1: NEWTONIAN PHYSICS AND APPLICATIONS

1.01. The spatial distance (L) between two points, separated by Δx, Δy, and Δz is given by
- A) $L=\Delta x + \Delta y + \Delta z$
- B) $L^2=\Delta x + \Delta y + \Delta z$
- C) $L^2=\Delta x^2 + \Delta y^2 + \Delta z^2$
- D) $L^3=2\Delta x +2 \Delta y+ 2\Delta z$
- E) $L^3=\Delta x^3 + \Delta y^3+ \Delta z^3$

1.02. The rate of time passing in our Universe, according to Newton
- A) Depends upon the mass of the Universe.
- B) Is 1 second per second.
- C) Is modified by the curvature of spacetime.
- D) Depends upon how fast you are travelling.
- E) Depends upon how fast you are accelerating

1.03. Linear velocity is defined as
- A) $\Delta x/\Delta t$
- B) $\Delta v/\Delta t$
- C) ma
- D) GM_1M_2/R^2
- E) F

1.04. A car moves forward at 30 km/hr. A passenger in the car throws a rock forwards at 10 km/hr. With respect to a person standing on the side of the road, how rapidly is the rock moving forwards?
- A) 10 km/hr
- B) 20 km/hr
- C) 30 km/hr
- D) 40 km/hr
- E) 300 km/hr

1.05. Unless being acted upon by an external force, an object at rest stays at rest, and an object in motion continues forwards without a change in velocity. This is known as
- A) Newton’s first law
- B) Newton’s second law
- C) Newton’s third law
- D) Newton’s law of gravity
- E) Newton’s action at a distance

1.06. An object of mass (m), acted upon by an unbalanced force (F), will accelerate (a) such that $F=ma$. This is known as

A) Newton's first law
B) Newton's second law
C) Newton's third law
D) Newton's law of gravity
E) Newton's action at a distance

1.07. For every force F_1, there is an equal but opposite reaction force F_2, such that $F_1 = -F_2$. This is known as

A) Newton's first law
B) Newton's second law
C) Newton's third law
D) Newton's law of gravity
E) Newton's action at a distance

1.08. If two masses (M, m) with their centers are separated by a distance (R). The mutually attractive gravitational force (F) is given by $F=GMm/R^2$. This is known as

A) Newton's first law
B) Newton's second law
C) Newton's third law
D) Newton's law of gravity
E) Newton's action at a distance

1.09. The equation $E=\frac{1}{2}mv^2$ calculates an object's

A) Kinetic energy.
B) Gravitational force.
C) Potential energy under a uniform gravitational field.
D) Energy gained by falling towards a massive object.
E) Equilibrium temperature

1.10. The equation $E=mgh$ calculates an object's

A) Kinetic energy.
B) Gravitational force.
C) Potential energy under a uniform gravitational field.
D) Energy gained by falling towards a massive object.
E) Equilibrium temperature

1.11. An interesting mystery about mass, is that the inertial mass in Newton's second law

A) Is never changing.
B) Is always changing.
C) Is not the same mass that Einstein uses in his equations.
D) Is the same mass that determines the force of gravity.
E) Also appears in the laws of electromagneticsm.

1.12. The equation $F=GMm/R^2$ calculates an object's
   A) Kinetic energy.
   B) Frictional force.
   C) Potential energy under a uniform gravitational field.
   D) Energy gained by falling towards a massive object.
   E) Gravitational force

1.13. The equation $F=mv^2/R$ calculates
   A) Gravitational force
   B) Frictional force
   C) The reaction force.
   D) The force of friction.
   E) Force needed to keep an object in a circular path.

1.14. Conservation of energy and momentum means
   A) We should turn off lights when we leave the room
   B) These quantities may change form, but are not lost or created
   C) Gravity pulls objects towards each other
   D) Your weight and mass are different things
   E) Energy can transform itself into momentum, and back again.

1.15. Newton's Laws represent a form of unification of laws of physics, because they
   A) Treated terrestrial and astronomical quantities using the same laws
   B) Combined electricity, magnetism, and optics
   C) Combined electromagnetism and the weak force
   D) Described space and time as being interchangeable
   E) Required an inexplicable "Action at a Distance" to work

1.16. Newton was dissatisfied by the law of gravity, because it required
   A) Mass to be different from weight
   B) The constant "G" to be very small
   C) The sun to be at the center of the Solar System
   D) An inexplicable "action at a distance"
   E) Photons to travel at very high speeds

1.17. If you are in a car that is making a turn to the right, your tendency is to travel forwards in a straight line. This is a consequence of
   A) Newton's first law
   B) Newton's second law
   C) Newton's third law
   D) Newton's law of gravity
   E) Newton's action at a distance

1.18. If you are in a car that is making a turn to the right, your tendency to travel forwards in a straight line results in your appearing to be pulled to the left (with respect to the interior of the car. Those who don't understand Newton's Laws mistakenly call this…

A) Gravitational force
B) Centripetal force
C) Centrifugal force
D) Frictional force
E) Drag force

1.19. Compared to the Earth's gravitational field measured in this classroom, the strength of the gravitational field on an orbiting satellite is…

A) Much higher
B) Only slightly higher
C) Exactly the same
D) Only slightly weaker
E) Much weaker

1.20. You throw an object exactly straight up. The instant it reaches the top of its trajectory (path), which of the following is correct?

A) Its velocity is not zero, its acceleration is not zero, its mass is not zero
B) Its velocity is not zero, its acceleration is not zero, its mass is zero
C) Its velocity is not zero, its acceleration is zero, its mass is zero
D) Its velocity is zero, its acceleration is zero, its mass is zero
E) Its velocity is zero, its acceleration is not zero, its mass is not zero

1.21. In Newton's the law of gravity, "G" stands for

A) The gravitational force of things on the surface of the Earth
B) The gravitational constant
C) The gravitational variation of space
D) The force of the Earth
E) Newton's middle name

1.22. A problem with Newton's use of action at a distance, is that it required gravity

A) To be a consequence of angels
B) To be nonlocal
C) To become stronger with distance
D) To travel at the speed of light
E) To be a consequence of spacetime

1.23. The term Locality refers to

A) How you should only eat food harvested near you
B) How gravitational mass is equivalent to kinetic mass
C) How objects can only directly affect other objects near them
D) How objects obtain their mass
E) How the cosmic microwave background was first generated

2: ELECTROMAGNETISM

2.01. The speed of light is
- A) 8×10^{15} m/s
- B) 5×10^{8} m/s
- C) 3×10^{8} m/s
- D) 2×10^{8} m/s
- E) 1×10^{5} m/s

2.02. The frequency of a photon is 3×10^{5} Hz. Its wavelength is
- A) Not determinable
- B) 1 m
- C) 10 m
- D) 100 m
- E) 1000 m

2.03. The most energetic form of electromagnetic radiation is
- A) Gamma rays
- B) Infrared rays
- C) Red light
- D) Microwaves
- E) Radio waves

2.04. The laws about the formation of continuum, emission, and absorption spectra are called
- A) Maxwell's Laws
- B) Kirchhoff's Laws
- C) Kepler's Laws
- D) Newton's Laws
- E) The Hubble Law

2.05. An excited, low density gas would produce
- A) An emission spectrum
- B) An absorption spectrum
- C) A continuum spectrum
- D) The electromagnetic spectrum
- E) A thermal spectrum

2.06. A low density gas in front of a continuum source would produce
- A) An emission spectrum
- B) An absorption spectrum
- C) A continuum spectrum
- D) The electromagnetic spectrum
- E) A thermal spectrum

2.07. An opaque, glowing object would produce
A) An emission spectrum
B) An absorption spectrum
C) A continuum spectrum
D) A laser beam
E) A beam of gamma rays

2.08. One continuum source produces radiation peaking in the violet part of the spectrum. A second continuum source is much hotter—its continuum spectrum peaks at a wavelength…
A) Longer than violet
B) In the ultraviolet or possibly even shorter
C) In the infrared
D) In orange to red
E) At the same wavelength

2.09. Which of the statements below is true?
A) An oven glowing red is hotter than an oven glowing orange
B) At room temperature, a yellow ball is hotter than a red one
C) The blue part of a flame is hotter than the red part
D) The temperature of a glowing object cannot be determined by its color
E) The peak wavelength of an object's continuum spectrum is determined by its composition

2.10. Two glowing objects are the same temperature. One is larger than the other. Which statement (below) is true?
A) They both produce the same amount of radiation
B) The continuum spectra from the two objects will peak at different wavelengths
C) The larger object will be more luminous
D) The larger object is farther away
E) The larger object is closer to us

2.11. The light produced by an object moving towards you is
A) Doppler shifted towards shorter wavelengths
B) Doppler shifted towards longer wavelengths
C) Not Doppler shifted at all
D) Traveling faster than the speed of light.
E) Traveling slower than the speed of light

2.12. The least energetic form of electromagnetic radiation is
A) Gamma rays
B) Infrared rays
C) Red light
D) Microwaves
E) Radio waves

2.13. A photon with the wavelength about as large as an atom (10^{-10} m) is a(n)

A) Radio wave
B) Infrared ray
C) Ultraviolet ray
D) X ray
E) Gamma ray

2.14. A photon with the wavelength about as large as an atomic nucleus (10^{-15} m) is a(n)

A) Radio wave
B) Infrared ray
C) Gamma ray
D) X ray
E) Ultraviolet ray

2.15. A prism breaks a beam of white light into its separate colors. Suppose you used a second prism, reversed, to recombine the separate colors back into a single beam. What would the beam look like?

A) You cannot do this
B) A spectrum, but with colors in reverse order
C) A multicolored beam of many colors
D) A beam of white light
E) A red light; this is how red lasers are made

2.16. The Hα spectral line is normally at 656 nm wavelength. You observe it to be at 706 nm. What can you conclude about the source?

A) It is made out of pure Helium
B) It is exploding
C) It is not moving with respect to you.
D) It is moving away at about 7.6% the speed of light
E) It is approaching at about 7.6% the speed of light

3: PARTICLES AND WAVES

3.01. Which is not an example of the wave-like nature of light?
- A) Light can knock electrons off the surface of clean metal
- B) Light (especially long wavelength) can flow into a room like a wave
- C) Light can create interference patterns
- D) Light refracts in substances like glass
- E) Light slows down in media other than a vacuum

3.02. Which is not true about Maxwell’s Equations?
- A) They describe electrical and magnetic fields
- B) They unified theories of electricity and magnetism
- C) They predict that an electromagnetic pulse would travel at c
- D) They unified the laws of gravity and electricity
- E) They are used by physicists to calculate how electrical and magnetic fields relate to each other

3.03. Maxwell’s Equations represented a form of unification of laws of physics, because they
- A) Treated terrestrial and astronomical quantities using the same laws
- B) Combined electricity, magnetism, and optics
- C) Combined electromagnetism and the weak force
- D) Described space and time as being interchangeable
- E) Combined gravity and spacetime

3.04. Which is *not* true about the luminiferous aether?
- A) It was believed to be the medium through which light traveled
- B) It was believed to be a kind of medium that filled all of space
- C) It was believed to be extremely stiff, so that light traveled very quickly
- D) It was detected by Michelson in 1887
- E) It was confounding physicists who believed in it, by not being detectable

3.05. Physics during Michelson’s time suggested that
- A) Light moved so fast, aether could be captured in suitable containers
- B) Aether could be used as an extraordinary energy source
- C) Aether emissions would be detectible at radio wavelengths
- D) Aether is a remarkable tranquilizer
- E) We should be able to detect changes in the speed of light as the Earth orbits the sun

3.06. Which is an example of the particle-like nature of photons?
- A) They have wavelengths
- B) They can create interference patterns
- C) They refract in substances like glass
- D) They can knock electrons off the surface of clean metal
- E) They change speeds as they travel through optically different media

3.07. Electrons, fired through a 2-slit interference apparatus
   A) Produce a 2-slit interference pattern, just like photons do
   B) Do not produce a 2-slit interference pattern
   C) Demonstrate that matter is not wavelike
   D) Show that particle-wave duality only applies to photons
   E) Demonstrate the invariance of the speed of light

3.08. Bohr's postulates were similar to Kepler's Laws because
   A) There are four of them
   B) While ultimately correct, there was no explanation for why they worked
   C) They allowed Bohr to calculate quantum-mechanical horoscopes
   D) They incorporated gravity
   E) Kepler used them in his quantum calculations

3.09. The de Broglie wavelength
   A) Is the wavelength of a de Broglie photon
   B) Is the wavelength of an electron
   C) Disproved particle-wave duality
   D) Does not help us understand why Bohr's postulates are correct
   E) Proved that the luminiferous ether does not exist

3.10. The Schrödinger wavefunction
   A) Applies only to photons
   B) Applies only to electrons
   C) Describes how you (yes, you!) are a wave
   D) Explains why the cat is dead
   E) Explains why the cat is alive

3.11. Schrödinger's cat is a thought experiment that explores
   A) Why physics, ultimately, is wrong
   B) How unobserved wavefunctions can be interpreted as having multiple, undetermined states
   C) How the Bohr atom is related to the de Broglie wavelength
   D) Why an over-determined system necessarily collapses to its anti-parity solution
   E) Why two fermionic particles cannot occupy the same quantum mechanical state

3.12. Just like light bending as it passes through glass, the wavefunctions of matter are reflected or modified by
   A) Glass
   B) Time
   C) Changes in its potential energy
   D) Changes to its temperature
   E) Changes in its kinetic energy (velocity)

3.13. If light was only describable as a wave, it could heat metal, but could not knock electrons off its surface. The fact that it can knock off electrons is called the
  A) Interference pattern
  B) Bohr postulate
  C) Einstein effect
  D) Michelson effect
  E) Photoelectric effect

3.14. When electrical charges are accelerated, they emit energy (photons). Accordingly, electrons orbiting an atom should spiral into the nucleus. Which scientist developed a set of laws explaining why they don't?
  A) Einstein
  B) de Broglie
  C) Schrodinger
  D) Bohr
  E) Michelson

3.15. The de Broglie wavelength of an electron in an atom
  A) Is about equal to the circumference of an electron's orbit around the atom
  B) Is about equal to the diameter of an atomic nucleus
  C) Is about equal to the electron's diameter
  D) Is about equal to one astronomical unit
  E) Is equal to the size of a proton

3.16. The Schrödinger wavefunction can be used to calculate
  A) The exact energy of an object in space and time
  B) The exact location of an object in space and time
  C) The probability distribution of a particle's location in space
  D) The age of a particle
  E) The size of a particle's de Broglie wavelength

3.17. What do we mean by the term realism in physics?
  A) The attributes of an object are only determined when they are measured
  B) The attributes of objects in space have actual values, even if they are not being observed
  C) The values of things like momentum or position are forced into existence by the moment or action of observing them
  D) The effects of "action at a distance" are real, and cannot be discounted.
  E) It is expected that things can affect each other, only if they are very close, such as in contact with each other.

3.18. What do we mean by the term instrumentalism in physics?

A) The attributes of an object are fixed and determined by the object itself
B) The attributes of objects in space have actual values, even if they are not being observed
C) The values of things like momentum or position are forced into existence by the moment or action of observing them
D) The effects of “action at a distance” are real, and cannot be discounted.
E) It is expected that things can affect each other, only if they are very close, such as in contact with each other.

3.19. Define Copenhagen interpretation of quantum mechanics

A) The attributes of an object are fixed and determined by the object itself
B) The attributes of objects in space have actual values, even if they are not being observed
C) The values of things like momentum or position are forced into existence by the moment or action of observing them
D) The effects of “action at a distance” are real, and cannot be discounted.
E) It is expected that things can affect each other, only if they are very close, such as in contact with each other.

3.20. Define nonlocality in physics

A) The idea that characteristics have values, only when they are being observed
B) The idea that characteristics have values, even when they are not being observed
C) The idea that quantum characteristics can jump from one value to another
D) The possibility that things could affect each other, only if they are near each other
E) The possibility that things could affect each other, even if they are not near each other

3.21. Einstein objected to the claims of quantum mechanics, saying that

A) The theory was too hard to understand
B) The theory violated Newton’s Laws
C) He didn’t like how Bohr dressed
D) Quantum’s claims that some values in physics could not be calculated, was an indication that the theory was incomplete
E) It demanded the presence of an ether

4: STELLAR ASTRONOMY (AND PLANETS)

4.01. The vast majority of the Solar System's mass is in
- A) Jupiter
- B) The asteroid belt
- C) The Sun
- D) The Öort cloud
- E) The Earth

4.02. The order of the planets, from center to edge of the Solar System, is
- A) Me-Ve-Ea-Ma-Ne-Ju-Sa-Ur
- B) Me-Ve-Ea-Ma-Ju-Sa-Ur-Ne
- C) Ve-Ea-Ma-Me-Ju-Sa-Ur-Ne
- D) Ju-Sa-Ur-Ne-Me-Ve-Ea-Ma
- E) Re-Or-Ye-Gr-Bl-In-Vi

4.03. The planet with the hottest surface is
- A) Mercury
- B) Venus
- C) Earth
- D) Mars
- E) Sun

4.04. The most massive planet in the Solar System is
- A) Saturn
- B) Uranus
- C) Neptune
- D) Jupiter
- E) Sun

4.05. What attribute of the Earth is known to also be shared by another terrestrial planet?
- A) It has an oxygen atmosphere
- B) It has oceans of liquid water on its surface
- C) It has life
- D) It has a magnetic field
- E) It has a single, large satellite

4.06. Other than the Earth, which terrestrial planet is most likely to have life?
- A) Mercury
- B) Venus
- C) The Moon
- D) Mars
- E) Europa

4.07. What world, further from the sun than the asteroid belt, is most likely to have life?
   A) Mars
   B) Jupiter
   C) Europa
   D) Pluto
   E) Earth

4.08. Formerly considered a planet, Pluto is now classified as
   A) An asteroid
   B) A terrestrial planet
   C) A dwarf planet
   D) An Öort cloud comet
   E) A Jovian planet

4.09. The first exoplanets (extrasolar planets) discovered were mostly
   A) Tiny asteroids
   B) Large asteroidal objects, much like our moon but a little smaller
   C) Terrestrial worlds like our Earth
   D) Jupiter-type planets, but much further from the central star than Jupiter is
   E) Jupiter-type planets, but much closer to the central star than Jupiter is

4.10. Of the exoplanets currently known, many are hot Jupiters. This could be because they are very common, but also because
   A) Hot Jupiters are only found near our Sun in the galaxy
   B) Terrestrial planets can only be seen in the infrared
   C) Cold Jupiters are only seen in the infrared
   D) Hot Jupiters are only found in the spheroidal component in our galaxy
   E) Hot Jupiters are simply easier to find

4.11. We are learning that our solar system is dynamic, meaning that
   A) The planets are constantly orbiting the Sun
   B) The planets periodically reverse the direction the orbit around the Sun
   C) The planets occasionally collide with each other
   D) The planets lose and regain atmospheres every 3 billion years
   E) Over the billions of years, the planets in our solar system have moved closer and farther from the Sun

4.12. Currently, interstellar gas consists of
   A) Pure hydrogen and helium
   B) Mostly elements more massive than hydrogen and helium
   C) Mostly hydrogen and helium gas, and about 2% other elements
   D) 50% hydrogen and 50% iron
   E) Mostly elements more massive that Silicon

4.13. The spectral class sequence, from hot to cold, is
   A) OBAFGKM
   B) ROYGBIV
   C) MVEMJSUNP
   D) TGCFAOQTCD
   E) JFMAMJJASOND

4.14. The Hertzsprung-Russell diagram plots
   A) Temperature vs. time
   B) Temperature vs. luminosity
   C) Pressure vs. luminosity
   D) Mass vs. age
   E) hertzsprungs vs. russells

4.15. Which is not a basic subatomic particle consisting of matter?
   A) Proton
   B) Neutron
   C) Photon
   D) Electron
   E) Neutrino

4.16. To penetrate the Coulomb barrier (i.e., the proton-proton repulsive force) in nuclear fusion, allowing the atomic nuclei to combine in nuclear fusion,
   A) The protons travel slower
   B) The protons quantum-tunnel
   C) The protons travel backwards in time
   D) The protons reflect
   E) The electrons neutralize the protons, allowing the other protons to approach

4.17. White dwarf stars are supported against gravity by
   A) Degeneracy pressure
   B) Thermal pressure
   C) The quark cloud
   D) Quantum tunneling
   E) The centrifugal effect

4.18. Which is not true about the Chandrasekhar Limit
   A) It is about 1.4 solar masses
   B) It determines the limit for electron degeneracy pressure
   C) It gives the highest possible mass for white dwarfs
   D) It plots the time vs. luminosity relation for Cepheid variables.
   E) It says that beyond the limit, a white dwarf star must collapse in upon itself

4.19. A Type Ia supernova occurs

A) When a low main sequence star runs out of hydrogen and attempts to burn helium
B) When a high mass, post-main-sequence star attempts to burn iron in its core
C) When the Chandrasekhar limit is exceeded by a white dwarf in a binary system
D) When two black holes collide!
E) When two white dwarfs collide!

4.20. What is the only one element that absorbs (not releases) energy if it is involved in either fusion or fission reactions.

A) Iron
B) Hydrogen
C) Helium
D) Uranium
E) Carbon

4.21. Dense supernova remnants that are made out of a densely packed mass of neutrons are called

A) White dwarfs
B) Neutron stars
C) Quark stars
D) Black holes
E) Black dwarfs

4.22. Neutrino telescopes tend to be very strange in design because

A) Neutrinos are blocked by the Earth's clouds
B) Neutrinos can't reach the Earth through its atmosphere, even on a clear day
C) Neutrinos have wavelengths too large to be focused by a normal telescope
D) Neutrinos produce so much charge, they would fry the electronics of normal telescopes
E) Neutrinos pass right through normal telescopes, without being gathered

4.23. Dense supernova remnants that are made out of a densely packed mass of quarks are called

A) White dwarfs
B) Neutron stars
C) Quark stars
D) Black holes
E) Black dwarfs

4.24. Dense supernova remnants that are made out of a densely packed mass of matter, so compressed that not even light can escape it, are called

A) White dwarfs
B) Neutron stars
C) Quark stars
D) Black holes
E) Black dwarfs

4.25. In the future, our Sun will run out of fuel and turn into a compact object with a mass of about 0.8 solar masses. If you were to collide this object with a second, identical object, the result would be

A) The formation of a new star, like our Sun is now
B) The formation of a hot Jupiter
C) The formation of a white dwarf
D) A nova event
E) A massive supernova event

4.26. 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

4.27. 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.)

4.28. As you fall through the event horizon of a black hole, what happens to your exit cone (the range of angles you could use to successfully exit the region of the black hole, if you travelled at the speed of light)?

A) it slowly expands to 360°
B) it stays fixed
C) it shrinks to half its original size
D) it gets very narrow
E) it shrinks down to zero size

4.29. Which of the following statements about quantum numbers is NOT true?

A) Quantum numbers are a feature of quantum mechanics
B) Quantum numbers specify the states allowable for certain aspects of a particle, such as its energy or angular momentum
C) Quantum numbers are a feature which define a type of particle called fermions
D) The quantum numbers of fermions are governed by the Pauli Exclusion Principle
E) Quantum numbers are a part of classical physics, i.e., the physics of Newton’s time.

4.30. While a free neutron readily decays into a proton, electron, and neutrino, neutrons in neutron stars are stable because

A) Gravity is so strong, the neutrons cannot escape
B) Relativistic effects force the neutrons to clump together
C) The electrons that would be produced would not have enough energy to reach unoccupied quantum numbers, so are forbidden by the Paulis Exclusion Principle
D) Neutrons are held in place by gluons
E) Neutron degeneracy pressure keeps the neutrons from moving.

4.31. The Pauli Exclusion Principle says that

A) Two fermions, with strongly overlapping wavefunctions, cannot have the same set of quantum values
B) Two photons, with strongly overlapping wavefunctions, cannot have the same quantum values
C) Pressure is related to density and temperature
D) White dwarf stars could be supported against gravity by electron degeneracy pressure
E) Neutron stars could be supported against gravity by neutron degeneracy pressure.

4.32. A kilonova is thought to result from

A) Gas spiraling from a giant star, into its companion white dwarf star
B) A neutron star colliding with another neutron star or black hole
C) A high mass star attempting to ignite iron in its interior
D) One of several hypotheses, such as a very hot star that is producing gamma rays in its interior which convert into electrons and positrons, encouraging massive core collapse
E) A white dwarf star being pushed over the Chandrasekhar limit.

4.33. r process reactions are nuclear reactions

A) Where right-handed molecules are formed
B) Are thought to be responsible for powering hypernova events
C) Where heavy, but unstable nuclei, are rapidly fed neutrons, making high mass atoms
D) That high-mass stars use to burn R
E) By which neutrons decay into protons, electrons, and neutrinos.

4.34. Which of the following is not currently considered a possible explanation for hypernovae?

A) Bipolar jets in the supernova channels the luminosity through the polar jets
B) Exploding supernova material crashes into circumstellar material
C) A neutron star collides with another neutron star or black hole
D) Stellar cores collapse because the gamma rays supporting the cores convert themselves into electron/positron pairs.
E) All of the above ideas are considered reasonable hypotheses for hypernovae.

5: GALACTIC ASTRONOMY

5.01. Which is not a component of our galaxy's spheroidal component?
- A) Galactic halo
- B) Galactic bulge
- C) Galactic nucleus
- D) Population II stars
- E) Galactic disk

5.02. Currently unobserved, these stars are theorized to have been the first generation of stars in the Universe
- A) Population 0
- B) Population I
- C) Population II
- D) Population III
- E) Black holes

5.03. The mysterious central object in our galaxy (probably a supermassive black hole) is called
- A) Sgr A*
- B) The Vela Pulsar
- C) The Milky Way
- D) The Andromeda Galaxy
- E) The strange attractor

5.04 Spiral galaxies
- A) Have very little interstellar material
- B) Have highly flattened disks
- C) Never have bars
- D) Never have arms
- E) Are always essentially perfectly spherical

5.05. Elliptical galaxies
- A) Have highly flattened disks
- B) Often have bars
- C) Have little or no interstellar material
- D) Usually, but not always, have arms
- E) Are always essentially perfectly spherical

5.06. The spiral arms of a galaxy
- A) Are much, much denser than the areas between the spiral arms
- B) Are about as dense as the areas between the arms, but are just brighter
- C) Are much, much less dense than the areas between the spiral arms
- D) Are places where you find concentrations of dark energy
- E) Only look brighter, because of the dark matter between the arms

5.07. The spiral arms of a galaxy
A) Are so bright because they are concentrations of dark energy
B) Are caused by the spiral warpage of space-time
C) Are caused by the passage of a density wave that encourage star formation
D) Cannot yet be explained by astronomical theories
E) Are formed by gas clouds winding around the galaxy in spiral patterns

5.08. You observe two galaxies: one is a spiral bar galaxy with a large nucleus and tightly wound arms; the second has no spiral bar, but a tiny nucleus, and loosely wound arms. These galaxies would be classed as
A) An SBa and an Sc
B) An Sc and an SO
C) An SBc and an Sa
D) An E7 and an SO.
E) An E0 and an SO

5.09. You observe two galaxies, both of which are perfectly round, and neither has spiral arms; upon further study you discover the first contains only Population II stars, while the second has both Population I and II stars. These galaxies would be classed as
A) An SBa and an Sc
B) An Sc and an SO
C) An SBc and an Sa
D) An E0 and an SO
E) An SBc and an E0.

5.10. The interstellar medium of the galaxy consists of
A) White dwarfs, neutron stars, and black holes
B) 50% dust; 50% gas
C) Supermassive black holes
D) 99% dust; 1% hydrogen and helium gas
E) 99% hydrogen and helium gas; 1% dust

5.11. 21 cm radiation is caused by
A) The hiss of the Big Bang, visible throughout the entire sky
B) Photons emitted by ^{21}Ne
C) Protons flipping orientation in a hydrogen atom
D) Electrons flipping orientation in a hydrogen atom
E) Protons flipping orientation in a helium atom

5.12. Currently, we believe that the Milky Way Galaxy spiral structure
A) Definitely consists of two arms
B) Definitely consists of three arms
C) Definitely consists of seven to nine arms
D) Definitely has two arms, but may have three or so more (and a ring or two, too!)
E) Cannot be accounted for with normal laws of gravity

5.13. Which of the following are not structures found in our Milky Way Galaxy?
   A) A disk component
   B) A spheroidal component
   C) A halo
   D) A slash
   E) A bulge

5.14. Which of the following are not structures found in our Milky Way Galaxy?
   A) A nucleus
   B) Spiral arms
   C) A central bar
   D) A pair of giant bubbles
   E) An enormous bosicle

6: CLUSTERS AND ACTIVE GALACTIC NUCLEI

6.01. The group of 30+ galaxies that includes our own is called
   A) The Milky Way
   B) The Virgo Supercluster
   C) Cosmic chains and voids
   D) The Virgo Cluster
   E) The Local Group

6.02. cD galaxies are
   A) Spiral Bar galaxies in the Virgo Supercluster
   B) Small irregular galaxies that are companions to our Milky Way galaxy
   C) Galactic cannibals
   D) Galaxies with intense, unsustainable amounts of star formation
   E) Galaxies with almost the exact relative dimensions as a CD or Blu-ray disk.

6.03. Starburst galaxies are
   A) Spiral Bar galaxies in the Virgo Supercluster
   B) Small irregular galaxies that are companions to our Milky Way galaxy
   C) Galactic cannibals
   D) Galaxies with intense, unsustainable amounts of star formation
   E) Pairs of galaxies colliding with each other

6.04. Radio lobe galaxies
   A) Are delicate, small objects approximately 65 LY long
   B) Are mind-bogglingly huge, up to 10^7 LY long
   C) Are probably powered by micro (0.5 solar mass) black holes
   D) Power the lobes by jets emitted by a powerful pulsar
   E) Power the lobes by jets emitted by a powerful supernova

6.05. The power source of active galactic nuclei and quasars is thought to be
   A) Supermassive (10^6-10^9 solar mass) black holes
   B) Micro (0.5 solar mass) black holes
   C) A dense cluster of O and B stars
   D) Intense, unsustainable amounts of star formation
   E) Pairs of white dwarf stars colliding with each other

6.06. Seyfert galaxies are
   A) Galaxies with intensely bright, compact cores less than a few LY across
   B) Small irregular galaxies that are companions to our Milky Way galaxy
   C) Galactic cannibals
   D) Galaxies with intense, unsustainable amounts of star formation
   E) Pairs of galaxies colliding with each other

6.07. The biggest known structures in our Universe are

A) Chains, sheets, and voids (formed by the distributions of clusters and superclusters), and even clusters of quasars
B) Galaxies (consisting of stars, star clusters, and interstellar material)
C) Galaxy groups and clusters (consisting of galaxies)
D) Superclusters (consisting of galaxy clusters)
E) Megasheets (consisting of intersections of cosmic chains and sheets)

6.08. As the Universe is about 14 billion years old, if we see an object at a distance of 5 billion light years, we are actually seeing the object

A) As it was when the Universe had just formed
B) As it looked when the Universe was 5 billion years old
C) As it looked when the Universe was 7 billion years old
D) As it was when the Universe was 9 billion years old
E) As it was when the Universe was 19 billion years old.

6.09. As the Universe is about 14 billion years old, if we see an object at a distance of 5 billion light years, and if our models say that the object only formed 2 billion years after the formation of the Universe, then we would infer that we are actually seeing the object

A) As it was when it had just formed
B) As it was when it was 5 billion years old
C) As it was when it was 7 billion years old
D) As it was when it was 9 billion years old
E) As it was when it was 14 billion years old.

6.10. If the energy source in a galactic object varies in brightness with timescales of about 3.5 years, we know the energy source

A) Is a Type Ia supernova
B) Is about 3.5 LY across, possibly smaller
C) Is about 3.5 LY across, possibly larger
D) Is a black hole about 3.5 times the mass of the Sun
E) Is a Cepheid variable

7: THE DISTANCE LADDER

7.01. Which is not an important step in the cosmic distance ladder?
- A) Binary neutron stars
- B) Radar ranging to planets
- C) Cepheid variables
- D) Type Ia supernovae
- E) Trigonometric parallax

7.02. The distances to rocky planets within our solar system are typically measured using
- A) Radar ranging
- B) Trigonometric parallax
- C) Spectroscopic parallax
- D) Cepheid variables
- E) Type Ia supernovae

7.03. The radar pulse to a probe takes 200 seconds to reach it and return. What is the distance to the probe?
- A) 200 m
- B) 3×10^{8} m
- C) 3×10^{10} m
- D) 6×10^{10} m
- E) 6×10^{11} m

7.04. The observation that stars wiggle back and forth in the sky, because of the Earth's motion around the Sun, is called
- A) Radar ranging
- B) Retrograde motion
- C) Spectroscopic parallax
- D) Period-Luminosity relation
- E) Trigonometric parallax

7.05. What is the distance to a star that has a parallax angle of 0.1"?
- A) It cannot be determined from the information given
- B) 0.1 pc
- C) 1 pc
- D) 10 pc
- E) 32.6 pc

7.06. Distances to stars can be calculated, by combining information of the star's true luminosity with its brightness in the sky. This method is called

A) Radar ranging
B) Trigonometric parallax
C) Cepheid variables
D) Period-Luminosity relation
E) Spectroscopic parallax

7.07. Comparing HR diagrams of clusters of star, to luminosity-calibrated cluster diagrams, can reveal the distance to the cluster. This is called

A) Radar ranging
B) Cluster fitting
C) Spectroscopic parallax
D) Period-Luminosity relation
E) Cepheid variable

7.08. Cepheid variables change in luminosity because

A) Circumstellar dust clouds block light from them
B) Helium from a neighboring star spirals onto the Cepheid's surface
C) The star exceeds the Chandrasekhar limit
D) The stars accretion disk dumps material onto the star, resulting in massive amount of nuclear fusion in the upper atmosphere of the star
E) A temperature-dependent opacity in the stellar layers (from He ionization) makes the star pulse in size and temperature

7.09. In Cepheid variables, there is a useful relationship between

A) Luminosity and temperature
B) Luminosity and volume
C) Luminosity and age
D) Luminosity and period
E) Mass and temperature

7.10. Cepheids can be used to determine distances to objects as far as

A) Other planets in our Solar System
B) Other nearby stars
C) Other nearby clusters
D) Other nearby galaxies
E) The farthest galaxies known

7.11. The primary reason that Type Ia supernovae are so useful as tools for learning distances is

A) They are extremely uniform in maximum brightness
B) They are very faint, so their radiation is easily blocked by dust
C) Their radiation is mostly produced in X-rays
D) They stay bright for more than a decade
E) They pulse very regularly in brightness, in a way related to their total luminosity

7.12. The Tully Fisher relationship is based upon the principle that
A) The stars vary in luminosity, proportional to the period
B) The farther the galaxy, the faster it is receding
C) The brighter galaxies have broader spectral lines
D) Type Ia supernovae are very reliable in maximum brightness
E) The stars that are closer to us will have a larger parallax shift during the year

7.13. In the Tully Fisher relationship, if two spiral galaxies are the same brightness in the sky, the galaxy with the broader spectral lines is inferred to be
A) Closer to us
B) The exact same distance
C) Further from us
D) A Seyfert galaxy
E) A colliding galaxy

7.14. The Faber Jackson relationship is based upon the principle that
A) The stars vary in luminosity, proportional to the period
B) The farther the galaxy, the faster it is receding
C) Type Ia supernovae are very reliable in maximum brightness
D) The stars that are closer to us will have a larger parallax shift during the year
E) The brighter galaxies have broader spectral lines

7.15. In the Faber Jackson relationship, if two elliptical galaxies are the same brightness in the sky, the galaxy with the broader spectral lines is inferred to be
A) Closer to us
B) The exact same distance
C) Further from us
D) A Seyfert galaxy
E) A colliding galaxy

7.16. Hubble's Law is based upon the observation that
A) The stars vary in luminosity, proportional to the period
B) The farther the galaxy, the faster it is receding
C) The brighter galaxies have broader spectral lines
D) Type Ia supernovae are very reliable in maximum brightness
E) The stars that are closer to us will have a larger parallax shift during the year

7.17. Suppose a galaxy is receding from us at 144 km/s. Using H=72km/s/Mpc, how far away would Hubble's Law predict the galaxy to be?
A) 1 Mpc
B) 2 Mpc
C) 72 Mpc
D) 144 Mpc
E) 720 Mpc

7.18. Suppose a galaxy is 10 Mpc away. Using H=72km/s/Mpc, how fast would Hubble's Law predict the galaxy to be moving from us?

A) 10 km/s
B) 72 km/s
C) 144 km/s
D) 720 km/s
E) 100 km/s

7.19 You are a scientist trying to verify the Hubble Law. You discover a galaxy that you establish (using a Type Ia supernova) to be 3 Mpc away. You measure its recessional speed to be 180 km/s. What would you calculate Hubble's constant (H) to be?

A) H=3 km/s/Mpc
B) H=60 km/s/Mpc
C) H=180 km/s/Mpc
D) H=540 km/s/Mpc
E) H=6000 km/s/Mpc

7.20. Radar ranging can be used to determine the distances to the Moon, Mercury, Mars, and Venus, but not the Sun, because

A) Radio waves from the Sun totally swamp the tiny radio signal we send to it
B) The Sun is so large, we cannot illuminate its entire surface with our signal
C) The Sun is soft, and so absorbs radio signals instead of reflecting them
D) The radio signal passes right through the Sun
E) Unlike on the planets, we have not, and cannot, place radio reflectors on the Sun

7.21. Brighter galaxies are more massive; more massive galaxies have more gravity; more gravity means faster orbital speeds; faster orbital speeds means more Doppler effects on the spectral lines. This line of logic is the basis to what method of determining distances?

A) Faber Jackson method
B) Radar ranging
C) Cepheid variables
D) Standard candles
E) Spectroscopic parallax

7.22. Brighter galaxies are more massive; more massive galaxies have more gravity; more gravity means faster orbital speeds; faster orbital speeds means more Doppler effects on the spectral lines. This line of logic is the basis to what method of determining distances?

A) Spectroscopic parallax
B) Radar ranging
C) Cepheid variables
D) Standard candles
E) Tully Fisher method

8: SPECIAL RELATIVITY

8.01. Einstein's principle of special relativity can be stated as
  A) $E=mc^2$
  B) $E=m^2c$
  C) The Lorentz contraction is invariant to time dilation
  D) The laws of physics are the same in all inertial reference frames
  E) Gravity acts at the speed of light

8.02. As an object approaches the speed of light
  A) Its length decreases
  B) Its relativistic momentum decreases
  C) Its relativistic momentum stays the same
  D) Its relativistic charge decreases
  E) Its color shifts to blue

8.03. For an object traveling at 0.9c, the factor γ is approximately
  A) 0.9
  B) 0.99
  C) 1
  D) 2.29
  E) 7.09

8.04. For an object traveling at 0.99c, the factor γ is approximately
  A) 0.9
  B) 0.99
  C) 1
  D) 2.29
  E) 7.09

8.05. Einstein's response to Michelson's inability to detect the effects of aether was that
  A) The aether simply did not exist
  B) Michelson's apparatus was insufficiently sensitive
  C) Michelson had detected it, but was unwilling to publish his data honestly
  D) The aether affected the detector the same way it affected photons
  E) The aether was being detected, but Michelson's analysis was simply wrong

8.06. Proper length is the length of an object
  A) Measured by a photon traveling along its length
  B) Measured by a stationary observer, as the object travels past it
  C) Measured by an observer traveling in the opposite direction as the object
  D) Measured by an observer who is in a frame of reference such that the object is stationary
  E) Measured by a photon traveling in the opposite direction

8.07. Proper time is measured

A) By a photon
B) At a point that is stationary in your reference frame, so that the time interval is measured at the same point in space
C) By an object moving at ½ the speed of light
D) By an object moving horizontally at the speed of light
E) Measured by a photon traveling in the opposite direction

8.08 Because of time dilation

A) The observed rate of time flow for a moving object is faster than 1 sec/sec
B) The observed rate of time flow for a moving object is slower than 1 sec/sec
C) The speed of light is always the same
D) A moving object becomes longer
E) The size of an object enlarges (or dilates)

8.09. Because of Lorentz contraction, compared to its proper length, an object moving at 0.5c

A) Is shorter by the factor 0.995
B) Is shorter by the factor 0.87
C) Is shorter by the factor 0.50
D) Is shorter by the factor 0.14
E) Is longer by the factor 1.50

8.10. Because of Lorentz contraction, compared to its proper length, an object moving at 0.99c

A) Is shorter by the factor 0.995
B) Is shorter by the factor 0.87
C) Is shorter by the factor 0.50
D) Is shorter by the factor 0.14
E) Is longer by the factor 1.50

8.11. The inhabitants on a passing space station are moving through time at the sluggish rate of 0.5 seconds per second. When they look at you, they see you are

A) Moving through time at the normal pace of 1 second per second
B) Moving through time at the sluggish pace of 0.5 second per second
C) Moving through time at the speedy pace of 2 seconds per second
D) Moving backwards through time
E) Always blueshifted

8.12. Two events are simultaneous in one frame where observer A is stationary. Observer B is in a train moving towards the right. To observer B,

A) Events that occur in the direction of the train’s travel appear to happen sooner
B) Events that occur in the direction of the train’s travel appear to happen later
C) Events that occur opposite the direction of the train’s travel appear to happen sooner
D) The speed of light is greater for objects heading towards a light source
E) The event does not happen

8.13. The equation $E=mc^2$ ultimately means that
- A) Matter must be converted into antimatter
- B) Protons and neutrons are essentially interchangeable
- C) Energy and matter are interchangeable, with c^2 being the conversion factor
- D) Gravity curves the structure of space, and that the speed of light is constant
- E) Doc Brown will stay in the past

8.14. Nonrelativistic momentum is given by p=mv. In contrast, relativistic momentum
- A) Is infinite
- B) Is given as mc^2
- C) Is given as mvc
- D) Is always zero
- E) Is given as γmv

8.15. Relativistic momentum confirms the speed of light as an absolute maximum because
- A) When things stop moving, they disappear from space
- B) A moving object has less mass
- C) Rockets cannot push at the speed of light
- D) If things move too fast, they redshift into oblivion
- E) To reach the speed of light would require an infinite amount of momentum and energy

8.16. If a rocket traveling at 0.5 c fired a pulse of light (traveling at 1c), the pulse of light (as viewed by a stationary observer) would appear to be traveling at
- A) 0.5 c
- B) 0.589 c
- C) 1.0 c
- D) 1.5 c
- E) Hah! Trick question! Nothing can travel at the speed of light

8.17. If a rocket traveling at 0.5 c fired a probe at 0.8c, the probe (as viewed by a stationary observer) would appear to be traveling at
- A) 0.8 c
- B) 0.589 c
- C) 0.93 c
- D) 1.3 c
- E) 1.8 c

8.18. If a rocket traveling at 0.6 c fired a probe at 0.9c, the probe (as viewed by a stationary observer) would appear to be traveling at
- A) 0.8 c
- B) 0.589 c
- C) 0.97 c
- D) 1.3 c
- E) 1.5 c

8.19. From the equation $E^2=m^2c^4$, Paul Dirac inferred that
A) Energy and mass were equivalent
B) $E= -mc^2$ implied the presence of antimatter
C) Neutrinos must have mass
D) Gravitation is caused by particles called gravitons
E) Schrödinger's cat was neither alive nor dead

8.20. Superluminal motion is a term describing
A) The fact that objects cannot travel at the speed of light
B) The fact that while objects cannot travel at the speed of light, they can exceed it
C) That some objects appear to be travelling faster than the speed of light
D) That Type Ia supernovae are extremely bright
E) Light traveling from the planet Krypton

8.21. Superluminal motion is explained by
A) An interesting geometric effect caused by high velocity blobs coming nearly directly towards us
B) The fact that the speed of light has not been a constant in time
C) A temporary suppression of natural laws, as we know them
D) The effects of light being dimmed and then brightened by interstellar dust and gas
E) The results of light speed modified by the luminiferous aether

8.22. Cherenkov radiation is produced by
A) Electrons spinning in a magnetic field
B) Any continuum source, as explained by Kirchhoff's laws
C) Electrons traveling at speeds greater than c
D) The results of light speed modified by the luminiferous aether
E) Electrons traveling at speeds greater than photons (but slower than c), in some medium such as water

8.23. Highly unstable muons are detectable at the surface of the Earth because
A) They are formed in the Earth' crust
B) They have a timescale for decay that is millions of years
C) They are traveling so slowly, that the Earth overtakes them in its orbit
D) They travel so fast that their short lifespans are (by time dilation) extended to a period long enough so they can reach the Earth's surface
E) They are made of antimatter, so they explode as they reach the Earth

8.24. Travelers moving with respect to each other, see each other aging more slowly. This leads to a counterintuitive notion called the "twin paradox." The resolution to this is that
A) Einstein's theory of relativity is wrong
B) Quantum mechanics is wrong
C) A wormhole can be used to circumvent the time stream
D) The overall mass of the system must be conserved
E) The situation is not, after all, symmetric, since one observer accelerates at least once

8.25. For an object traveling at 0.9c, the factor β is
A) 0.9
B) 0.99
C) 1
D) 2.29
E) 7.09

8.26. There is an old joke that asks, "If you were in a spaceship, traveling at the speed of light, what would happen when you turned on your headlights?" What is the true answer to this question?
A) The photons would not be able to leave the body of your headlights
B) You would fly along with the photons,
C) You would see the photons leave you at the speed of light
D) The photons would be redshifted to extremely long wavelengths
E) The whole joke is based on an impossible premise. You cannot travel at the speed of light, therefore you cannot give an answer based in physics.

8.27. Imagine a Universe completely empty of everything, except for you floating in space (in a life support suit), and your toolbox which is filled with a huge variety of cool, sophisticated equipment. As you float in space, you decide to pass the time by measuring how fast you are coasting through the empty Universe. How can you do this?
A) Turn on your space flashlight, and measure the speed of light
B) Fire a bullet, and when the bullet comes to rest, measure your speed compared to the stationary bullet
C) Create an explosion; measure your speed from the reference frame of the explosion's center
D) Travel in a circle
E) All this is nonsense; how fast you are moving in space is arbitrary, and depends completely on your reference frame

8.28. You start an experiment when you are 25 years old. You travel at a speed v (relative to a space station you're passing) so fast that the factor γ is 3.0. After fifteen years of this travel

A) Your age is 28
B) Your age is 30
C) Your age is 40
D) Your age is 50
E) Your age is 55

8.29. You start an experiment when you are 25 years old. You travel at a speed v (relative to a space station you're passing) so fast that the factor γ is 3.0. A colleague on the space station is also 25 years old. After fifteen years of this travel, you observe that

A) The age of your colleague is 28
B) The age of your colleague is 30
C) The age of your colleague is 40
D) The age of your colleague is 50
E) The age of your colleague is 55

8.30. Imagine a hollow metal ball, which is perfectly reflective on the inside, but otherwise its interior is a perfect vacuum. You put the ball on a scale in your lab on Earth, and determine that this ball has a mass M_B. Through a tiny glass window into the ball, you shoot a stream of photons and when you are done, you cover up the window with another mirror so the photons cannot escape—they are trapped inside the ball. You determine that the energy stored in all the photons in the ball is E_P. You now put the ball back on the scale—what does the scale say the mass of the ball is?

A) M_B
B) $M_B + E_P$
C) $M_B + (E_P/c^2)$
D) $M_B - (E_P/c^2)$
E) $\gamma(M_B - (E_P/c^2))$