
E) neutrinos

10.06 What does the Big Bang theory say about before t=0, and why the Universe came into being?

A) It says that a supernatural force (such as a god) was involved
B) It says that a supernatural force (such as a god) was not involved
C) It says that the giant rainbow serpent came from under the Earth, and brought life to the cosmos
D) It says that Xenu brought Thetans to planet Earth, and dropped them into volcanoes, where their spirits still reside
E) The theory does not (yet) address times at, or before, the moment of creation

10.07 Times earlier than 10^{-43} sec correspond to

A) the Planck era
B) the GUT era
C) the electroweak era
D) the particle era
E) the era of nucleosynthesis

10.08 In the GUT era, the TOE force froze out into the GUT force and

A) weak force
B) gravity
C) color force
D) electromagnetic force
E) strong force

10.09 At the beginning of the electroweak era, the GUT force froze out into the Electroweak force and

A) gravity
B) weak force
C) centrifugal force
D) electromagnetic force
E) strong force

10.10 The Big Bang predictions of the abundances of elements, hinged upon the ultimate fate of what particles in the nucleosynthesis era?

A) protons
B) neutrons
C) electrons
D) photons
E) neutrinos

10.11 When matter and energy stopped being so intimately connected during the era of nuclei, space became clear—this is called
A) decoupling
B) cosmic clearing
C) cosmic inflation
D) symmetry breaking
E) the flatness problem

10.12 The roar of the Big Bang is all around us in the form of
A) the cosmic background radiation
B) the antimatter asymmetry
C) dark energy
D) both dark matter and dark energy
E) neutrinos

10.13 Quarks, and then other particles such as protons and neutrons, first became stable during
A) the Planck era
B) the GUT era
C) the electroweak era
D) the particle era
E) the era of nucleosynthesis

10.14 Astronomy 25 was taught at Sierra College during
A) the Planck era
B) the era of atoms
C) the era of galaxies
D) the particle era
E) the era of nucleosynthesis

10.15 The Big Bang Theory predicts a few things with extraordinary accuracy. Which is NOT one of them?
A) the presence of a cosmic microwave background
B) the overall composition of the Universe (mostly H and some He)
C) the presence of dark matter
D) the power of the cosmic microwave radiation, as a function of wavelength
E) Trick question! All the above are predicted by the Big Bang Theory

11: INFLATION

11.01 One way of explaining or describing inflation is that
- A) an as-yet undiscovered particle (called an inflaton) expanded the Universe by its inflation field
- B) dark energy, created during the dark energy era, inflated the Universe
- C) dark matter, converting into dark energy, released the energy needed to inflate the Universe
- D) matter released by matter-antimatter recombinations inflated the Universe
- E) the neutrino emissions drove the Universe to rapid expansion

11.02 One explanation for inflation is that
- A) two branes in the bulk intersected, releasing the energy necessary for inflation
- B) quantum fluctuations allowed for the spontaneous expansion of the Universe
- C) dark matter, converting into dark energy, released the energy needed to inflate the Universe
- D) energy released from the Higgs boson inflated the Universe
- E) the freezing out of the strong and electroweak forces released the energy that inflated the Universe

11.03 During the inflationary era, objects moved away from each other faster than the speed of light. This is resolved because
- A) the speed of light was not a limit until after the electroweak era
- B) the speed of light limit does not apply to inflatons
- C) objects were pure energy, and therefore not subject to such limitations
- D) the space is what was expanding; the objects were stationary within the expanding space
- E) inflation turned out to be wrong

11.04 Inflation is different from the expansion of the Universe (“the Hubble Flow”) because
- A) inflation happened only once, for a short amount of time
- B) the Universe’s expansion happened only once, for a short amount of time
- C) inflation is a much, much slower kind of expansion than the Hubble Flow
- D) the Hubble Flow was possibly driven by a freezing out of the strong and electroweak forces
- E) inflation was originally predicted by Einstein’s equations

11.05 During the inflationary phase, the Universe
- A) increased its size by a factor of about 10 to 100, in a period of about 300 sec
- B) increased its size by a factor of about 10^{26} to 10^{30}, in a period of less than 10^{-32} sec
- C) quickly collapsed and then equally quickly rebounded
- D) slowly collapsed and then equally slowly rebounded
- E) finally started to expand, slowly at first, but then at the rate we see in the Universe today

11.06 The smoothness problem in the standard big bang theory is that
A) the night sky is smoothly and uniformly black
B) the density in the observed Universe is very close to the critical density
C) the theory predicts the Universe should have gigantic, dense clumps which are not seen
D) the theory predicts the Universe should be far smoother than we observe
E) the calculations in the big bang theory are difficult (bumpy), and not easy (smooth)

11.07 The Horizon Problem, the fact that parts of our Universe that were never before in contact have identical conditions, has been reconciled by
A) inflation
B) the Planck era in the Big Bang
C) dark matter
D) decoupling
E) special relativity

11.08 The Flatness Problem, the fact that the geometry of space in our Universe is remarkably close to flat, has been resolved by
A) the Planck era in the Big Bang
B) dark matter
C) inflation
D) decoupling
E) special relativity

11.09 The sizes of the blobs in the cosmic microwave background are predicted by
A) general relativity
B) inflation
C) dark matter
D) dark energy
E) special relativity

11.10 Microsopic quantum fluctuations in the energy and matter in the GUT era were inflated, so that they would later result in the formation of what kind of massive structure
A) entire planets
B) protostellar clouds, which then became entire stars
C) protostellar clouds, which then became enormous star clusters
D) spiral arms
E) protogalactic clouds, which then became galaxies

11.11 Inflation predicted that the density of the Universe should be equal to the critical density. While it was found to be only 30% critical, inflation was saved by the discovery of
A) the cosmic background radiation
B) the antimatter asymmetry
C) dark matter
D) the Higgs boson
E) dark energy

11.12 Inflation solves the issue of the currently undetected magnetic monopoles by
A) combining them with antipoles
B) making them so rare, they have simply not yet been found
C) making them unstable, so they decay into neutrons
D) hiding them in the cosmic microwave background
E) having them be destroyed in the particle era

11.13 If everything we see in the Universe originated from the inflation of a tiny bit of space, the inflationary big bang theory leads us to speculate that
A) everywhere, throughout all of space, the Universe MUST look the same
B) the big bang theory is therefore so fully and completely flawed, the theory must be discarded
C) it is possible that other distant Universes may exist, where the laws of physics could be quite different—we may in fact be part of a multiverse
D) ultimately, inevitably, the Universe must deflate back to a microscopic speck, just to repeat the process again and again
E) the flying spaghetti monster must surely exist

11.14 The Inflationary Big Bang Theory predicts a few things with extraordinary accuracy. Which is NOT one of them?
A) the presence of a cosmic microwave background
B) the overall composition of the Universe (mostly H and some He)
C) the presence of dark matter
D) the power of the cosmic microwave radiation, as a function of wavelength
E) the spectrum of lumps in the cosmic microwave radiation, as a function of number of lumps vs. lump size

12: DARK MATTER

12.01 Dark matter is indicated by which observed mystery in astronomy
- A) the mass of Type Ia supernovae
- B) the presence of dark energy
- C) flat galactic rotation curves
- D) black holes
- E) radio lobe galaxies

12.02 Flat galactic rotation curves, as observed by Ruben and Ford, are characterized by
- A) galaxies that are structurally flatter than expected
- B) galaxies that orbit each other on curving paths
- C) having stellar orbits that move on straight lines, directly into the center of the galaxy
- D) galaxies with spiral arms that curve the wrong way
- E) having stellar orbits that are more or less the same speed, regardless of the distance from the center of the galaxy

12.03 In situations like our solar system, where essentially all the matter is concentrated in the center, the rotation curve
- A) is flat
- B) increases with increasing distance from the Sun, by R^2
- C) increases with increasing distance from the Sun, by R^4
- D) decreases with distance, by $1/\sqrt{R}$
- E) decreases with distance, by $1/R^4$

12.04 In a symmetric distribution of matter, orbital speeds depend
- A) only on the matter exterior to the orbit
- B) only on the matter interior to the orbit
- C) both the matter interior and exterior to the orbit
- D) upon the age of the star orbiting
- E) upon the temperature of the gas in the matter

12.05 Rotation curves indicate that the mass of the galaxy (interior to 10 kpc) is approximately
- A) 1 solar mass
- B) 200 solar masses
- C) 10^5 solar masses
- D) 10^{11} solar masses
- E) 10^{31} solar masses

12.06 The rotation curve of our galaxy is fairly constant; when we look at the rotation curves of other galaxies

A) we are unable to see any rotation at all in them
B) we see that rotation speeds increase, the further objects are from the centers of the galaxies!
C) we see that rotation speeds are more or less constant with distance from the centers of the galaxies!
D) we see that rotation speeds decrease, the further objects are from the centers of the galaxies!
E) we find that our galaxy is the only one with signs of dark matter

12.07 The ratio of all matter (detected gravitationally) in our galaxy, vs. visible matter, is approximately

A) 1000 to 1
B) 100 to 1
C) 10 to 1
D) 1 to 1
E) 1 to 10

12.08 Modern scientific studies indicate that elliptical galaxies

A) have no dark matter
B) have a tiny amount of dark matter
C) have plenty of dark matter
D) have approximately 100 times as much dark matter as spiral galaxies have
E) formed within the last 6000 years

12.09 A 600 solar mass gas cloud that glows with 6000 solar luminosities has a mass/luminosity ratio of

A) 6:1
B) 1:6
C) 10:1
D) 1:10
E) 6:10

12.10 A 100 solar mass gas cloud that glows with 10 solar luminosities has a mass/luminosity ratio of

A) 6:1
B) 1:6
C) 10:1
D) 1:10
E) 6:10

12.11 In our galaxy, dark matter appears to mostly lurk in
A) the inner parts of the galactic disk
B) the outer parts of the galactic disk
C) throughout the galactic disk
D) the spiral arms
E) the galactic halo

12.12 The Virial Theorem assumes that
A) a system has had time to reach a state of equilibrium
B) the dark matter is situated mostly between galaxies
C) X-ray gas is held in clusters by gravity
D) email attachments from strangers should not be opened
E) the path of light is bent by gravity

12.13 Zwicky's measurements of galaxy clusters indicated that
A) clusters appear to lack dark matter
B) the path of light is bent by gravity
C) clusters appear to have small amounts of dark matter
D) clusters appear to have small amounts of dark energy
E) clusters appear to be dominated by dark matter

12.14 To measure the mass of a cluster of galaxies, we need to know
A) the cluster size and the typical orbital speeds of the galaxies in it
B) the cluster distance and the types of galaxies in the cluster
C) the cluster distance and the age of the cluster
D) the recessional speed of the cluster and its size
E) the composition of the cluster and the temperature of its gas

12.15 X-ray emissions from gas in galactic clusters indicate that
A) the path of light is bent by gravity
B) the gas is extremely low temperature
C) the gas is escaping the galaxy cluster's gravity
D) the galaxy cluster is very low mass, since the gas has such little energy
E) the galaxy cluster is very high mass, in order to retain such hot gas

12.16 Big Bang nucleosynthesis models indicate that the dark matter must be mostly made out of
A) baryons
B) black holes
C) nonbaryonic matter
D) protons and neutrons, either naked or in elements
E) brown dwarf stars

12.17 Which of the following is an example of non-baryonic material?
- A) proton
- B) Higgs boson
- C) neutron
- D) stars
- E) hydrogen gas clouds

12.18 Which of the following is an example of baryonic material?
- A) neutrinos
- B) Higgs bosons
- C) photons
- D) electrons
- E) you

12.19 Gravitational microlensing events result in
- A) an object's temperature quickly rising and falling
- B) an object's brightness quickly rising and falling
- C) distorted shapes, such as Einstein rings
- D) the disappearance of stars by black hole effects
- E) great increases in the masses of gas clouds

12.20 Gravitational microlensing is used in dark matter studies to
- A) look for Type Ia supernovae
- B) numerically compute the distribution of matter, both visible and dark
- C) understand the distribution of antimatter in the Universe
- D) estimate how common MaCHOs might be
- E) estimate how common WIMPs might be

12.21 Weak gravitational lensing can be used to numerically calculate
- A) the distribution of matter
- B) the distribution of dark energy
- C) the location of magnetic monopoles
- D) the location of antimatter in the Universe
- E) the nature of superluminal motion

12.22 The Bullet Cluster provides evidence for
- A) dark energy
- B) MaCHOs
- C) black holes
- D) tachyons
- E) WIMPs

12.23 Modified gravity theories suggest that

A) our understanding of gravity is wrong at large scales, and must be modified
B) our understanding of how light moves through space must be modified
C) gravity actually can travel at greater than the speed of light
D) gravity is transmitted by photons, not gravitons, so our analysis of it is incorrect
E) have been very successful at explaining dark matter

13: GENERAL RELATIVITY

13.01 A critical problem with Newton's law of gravity is that
- A) it does not interact with dark matter
- B) it does not explain spacetime
- C) it overestimates the gravity of the Universe
- D) it cannot calculate the mass of a neutrino
- E) its instantaneous "action at a distance" violates relativity

13.02 A critical problem with Einstein's theory of special relativity, is that
- A) it did not predict the presence of dark matter
- B) it did not predict the presence of quarks
- C) it cannot calculate the speed of light
- D) it cannot calculate the mass of a neutrino
- E) it cannot incorporate gravity

13.03 General relativity's equivalence principle is
- A) the laws of physics are the same for all observers
- B) a uniform acceleration cannot be distinguished from a gravitational field
- C) matter-energy warps spacetime, while spacetime tells matter how to move
- D) nothing can travel faster than the speed of light
- E) $E=mc^2$

13.04 Suppose your 110 lb nephew is in an amusement park ride; he is in a small room that is dropped in free fall. As he is falling
- A) he is moving downwards at a constant velocity, and his weight is 110 lbs
- B) he is moving downwards at a constant velocity, and his weight is 0 lbs
- C) he is accelerating downwards at 1 g, and his weight is 110 lbs
- D) he is accelerating downwards at 1 g, and his weight is 0 lbs
- E) he turns into a black hole (good riddance!)

13.05 Einstein concluded that, since you can shift into a reference frame where gravity has zero value,
- A) gravity is mediated by gravitons
- B) gravity is mediated by gluons
- C) gravity is described by Newton's Laws
- D) gravity is the only force that can exceed the speed of light
- E) gravity is a fictional force

13.06 In warped space, the path of least travel time is called a
- A) geodesic
- B) spacetime warp
- C) tachyons
- D) fictional force
- E) gravitational force

13.07 Einstein developed his theory of general relativity based upon an analysis of
A) the effects of gravity
B) the effects of centrifugal force
C) the effects of tidal gravity
D) the speed of light
E) the luminiferous aether

13.08 In Einstein's field equations ($G_{\mu\nu} = (8\pi G/c^4)T_{\mu\nu}$), the Einstein tensor ($G_{\mu\nu}$) describes
A) the distribution of matter
B) the distribution of matter and energy
C) the warpage of space
D) the location of black holes
E) dark energy

13.09 In Einstein's field equations ($G_{\mu\nu} = (8\pi G/c^4)T_{\mu\nu}$), the stress-energy tensor ($T_{\mu\nu}$) describes
A) the distribution of matter
B) the distribution of matter and energy
C) the warpage of space
D) the location of black holes
E) dark energy

13.10 The General Theory of Relativity does away with "action at a distance" between two objects because
A) photons emitted from the first object travel through spacetime to the second object, hence gravity travels at the speed of light
B) the mass of the first object acts locally upon space to warp it, the warpage is transmitted through spacetime, and then acts locally upon the second object
C) photons emitted from the first object warp spacetime, then travel through the warped spacetime to reach the second object directly
D) the Higgs mechanism adds a drag to spacetime, giving objects that resist it mass
E) of something to do with tachyons

13.11 In the expanded form of Einstein's field equations ($R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + g_{\mu\nu}\Lambda = (8\pi G/c^4)T_{\mu\nu}$), the quantity Λ is called
A) the Ricci tensor
B) the metric tensor
C) the cosmological constant
D) the scalar curvature
E) the stress-energy tensor

13.12 That photons climbing out of a gravitational field are stretched to longer wavelengths, is called
A) frame dragging
B) gravitational time dilation
C) gravitational waves
D) gravitational redshifts
E) gravitational blueshifts

13.13 That time runs more slowly in a gravitational field is called
A) frame dragging
B) gravitational time dilation
C) gravitational waves
D) gravitational redshifts
E) gravitational blueshifts

13.14 That spacetime near a dense, rotating object is pulled into a rotating vortex is called
A) frame dragging
B) gravitational time dilation
C) gravitational waves
D) gravitational redshifts
E) gravitational blueshifts

13.15 Measurable effects of spacetime warpage, described by general relativity, DO NOT include
A) the perihelion precession of Mercury's orbit
B) the deflection of starlight passing near the sun
C) time delays that affect GPS signals
D) frame dragging
E) the formation of virtual particle-antiparticle pairs

13.16 A characteristic of positively curved space is
A) geometry such that the interior angles of a triangle sum to 180°
B) geometry such that the interior angles of a triangle sum to less than 180°
C) the density of the Universe is equal to the critical density
D) parallel lines converge towards each other
E) parallel lines diverge from each other

13.17 When Einstein developed his General Theory of Relativity, no one knew the Universe was expanding. When his mathematical theory said it must be, Einstein
A) wrote a paper about how his new theory predicted the Universe must be expanding
B) said that "God made the Universe expand, but I explained how God did the work"
C) added a fudge factor (the Cosmological Constant) to his equation, which he later retracted as being a big "blunder"
D) told Hubble to look for the cosmic expansion of the Universe
E) celebrated by dumping yet another wife

13.18 Changes in a gravitational field (resulting from objects changing their positions) propagate through space

A) at a changing speed, depending upon how massive the objects are
B) at the speed c/γ
C) at the speed $c \times \gamma$
D) at the speed c
E) at the speed $c \times \beta$

14: COSMIC ACCELERATIONS

14.01 Primary evidence for dark energy came to astronomy through the study of

A) dark matter
B) Cepheid variables
C) black holes
D) Type Ia supernovae
E) neutrinos

14.02 The Type Ia supernovae in the dark energy studies were first detected and identified by their

A) brightness changes and spectra
B) locations in our Milky Way galaxy
C) extraordinarily low velocities and strange compositions
D) orbits around dark matter stars
E) masses

14.03 The value of Type Ia supernovae, in dark energy studies, comes from the fact that we can determine what two things about them

A) gravity (how fast stuff is pulled towards them) and temperature (their color)
B) redshifts (how much space has expanded) and brightnesses (how far away they are from us)
C) composition (their baryonic composition) and age (time since decoupling)
D) orbital rate (gravitational energy) and surface gravity (i.e., above event horizons)
E) rotation rate (angular speed) and age (time since formation)

14.04 The teams studying Type Ia supernovae were surprised to discover that the expanding Universe is apparently

A) decelerating towards recollapse
B) at critical density
C) accelerating
D) coasting into infinity
E) shrinking

14.05 The conclusion that dark energy must exist was accepted readily by astronomers, as opposed to dark matter results, which took decades of controversy to be adopted. Why might this be the case?

A) dark energy disproved the steady state hypothesis
B) dark energy explained the presence of the cosmic microwave background
C) dark energy explained why we cannot see population III stars
D) while dark matter data were obtained with ground-based telescopes, dark energy images were taken with the Hubble Space telescope
E) after decades of getting used to the idea of dark matter, another contribution to the "dark sector" didn't seem much more difficult

14.06 The conclusion that dark energy must exist was accepted readily by astronomers, as opposed to dark matter results, which took decades of controversy to be adopted. Why might this be the case?

A) dark energy proved that general relativity was correct
B) the dark energy explained gravitational microlensing of distant quasars
C) two separate, competing teams using different methods came upon the same results
D) the original dark matter studies were falsified
E) Einstein famously claimed that dark matter could not exist

15: DARK ENERGY

15.01 Before dark energy's discovery, three cosmological problems frustrated astronomers—which was not one of them?
- A) the age of the oldest stars was greater than the age of the Universe
- B) the density of the Universe was not budging from $0.30\rho_{crit}$ to $1.0\rho_{crit}$
- C) the composition of the Universe was wrong; far too much lithium was observed
- D) density models of the Universe said it should have clumped earlier than it did

15.02 How does dark energy solve the flatness problem?
- A) it lowers the energy of the Universe to zero
- B) it sets the composition of the Universe to 100% neutrinos
- C) it brings the average size of stars to 10 solar masses
- D) it brings the density of the Universe to the critical value
- E) it initiates the formation of supermassive black holes

15.03 The Concordance Cosmology involves what ratios of visible matter, dark matter, and dark energy?
- A) 5%, 25%, 70%
- B) 33%, 33%, 33%
- C) 40%, 5%, 55%
- D) 70%, 25%, 5%
- E) 90%, 5%, 5%

15.04 Of the two components of the dark sector…
- A) dark energy was rapidly accepted by scientists while dark matter took decades to be taken seriously
- B) dark matter was rapidly accepted by scientists while dark energy took decades to be taken seriously
- C) both dark energy and dark matter were immediately adopted by scientists as mainstream science
- D) both dark energy and dark matter took decades to be adopted by scientists as mainstream science
- E) neither dark energy or dark matter have ever been proved to the satisfaction of scientists

15.05 While we know little about dark energy, we know it has two characteristics; one of these is that
- A) dark energy is made out of Higgs bosons
- B) dark energy is smoothly distributed in space
- C) dark energy was created during the era of nuclei
- D) dark energy is the exact same thing as inflation
- E) dark energy consists of a neutrino field

15.06 While we know little about dark energy, we know it has two characteristics; one of these is that

A) dark energy is made out of Higgs bosons
B) dark energy was created during the era of nuclei
C) dark energy is the exact same thing as inflation
D) dark energy consists of a neutrino field
E) dark energy is persistent in time

15.07 Over time, as the Universe enlarges by a factor R, the densities of matter, energy, and dark energy decrease by the following factors, respectively

A) R^3, R^4, R^3
B) R^4, R^3, R^3
C) R^4, R^3, no change
D) R^3, R^4, no change
E) R^3, R^4, R^4

15.08 Dark energy seems to violate the conservation of energy; which is not a true statement related to this issue?

A) This is not a problem, since it turns out that energy is simply not a conserved quantity in our Universe
B) Dark energy is a negative energy, which is not subject to the rules of conservation of energy that the rest of the Universe must obey
C) Noether's Theorem tells us that since the Universe is changing, energy does not have to be conserved
D) The reason the energy is not conserved is that as the Universe enlarges, the amount of dark energy in it increases
E) In a steady state Universe, where the Universe was never changing with time, dark energy would have to follow a conservation of energy law

15.09 Dark energy has negative pressure, meaning that as space expands

A) the energy density in it decreases
B) the energy density in it increases
C) the energy density in it stays the same
D) the overall energy in the Universe gets smaller
E) the overall energy in the Universe stays the same

15.10 Quantum mechanics predicts space should be filled with an equivalent of dark energy, and it is called

A) dark matter
B) vacuum energy
C) strings
D) quintessence
E) the Matrix

15.11 The Casimir effect is something measured in laboratories, which

A) was the first detection of actual dark matter
B) was the first detection of actual dark energy
C) is a result of virtual particles winking in and out of existence
D) demonstrates that dark energy must be due to virtual particles
E) detected the mass of neutrinos, thus showing they could not be the explanation for dark energy

15.12 The sea of virtual particles and antiparticles in an otherwise complete vacuum would have a tiny, residual amount of energy; the energy is called

A) virtual energy
B) residue energy
C) zero-point energy
D) Casimir energy
E) vacuum energy

15.13 A serious problem with explaining dark energy by vacuum energy, is that vacuum energy

A) is not persistent
B) is not smoothly distributed
C) is predicted to only occur in the galactic core
D) is predicted to be about 10^{120} times more energetic than dark energy
E) has a density that cannot be predicted or calculated

15.14 Models where dark energy changes in time are called

A) dynamical dark energy
B) persistent dark energy
C) cosmological constants
D) vacuum energy
E) dark matter

15.15 That the densities of matter and energy are currently comparable is called

A) the Big Bang theory
B) the Great Coincidence Scandal
C) Vacuum Energy Hypothesis
D) Cosmic Inflation
E) Quintessence

15.16 The leading theory of dynamical dark energy is called

A) dark matter
B) cosmic voids and sheets
C) Vacuum Energy
D) String Theory
E) Quintessence

16: STRING THEORY

16.01 A key failing of the theory of General Relativity is
- A) that it sets a value for the speed of light
- B) the presence of antimatter
- C) string theory
- D) its inability to mesh with quantum mechanics
- E) it is inconsistent with dark energy

16.02 A major criticism about string theory is that
- A) it makes no predictions which are at all testable
- B) it is really weird
- C) it holds no promise of being able to unite the forces of nature
- D) it introduces large numbers of new particles, a far-too complex situation
- E) it cannot mesh quantum and general relativity

16.03 A major criticism about string theory is that
- A) it is really weird
- B) its mathematics are so complex that no one can tackle them, even with vast computers
- C) it holds no promise of being able to unite the forces of nature
- D) it introduces large numbers of new particles, a far-too complex situation
- E) it cannot mesh quantum and general relativity

16.04 String theory is
- A) a study of giant cosmic strings
- B) an alternate theory about the Big Bang
- C) a mathematical model that might describe the nature of subatomic particles
- D) the science that got its start by trying to explain action at a distance
- E) the mathematical construct that got its start by trying to explain action at a distance

16.05 String theory got its start 1968-1970, when scientists noted that
- A) general relativity was not working well with quantum
- B) the Universe was filled with dark matter
- C) the Universe was filled with dark energy
- D) subatomic particles could be described using the same equations that are used for tiny vibrating loops
- E) gravity could easily be unified with other forces

16.06 Early formulations of string theory were
- A) hobbled because there were five separate theories
- B) hobbled because string theory predicted 6 dimensions of space
- C) successful at predicting the masses of electrons and protons
- D) successful at predicting the age of the Universe
- E) successful at predicting the value of the Chandrasekhar limit

16.07 In 1995, Edward Witten re-energized string theory work by noting that the five separate string theories
A) were actually parts of a single M-theory
B) were in conflict, thus paving the way for M-theory
C) worked together to predict the masses of black holes
D) worked separately to predict the masses of quarks
E) were in fact exactly the same

16.08 The “M” in M-theory stands for
A) Membrane
B) Matrix
C) Magic
D) Murky
E) No one really knows (or at least is talking)

16.09 According to string theory, an individual string is
A) is made out of six quarks
B) is about 15 kpc long
C) about the same mass as an elliptical galaxy
D) rigid and not prone to vibrational energy states
E) about the size of the Planck length

16.10 According to string theory, the only thing that makes one string different from another is
A) whether its spin is 1/2 (i.e., it is a fermion), or an integer (boson)
B) how large it is
C) its vibrational state
D) its quark color
E) its charge

16.11 While strings can vibrate in an infinite number of ways, we have not observed an infinite number of types of particles because
A) string vibrations duplicate, so extra vibrations correspond to the same particles
B) particle type is determined by string speed, not string vibration
C) the most energetic vibrational states correspond to high mass, and therefore highly unstable particles
D) the most energetic strings are antiparticles
E) high vibrational states are prohibited by the Uncertainty Principle

16.12 String theory would make it easier to reconcile general relativity and quantum mechanics because
A) strings move at the speed of light
B) strings are massless, and therefore not affected by general relativistic space warps
C) strings are point masses, and therefore not affected by spatial distortions
D) the non-zero size of strings smears out the ultramicroscopic foamy structure of spacetime to something more acceptable to general relativity
E) strings are made out of pure light

16.13 Modern string theory predicts that spacetime consists of
A) three spatial dimensions and one time dimension
B) nine spatial dimensions and two time dimensions
C) ten spatial dimensions and one time dimension
D) three spatial dimensions and eight time dimensions
E) three time dimensions and one spatial dimension

16.14 The reason that Kaluza-Klein theories of space require so many dimensions is that the additional dimensions
A) let strings travel through time
B) provide strings with extra dimensions to vibrate in
C) let strings collide without tearing spacetime
D) provide new dimensions for photons
E) allow strings to wormhole through space

16.15 String theory seems to allow strings to expand into larger shapes, including blobs, disks, and large sheets. The large membranes are referred to as
A) branes
B) M-theory
C) Calabi-Yau shapes
D) the bulk
E) the Local Group

16.16 It has been suggested that the collision of two branes may have resulted in
A) the energy source inside the Sun
B) the formation of the Sun
C) the creation of dark energy
D) the source of matter-antimatter asymmetry
E) the Big Bang

16.17 String theory, if it is correct, seems to imply
A) space is populated with antimatter
B) the existence of 11 spacetime dimensions
C) a fundamental conflict between General Relativity and Special Relativity
D) the Higgs field
E) the existence of dark energy

17: BLACK HOLES

(The first two questions are really treated in the first part of the semester, but are so important for discussing black holes, that I resurrect them here.)

17.01. What is the Schwarzschild radius for a 10 solar mass black hole, which might form from a star in a supernova?

A) 3 km
B) 10 km
C) 30 km
D) 60 km
E) 100 km

17.02 What is the Schwarzschild radius for a 10^7 solar mass, supermassive black hole, which might be lurking in the core of a galaxy?

A) 3×10^6 km (0.02 a.u.)
B) 3×10^7 km (0.2 a.u.)
C) 9×10^7 km (0.6 a.u.)
D) 3×10^8 km (2 a.u.)
E) 9×10^6 km (6 a.u.)

17.03 At a certain distance from a black hole's center, the escape velocity is greater than the speed of light. We have used several names for this radius—which of the below was not?

A) Schwarzschild radius
B) event horizon
C) critical radius
D) Planck length
E) all the above are names for that radius

17.04 Embedding diagrams illustrate how

A) objects that crash into black holes embed into the event horizon
B) the only thing that can warp spacetime are black holes
C) spacetime is warped by the presence of matter
D) black holes have no hair
E) the event horizon is a one-way trip into the black hole

17.05 The gravitational influence of an object about twice the critical radius in size would be to shift the wavelength of light leaving its surface by about

A) nothing at all, since the object is not a black hole
B) 0.002% (i.e., not at all)
C) 40%, for example shifting visible photons into the infrared
D) an infinite amount, making it impossible to leave the surface at all
E) actually, this is not something that could be measured or calculated because of the uncertainty principle

17.06 The gravitational influence of an object equal to the critical radius in size would be to shift the wavelength of light leaving its surface by about

A) nothing at all, since the object is not a black hole
B) 0.002% (i.e., not at all)
C) 40%, for example shifting visible photons into the infrared
D) an infinite amount, making it impossible to leave the surface at all
E) actually, this is not something that could be measured or calculated because of the uncertainty principle

17.07 As viewed from a person far from a black hole, the rate of time flow very close to the surface of the event horizon is

A) extremely slow, even frozen completely
B) the same rate as it is everywhere
C) backwards in time
D) infinitely fast
E) not defined, because as you approach a black hole time has no meaning

17.08 Black hole scientists often use "critical circumference" instead of "critical radius" because…

A) it is easier to draw a circle than a straight line
B) it is really just a matter of tradition
C) really, the radius of the event horizon is poorly defined since one end of the line is at the singularity
D) time is distorted at the event horizon
E) time flow at the event horizon is subject to quantum entanglement with Hawking Radiation.

17.09 "Black holes have no hair," refers to the fact that black holes are very simple. Which of the following quantities does not determine to a black hole's characteristics?

A) composition
B) mass
C) charge
D) angular momentum (spin)
E) Careful! ALL the above determine a black hole's characteristics

17.10 For a nonrotating, uncharged black hole, order the following points/boundaries in order of increasing radius/distance from the center of the black hole

A) singularity—event horizon—photon sphere
B) event horizon—photon sphere—singularity
C) photon sphere—singularity—event horizon
D) photon sphere—event horizon—singularity
E) photon sphere—singularity—event horizon

17.11 A rotating black hole has
A) 2 event horizons, 1 photon sphere, and a point singularity
B) 2 event horizons, 2 photon spheres, and a point singularity
C) 2 event horizons, 2 photon spheres, and a disk-shaped singularity
D) 1 event horizon, 1 photon sphere, and a disk-shaped singularity
E) 1 singularity, 1 photon sphere

17.12 Rotating black holes have a region where particles are not trapped by speed of light limitations, yet are forced to move by frame dragging and gravity. What is this region called?
A) photon sphere
B) singularity
C) event horizon
D) ergosphere
E) Schwarzschild radius

17.13 Strange things would happen to an astronaut falling towards a 5 solar mass black hole; which is something that would not happen?
A) tidal forces would rip the astronaut apart
B) to a distant observer, the astronaut's rate of time would slow down and stop
C) to a distant observer, the astronaut's image would become infinitely redshifted
D) to a distant observer, the astronaut would never quite fall into the black hole
E) the astronaut's temperature would drop to about 10^{-5} K

17.14 Virtual particles, formed near a black hole and escaping its gravity, produce a phenomenon referred to as
A) the Schwarzschild radii
B) Hawking radiation
C) the ergospheres
D) singularities
E) dark energy

17.15 If Hawking radiation is an actual effect, the far future fate of all black holes will be to
A) evaporate by radiating virtual particles and photons into space
B) disrupt via collosions with each other
C) create their own wormholes into the spacetime continuum
D) blow up via an accretion mechanism
E) collapse into a naked singularity

17.16 Regarding the detection of black holes, which of the following is NOT correct
- A) a black hole minding its own business in space, far from other objects, would be very hard to detect on Earth
- B) we know of binary star systems, where stars are orbiting a nonluminous, mysterious, dark objects 5-15 solar masses in mass
- C) some gamma ray bursts observed may be due to black hole phenomena
- D) they were rapidly observed, shortly after being mathematically predicted
- E) we believe that the active cores of galaxies that we easily see, must be due to supermassive black holes

17.17 In the last few decades, much of the work on black holes has focused on the fate of which two attributes of matter and energy drawn into the event horizon?
- A) mass and temperature
- B) size and angular momentum
- C) age and luminosity
- D) entropy and information
- E) charge and speed

17.18 The discovery that the entropy of material drawn into a black hole can be compared to the surface of a black hole has led to the idea of what kind of cosmology?
- A) the expanding Universe
- B) the holographic principle
- C) the big bang
- D) dark energy
- E) the black hole Universe

17.19 The holographic principle suggests that
- A) the Universe is just the matrix set up by machines to keep humans docile
- B) the three dimensional Universe is really simply a projection of data stored on the distant event-horizon-like boundary of the Universe
- C) three dimensional images can be created by lasers
- D) material drawn into black holes are instantly incinerated in the firewall
- E) the entropy stored in black holes is radiated out via Hawking radiation

17.20 Which is NOT true about the hypothesis of firewalls in black holes?
- A) predicted by quantum physics, they say objects will be incinerated when they pass through the event horizon
- B) firewalls are apparently in violation of General Relativity, as they say that the event horizon is a distinct region, and not just a mathematical boundary in space
- C) Hawking argued around them by suggesting event horizons might not exist, or might be replaced by a poorly-explained “apparent horizon”
- D) they may be a fictional consequence of our current inability to reconcile General Relativity and Quantum
- E) firewalls were first modelled by Schwarzschild, shortly after Einstein published his theory of General Relativity

18: WARPS IN SPACE AND TIME

18.01 Gravitational waves are created by
- A) lone neutron stars
- B) massive objects like black holes
- C) massive objects like black holes moving at high velocities
- D) accelerating asymmetric objects like binary pulsars
- E) spacetime wormholes

18.02 Gravitational waves were detected (in 2016) by an event believed to be
- A) a white dwarf star turning into a black hole
- B) a pair of colliding white dwarf stars
- C) a pair of colliding black holes
- D) a black hole turning into a white hole
- E) a destabilizing wormhole

18.03 LIGO has detected
- A) no gravitation waves at all, despite years of operation
- B) only one gravitational wave event—in 2016
- C) at least three events corresponding to black hole mergers
- D) white dwarf stars blowing up at Type Ia supernovae
- E) a number of traversable wormholes

18.04 A spacetime wormhole
- A) connects black holes to white holes
- B) connects quasars to black holes
- C) is a shortcut through spacetime that could allow for faster travel through space
- D) has been detected in the gamma quadrant
- E) would need no special physics to be stabilized

18.05 Which is not true about Einstein-Rosen bridges?
- A) they are wormholes
- B) they can be used to travel through space
- C) they pinch off so fast, they cannot be used for travel
- D) they are unstable
- E) they are theoretical shortcuts connecting two different points in space

18.06 Wormholes can be stabilized
- A) only if they are used as time machines
- B) only if they are held stationary, without time warps
- C) by exotic matter
- D) by antimatter
- E) by neutrinos

18.07 Exotic matter
- A) Can be bought in Chinatown
- B) is matter that has strange properties, such as negative mass and energy
- C) is antimatter
- D) is also simply called dark matter
- E) is also simply called dark energy

18.08 If stabilized by exotic matter and properly manipulated, what could be used to travel back through time?
- A) Alcubierre metrics
- B) black holes
- C) strings
- D) wormholes
- E) neutrinos

18.09 Einstein, Podolsky, and Rosen objected to quantum mechanics because
- A) it did not incorporate gravity
- B) they did not like the idea of string theory
- C) they felt the whole idea of things not having values until being measured was a symptom of the theory being incomplete
- D) the theory requires exotic matter
- E) it required an infinite amount of matter!

18.10 "Spooky action at a distance" refers to how
- A) entangled particles seem to communicate across space somehow
- B) string theory seems to require so many additional dimensions
- C) the Newtonian force of gravity requires "action at a distance"
- D) black holes will, in time, evaporate
- E) "The Ring" is a scary movie, whether you watch it at home or at a friend's house.

18.11 "Locality" refers to how
- A) electrons have de Broglie wavelengths
- B) gravity strings can move through the spacetime bulk
- C) wormholes can function, if given exotic matter
- D) in physics, things should act upon their surroundings, at not via "action at a distance"
- E) matter can be transformed into pure energy.

18.12 With quantum entanglement,
- A) you can physically transport objects across space and time!
- B) gravity is revealed to be a fiction
- C) quantum mechanics and general relativity are reconciled
- D) there must always be as many protons in an atom, as there are electrons
- E) events happening to one particle can seem to have consequences on their entangled partners.

18.13 What we interpret as empty space, might actually be

A) inverted time flow
B) a giant blueberry pancake, with extra butter and syrup
C) that great mysterious place where unpaired socks go
D) Oh, I don't know. Beats me.
E) a giant, interconnected ensemble of wormholes connecting entangled particles.

19: TIME

19.01 Which is not correct about the Alcubierre drive
- A) it is a form of wormhole travel
- B) it is a proposed form of warp drive
- C) it requires stabilization by exotic matter
- D) it warps space in front of, and behind, the space craft.
- E) while a faster-than-light travelling method, it does not violate relativity

19.02 Using the “now-list” paradigm, we can shift an event into the future (a “now” that has not yet occurred) by
- A) standing still and watching it
- B) walking towards it
- C) walking away from it
- D) quantum entanglement
- E) falling into a black hole

19.03 Using the “now-list” paradigm, we can shift an event into the past (a “now” that occurred longer ago) by
- A) standing still and watching it
- B) walking towards it
- C) walking away from it
- D) quantum entanglement
- E) falling into a black hole

19.04 The problem with an absolute, unchanging sense of what is happening *now*, is that
- A) now depends completely upon the equipment you use to measure it
- B) if you use an instrument to measure now, it is too late since it already happened
- C) travelling through a spacetime wormhole can modify time
- D) what we call *now* can be shifted into the past or the future by simply moving
- E) what we call *now* can be shifted into the past or the future by simply accelerating

19.05 That time only moves forward is known as
- A) entropy
- B) thermodynamics
- C) spacetime
- D) the arrow of time
- E) special relativity

19.06 Entropy is a measure of
- A) how much disorder is in a system
- B) how rapidly a system moves forwards in space
- C) how rapidly a system moves forwards in time
- D) how much exotic matter is in a system
- E) how rapidly gravity changes in a system

19.07 That time only moves forward is probably connected to the increasing entropy of
A) the Universe in its continued expansion
B) the past
C) vibrating strings
D) the interstellar medium
E) dark energy

20: HYPERDIMENSIONALITY—FLATLAND

20.01 A spatial dimension beyond the conventional spatial dimensions that we can explore, is called
A) entropy
B) photon sphere
C) an extended spatial dimension
D) branes
E) hyperspace

20.02 Conventional physics (i.e., without invoking string theory), indicates that our universe consists of what kind of space-time dimensionality?
A) 1+1
B) 2+2
C) 3+1
D) 4
E) 11+1