Final; Phys 100   Name _____

1. (5 points) According to Heisenberg's uncertainty principle, $\Delta x \Delta p \geq h/4\pi$, decreasing uncertainty about the location of a particle comes at the expense of increasing uncertainty about its

(a) Pressure

(b) Probability

(c) Mass

(d) Momentum

(e) Intersubjectivity

2. (5 points) Which of the following is *not* a major difficulty for practical (fast) interstellar space travel with human crews?

(a) The need for high accelerations that humans can't survive

(b) Huge amounts of fuel needed to achieve speeds close to light

(c) The lack of shortcuts such as navigable wormholes

(d) Planet-antiplanet pairs that exist in the quantum vacuum

(e) The impossibility of warp drive without probably nonexistent negative mass

3. (5 points) A wormhole

(a) Consists of an inverted black hole that spews matter out all the time

(b) Is a pure science fiction invention with no basis in physics

(c) Would, if real and stable, act as a shortcut between far-apart regions of spacetime

(d) Exists at the center of every gas giant

(e) Illustrates the Einstein-Griffiths paradox in quantum gravity

4. (5 points) If you put water under high enough pressure you can achieve

(a) Nuclear fission

(b) Accelerated beta decay

(c) Ice, even at high temperatures

(d) Extremely low gravity

(e) Large increases in length dilation

5. (5 points) You have a radioactive sample in the lab with a half-life of 60 days. You measure its activity in a lab where the background radiation is 2 counts/second, and find 8 counts/second. What would you have measured the activity to be 180 days ago, when the sample was just bought?

(a) 50 counts/second

(b) 61 counts/second

(c) 69 counts/second

(d) 70 counts/second

(e) 94 counts/second

6. (5 points) Which of the following is *not* one of the fundamental forces of nature?

(a) Friction

(b) Electromagnetism

(c) Gravity

(d) The weak nuclear force

(e) The strong nuclear force

7. (5 points) Which of the following photons has the highest energy?

(a) Infrared, because infrared indicates heat

(b) Red, because that is the warmest visible color

(c) Green, because it's the color for photosynthesis

(d) Violet, because it is the coolest visible color

(e) Ultraviolet, because it has the highest frequency

8. (5 points) What does "space opera" refer to?

(a) An avant-garde musical performance on a space station

(b) A genre of science fiction where events take place at galactic scale

(c) High-frequency sound wave patterns within gas giant atmospheres

(d) A short musical act taking place during a scene change in a grand opera

(e) Congressional debates over funding of the US space program

9. (5 points) Which of the following is a theory of gravity?

(a) Quantum mechanics

(b) General relativity

(c) Time dilation

(d) The center of a gas giant

(e) Stellar evolution

10. (5 points) Imagine that you were in a spaceship going at 99.9% of the speed of light relative to Earth. Which of the following would be true?

(a) Everything in the spaceship would move as in slow motion

(b) You would see every object in the spaceship as smaller than usual

(c) Everything inside the spaceship would look and act as normal

(d) You would see every object in the spaceship as larger than usual

(e) Everything in the spaceship would move as if it were speeded up

11. (5 points) Which of the following is *not* an "existential risk"—a risk that threatens human civilization—that scientists today worry about?

(a) Superintelligent AI's that get out of human control

(b) Global warming

(c) Nuclear warfare

(d) Earth colliding with a black hole

(e) Cheap genetic engineering creating a superlethal virus

12. (5 points) The pressure you experience within a fluid is due to

(a) Quantum measurement

(b) The magnetic field of the Earth

(c) The small difference between the masses of quarks

(d) The weight of the fluid column above you

(e) The speed of light being constant in all reference frames

13. (5 points) Quantum mechanics is not directly relevant to one of the following questions. Which one?

  (a) The behavior of the very early universe, just after the big bang

  (b) How to pack more and more computer memory into smaller circuits

  (c) The structure of the periodic table of elements

  (d) The psychological component of medical treatments

  (e) How to understand the interaction of materials with gamma radiation

14. (5 points) In what kind of path would the planets move if no force acted on them?

  (a) They would continue in their present orbits, since they already have no force on them

  (b) Larger elliptical orbits

  (c) Parabolas, like any projectile

  (d) Straight line with an acceleration of 9.8 m/s^2

  (e) Straight line with constant speed

15. (5 points) Will the Earth ever collapse to form a black hole?

  (a) No; it's not massive enough

  (b) Yes, once the radioactivity of its core is exhausted

  (c) No; it doesn't have enough Hydrogen

  (d) Yes; all rocky planets become black holes

  (e) No; it's too far away from the galactic core

16. (5 points) Which of these features in *The Algebraist* is unlikely according to our current understanding of physics?

  (a) Machine sentience

  (b) Treatments that can extend human life for centuries

  (c) Craft capable of travel into the depths of gas giants

  (d) The existence of a religion such as "The Truth"

  (e) A galaxy-spanning network of stable wormholes

17. (5 points) Suppose you observe a single radioactive nucleus. The length of time until that particular nucleus decays is

(a) unpredictable because of the practical difficulties of obtaining all the information needed to make the prediction

(b) unpredictable because of fundamental uncertainties arising from quantum physics

(c) predictable only if the speed of light does not fluctuate

(d) predictable, provided you know the precise nuclear state of this nucleus

(e) predictable from the known half-life of the nucleus

18. (5 points) Which of the following is an argument used to suggest that intelligent, technology-using alien life is not very common in the universe?

(a) Quantum mechanics makes life of any form extremely improbable

(b) The Fermi paradox: if they exist, they should have already been here

(c) Gas giants are extremely rare, and therefore life does not have many opportunities to evolve

(d) The universe contains too many black holes that suppress gamma radiation

(e) The Heisenberg uncertainty principle makes alien life forms almost impossible to detect

19. (5 points) According to Newtonian physics, force is proportional to

(a) Diameter

(b) Velocity

(c) Acceleration

(d) The speed of light squared

(e) Planck's constant

20. (5 points) Which of the following is *false*?

(a) Objects, whether they are moving or not, do not contain forces

(b) The velocity of an object can be zero even if the position is changing

(c) Any change in velocity must be due to a net force

(d) All interactions involve change, and therefore forces

(e) The acceleration of an object can be non-zero even at an instant when its velocity is zero

21. (20 points) Fill in approximate (ballpark) values for the following, using the following numbers: $10^{-15}, 10^{-10}, 1, 1, 10^2, 10^5, 10^7, 10^{10}, 10^{17}, 10^{24}$.

(a) Radius of the Earth: _____ m

(b) The distance to the star nearest to the Sun: _____ c·years

(c) The mass of a typical adult human: _____ kg

(d) Size of our galaxy (the Milky Way): _____ c·years

(e) Size of an atom: _____ m

(f) Number of electrons in the most common element in the universe: _____

(g) Size of an atomic nucleus: _____ m

(h) Number of atoms in an everyday object: _____

(i) Age of our universe: _____ years

(j) Number of Joules of energy in a mass of 1 kg ($c = 3 \times 10^8$ m/s): _____

22. (20 points) The charge of an electron is -1.60×10^{-19} C (C stands for "Coulomb," the standard international charge unit). The electron mass is 9.11×10^{-31} kg.

The charge of a proton is equal and opposite to the charge of an electron. The mass of a proton is 1.67×10^{-27} kg.

The equation for the electrical attraction between two particles with charges q_1 and q_2 separated by a distance d is

$$F_E = -k \frac{q_1 q_2}{d^2}$$

Here, the constant $k = 8.99 \times 10^9$ N·m²/C².

The equation for the gravitational attraction between two particles with masses m_1 and m_2 separated by a distance d is

$$F_G = G \frac{m_1 m_2}{d^2}$$

Here, the constant $G = 6.67 \times 10^{-11}$ N·m²/kg².

(a) Calculate the ratio of the gravitational attraction between an electron and a proton to the electrical attraction between an electron and proton. (Find F_G/F_E.)

(b) In the light of this calculation, explain why physicists working with atomic or subatomic scale phenomena routinely ignore the effects of gravity.

23. (20 points) Modern physics is counterintuitive: it often goes against our everyday expectations of how the world should work. Give *two* examples of cases where what you've learned this semester was counterintuitive, and explain how in a paragraph for each case.

24. (20 points) What do you think might be the *intellectual* value of science fiction? (I'm not interested in whether you find it entertaining.) Illustrate your argument with at least one example involving *The Algebraist.*

25. (20 points) You took this course because it was a requirement. Given your experience, argue whether students in your position should or should not be required to take a physics course. Use at least one thing you have learned this semester as an example in your argument.