Correct answers shown in boldface. Be sure to write your name and student ID number on the first blank at the bottom of the form, the exam version number and letter on the second (subject) one, and your section number (7 for 11:00, 8 for 12:00) in the "period" one. If you need to erase an answer, please do so carefully and remove all of the old mark.

1. A neutron star is mostly neutrons because
   a. the huge pressure has caused its electrons to merge with its protons to make neutrons
   b. the protons it used to contain have collected into a proton star
   c. it has a proton core, but neutrons cover the surface
   d. antiprotons have annihilated all the protons it used to contain
   e. the protons have collapsed into a black hole in its core

2. The Sun will end its life as
   a. a neutron star
   b. a pulsar
   c. a black hole
   d. a brown dwarf
   e. none of the above

3. Stars on the main sequence all
   a. are in hydrostatic equilibrium
   b. have the same mass
   c. have the same temperature
   d. have the same diameter
   e. there is no property in common among main sequence stars

4. A star will become a red giant when
   a. it begins to convert H to He
   b. when its composition changes
   c. when it can no longer convert H to He in its core
   d. when it gains mass
   e. just before it explodes as a supernova

5. If you add mass to a white dwarf to "bulk it up" above 1.4 solar masses,
   a. it will get smaller and smaller and finally collapse into a neutron star
   b. it will develop strong coronal lines because of its high surface temperature
   c. it will increase in radius in proportion to the cube root of the additional mass
   d. the new matter will cause it to cool on the surface and get fainter
   e. the matter will disappear beyond its event horizon and we will not know what happens

6. The cosmic background radiation provides strong evidence that
   a. the early Universe was very cold, only 3 degrees above absolute zero
   b. stars formed almost immediately in the early Universe
   c. the Universe has been expanding steadily forever
   d. the Universe evolved from a hot, dense state
   e. a lot of energy was produced through hydrogen fusion early in the life of the Universe

7. An astronomer is designing a new telescope to use in space. The Hubble Space Telescope operates at wavelengths close to 500nm (1nm = 10^{-9} meter). The new telescope is to be used at 50,000nm (100 times the HST wavelength and in the infrared).
   a. such a telescope is not needed because nothing emits at 50,000nm
   b. such a telescope would be better built at sea level
   c. to keep costs down, the new telescope should be a refractor instead of a reflector
   d. such a telescope will need to be 100 times larger in diameter than HST to see the same level of detail
   e. because we already have observed so much at 50,000nm, the new telescope won't find anything new.

8. Gravity is an important force in shaping the Universe because
   a. it is the strongest force we know
   b. it works well over long distances and there is no antigravity
   c. actually, it does not play much of a role off the surface of the earth
   d. it holds the protons and neutrons in the nucleus of an atom
   e. it is the only inverse r squared force

9. We know that the Universe is only about 6% protons and neutrons - baryons - because
   a. if there were more, the Universe would be closed
   b. fusion reactions would have produced more lithium and maybe heavier elements if there had been more baryons
   c. we don't really know this because most of the mass is in a poorly understood form
   d. because the things around us are made of 6% baryons
   e. from measuring the properties of dark matter

10. Sunspots are
    a. regions where strong absorption lines reduce the output of the sun
    b. regions where a strong magnetic dipole interferes with the outward transport of energy
    c. clouds above the surface of the sun that block some of its light
    d. where solar flares have carried away some of the energy to cool the solar surface
    e. where solar storms bring cooling flows

11. If we have a container of hydrogen gas sitting in a laboratory on Earth, why doesn't it turn into helium?
    a. because deuterium is required for fusion b. because oxygen is needed for a reaction
    c. because an electric spark is needed **d. because the temperature and pressure are too low**
    e. it will become helium if you wait long enough

12. Two stars both have spectral type A. One has a luminosity that is 1000 times larger than the other. What parameter differs the most between these two stars?
    a. temperature b. color **c. size** d. spin rate e. distance

13. The upper limit on the size of a star is set by
    a. the size of cloud fragment that can form b. the gravitational field of a cloud
    c. there is no upper limit **d. the stability against photon pressure**
    e. the mass require to get the core hot enough for conversion of Si to Fe

14. A white dwarf does not collapse further because
    a. it is converting H to He b. it is held up by neutron pressure
    c. its electrons can't be squeezed together any more d. its dark matter can't be compressed
    e. it is so hot that the internal pressure is too large

15. Planetary nebulae are
    a. in the process of forming planets b. material ejected by nova explosions
    c. the ejected outer layers of a dying star d. the precursors to black holes
    e. material left over from the protoplanetary disks of protostars

16. These days, astronomers usually use _____ for obtaining observations of visible photons from stars
    a. their eyes b. refracting telescopes c. galvanometers **d. electronic detectors**
    e. notebooks of previous astronomers

17. We will eventually be able to locate where the Big Bang occurred
    a. by accurate measurements of galaxy velocities and distances
    b. by measuring the redshifts of very distant quasars
    c. using gravitational lenses
    d. by measuring anisotropies on the cosmic background radiation
    e. it is not possible to locate the big bang in these ways

18. Astronomers locate black holes by
    a. looking for regions in space that appear not to have any background stars
    b. detecting the X-rays emitted by matter heated in the process of falling into the black hole
    c. using dark matter detectors
    d. looking for unexplained deflections in the motions of stars through space
    e. there is no good way to look because they are so black

19. When matter has been "used up" in a massive star and is ejected, it
    a. is exhausted and plays no further role in the Universe
    b. can form into white dwarfs and neutron stars but no longer can form normal stars
    c. gets caught up in interstellar clouds and eventually may form into new stars
    d. escapes into intergalactic space where it can eventually form new galaxies
    e. none of the above

20. Astronomers cannot look directly back to further than when the Universe was 300,000 to 500,000 years old because
    a. before that, the Universe was too crowded with stars
    b. visible photons were not produced until the Universe was 300,000 years old
    c. dust in the early Universe absorbed the light
    d. the Universe was made of dense, ionized gas that was opaque to light
    e. of Olber's paradox

21. What came before the Big Bang is
    a. described by subnuclear physics
    b. another Universe
    c. revealed in our understanding of the Planck era
    d. a vexing philosophical question for science, as for religion and other disciplines of thought
    e. a sea of quarks that formed the raw material for the Universe

22. How does the average density of the Universe affect its predicted fate?
    a. a high density Universe will expand more vigorously than a low density one
    b. if the Universe has a high density, its expansion is expected to reverse and it will collapse
    c. if the Universe has a high density, it will eventually form many more galaxies than now
    d. a high density Universe will have many more stellar collisions
    e. if the density is too high, the Universe will form too few heavy elements like lithium

23. To a physicist studying the early Universe, unification is
    a. a political movement to discredit unpopular theories
    b. a theory combining aspects of biology and physics
    c. a merger of observational and theoretical results to get a consistent picture of the early Universe
    d. a process for combining different theories in a computer code
    e. the concept that the fundamental forces of physics unified into one force law under extreme conditions

24. The period of very rapid inflation in the early Universe solves the mystery
    a. **of why the Universe is at the critical density**
    b. why the Universe is expanding
    c. why balloons are sometimes used to illustrate the expansion
    d. why there is so much empty space
    e. how the ratio of hydrogen to helium is what it is

25. Hubble's Law implies that
    a. galaxies must be far away **b. the Universe is expanding**
    c. the Universe is open d. the other galaxies were shot from the Milky Way
    e. we are near the center of the Universe

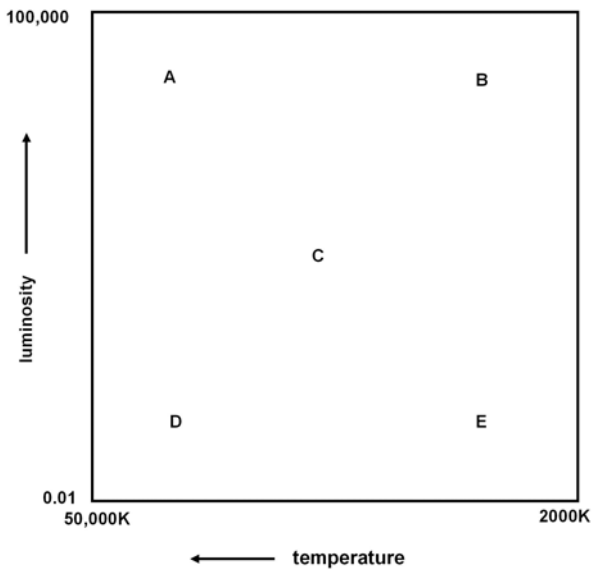
26. The Sun's photosphere has a temperature of about 6000 degrees. What wavelength regime would be most useful for studying the photosphere?
    a. X-rays b. long wavelengths c. far infrared light d. radio waves **e. visible light**

27. We are confident the output of the sun has remained nearly constant over billions of years because
    a. the theory of hydrogen fusion indicates so b. weather records show little change with time
    c. fossils show similar life forms to some that are still around
    d. the solar activity counteracted the effects of its gravitational contraction
    e. none of these

28. The sequence of spectral types with hydrogen line strength that Miss Cannon discovered is actually a sequence
    a. of percentage of hydrogen in a star **b. of temperature** c. of apparent magnitudes
    d. of velocity through space e. of levels of activity such as sunspots

29. To measure the luminosity of the sun from the earth, we need to measure
    a. Earth's distance from the sum
    b. the flux Earth receives from the sun (the apparent brightness of the sun at the earth)
    c. the sun's composition
    d. all of a., b., and c.
    e. **both a. and b**.

30. In the figure at the right, which star has the smallest surface area?
    a. star A b. star B
    c. star C **d. star D**
    e. star E



31. The basic properties that control the current status of a star are
    a. age, mass, initial composition
    b. temperature, distance, color
    c. spectral type, composition, temperature
    d. distance, magnitude, color
    e. age, color, spectral type

32. The Sun's output is so stable because
    a. release of energy by gravitational contraction makes up for any change in the rate of fusion
    b. the Sun doesn't produce much energy, so its reserves will last a long time
    c. the Sun rotates fast enough to keep everything inside well mixed
    d. the Sun has only small sunspots
    e. pressure of Sun's gas just balances gravitational contraction, maintaining constant conditions inside the sun

33. If the earth were further from the Sun than it actually is, the parsec (assuming we kept the same definition) would be
    a. larger b. smaller c. the same d. could not be determined

34. The most important aspect (to us) of the material ejected by dying stars is
    a. it makes beautiful nebulae that inspire our interest in astronomy
    b. it shields us from dangerous radiation emitted by the dying star itself
    c. it reduces the mass of the star so its end is less violent
    d. we are made of material ejected by dying stars a long time ago
    e. it causes interstellar extinction

35. Which of the following can escape from inside the event horizon of a black hole?
    a. particles of matter b. particles of antimatter c. quarks
    d. gamma rays **e. none of the above**

36. Supernovae occur when
    a. the core of a star blows up because it gets too hot
    b. the outer layers of a star collapse onto the core, and explode in the shock wave sent back from the impact
    c. a layer of hydrogen on the surface of the star undergoes fusion converting hydrogen to helium
    d. a catastrophe in the stellar nucleus sends a heat pulse out through the star
    e. the neutrinos escape from the core of the star, causing it to cool and collapse

37. Massive stars cannot burn iron because
    a. they cannot form iron to burn
    b. iron does not react with other elements
    c. they cannot reach high enough temperatures to burn iron
    d. when iron burns, it removes energy and causes the star to collapse
    e. rather than burning in fusion, the iron nucleus splits into lighter elements

38. The assumption that the Universe is homogeneous on very large scales is
a. a starting point for ideas about the Universe, called the Cosmological Principle
b. contradicted by the expansion shown in Hubble's Law
c. just an assumption with nothing to back it up
d. now known to be incorrect, an issue called the Horizon Problem
e. shown to be wrong by the structure on the 3 degree background

39. In the first half of the Twentieth Century, Harvard rose to the top among world observatories because its directors
a. Raised money to build a major new telescope
b. Established strong interdisciplinary ties with the physics department
c. Hired women astronomers
d. Moved it to an outstanding site for observations
e. Got a lot of funding from the Federal Government

40. Observatories are put into space to
a. get above bad weather and clouds
b. keep NASA busy doing things in the public interest
c. as a demonstration of the capabilities of astronauts
d. to observe at wavelengths where the photons do not reach the ground
e. to get them closer to the stars

41. The “flatness” problem refers to
a. why space-time is not curved
b. the high level of uniformity in the cosmic background radiation
c. how the Universe got itself into a shape like a giant pancake
d. how the Universe came out at just the density that balances its gravity
e. the large amount of mass in forms we do not understand

42. The cooling rate of SN 1987A showed that
a. it was so full of hot gas it could only lose energy slowly
b. it was a Type I supernova
c. it was still deriving a lot of energy from the new neutron star at its core
d. it contained huge amounts of newly formed cobalt
e. its neutrinos were captive and contributing heat

43. Most of the helium in the Universe was made
a. when the first generation of stars fused their hydrogen into helium
b. in reactions in supernova explosions
c. it was created at the beginning from fundamental particles
d. in ways we are still trying to understand
e. in fusion reactions during the first few minutes of the Universe

44. To make higher resolution pictures of astronomical objects, one can
a. change the shape of the surface of the telescope mirror to interfere the light, not image it
b. observe at longer wavelengths
c. use more than one telescope and bring their outputs together in an interferometer
d. observe for longer times to gather more signal
e. use the sharpen filter in PhotoShop

45. The best way to "weigh" the Universe – see how much mass it contains – is to
    a. count up all the mass in the galaxies
    b. use Newton's and Kepler's laws
    c. study the sizes of the faint emission features in the cosmic background radiation
    d. measure the light output from the dark matter
    e. wait and see if its expansion continues or slows down

46. To determine the relative amounts of dark matter and baryons, we can
    a. measure the amount of lithium
    b. measure the contrast of the emission features on the cosmic background radiation
    c. compare the dark matter in stars with their hydrogen and helium
    d. measure the brightness of distant supernovae to get accurate distances to the remote Universe
    e. do both a. and b.

47. The underlying cause of the solar cycle is
    a. winding up of the sun's magnetic field due to differential rotation
    b. oscillations in the center of the sun
    c. changes in the temperature of the sun
    d. the sunspots appear at different latitudes on the sun
    e. changes in the rate of coronal mass ejections

48. Heavy elements like silver and gold are formed
    a. on planetary surfaces
    b. in planetary nebulae
    c. in main sequence stars
    d. in supernova explosions
    e. in the Big Bang

49. Hydrogen fusion can produce energy because
    a. at the end the electrons in the atoms have gone to lower energy levels and given off the energy they lost
    b. the atoms join together into bigger molecules, and the molecular binding energy is released
    c. the fusion products weigh a little less than the input materials, and the mass that is lost appears as energy
    d. the helium that is produced has been heated to very high temperature
    e. the high pressure where the fusion takes place yields some of its energy

50. The early stages of development of the Universe
    a. **are surprisingly well understood through a combination of physics and astronomy**
    b. are really hard to study because conditions were so extreme
    c. cannot be studied well because the redshift has shifted all the light into the low frequency radio region
    d. may have been either steady state or big bang in nature
    e. were a time when a totally different physics operated