

1. (5 points) Which of the following reflects the present best judgment of physicists concerning space travel?

- (a) The engineering problems in making stable wormholes will take fifty years to resolve
- (b) High-speed interstellar transportation of human crews is not feasible
- (c) We will not need space travel if we train psychics to visualize other planets
- (d) Interstellar travel depends on whether we have a large enough source of antimatter
- (e) Superconducting magnets will let us overcome the speed-of-light barrier

2. (5 points) In  $\Delta v \Delta x \geq h/4\pi m$ , what does the quantity  $\Delta x$  refer to?

- (a) The difference between successive measured values of a particles' position  $x$
- (b) The de Broglie wavelength of a large number of electrons making up a sample
- (c) The likelihood of obtaining an exact measurement of  $x$ , if given an exact value of  $v$
- (d) A statistical measure, akin to standard deviation, describing the probability distribution for  $x$
- (e) The experimental error in  $x$  measurement introduced by the imperfections of equipment

3. (5 points) What the difference between alpha ( $\alpha$ ) radiation and infrared (IR) radiation?

- (a)  $\alpha$  is generated by gravitational force, IR is due to the weak nuclear force
- (b)  $\alpha$  is an elementary particle, IR is composed of gluons
- (c)  $\alpha$  is very low in total energy, IR particles are highly destructive
- (d)  $\alpha$  is a Helium nucleus, IR is a form of electromagnetic wave
- (e)  $\alpha$  is , IR is

4. (5 points) You lift an object with weight  $w$  by a height  $h$ . By approximately how much does the object's mass increase?

- (a) It does not increase at all
- (b)  $wc^2/h$
- (c)  $wh/c^2$
- (d)  $\frac{1}{2}wh^2/c$
- (e)  $\sqrt{w}/ch$

**5. (5 points)** If you built a “Dyson sphere” to completely enclose a star

- (a) The star would become totally invisible to the rest of the universe
- (b) The energy within would be effectively converted to “dark energy”
- (c) The sphere would still radiate electromagnetically, due to its temperature
- (d) The accumulation of energy within would lead to the creation of a black hole
- (e) The intensity of beta radiation within the sphere would quadruple

**6. (5 points)** Which of the following is a good estimate for the *smallest possible* amount of time it would take to communicate a signal to the farthest point on Earth, from where you stand? (*Hint:* You don’t need to remember any precise numbers. Only one option is even remotely reasonable.)

- (a)  $10^{-24}$  seconds
- (b)  $10^{-10}$  seconds
- (c)  $10^{-1}$  seconds
- (d)  $10^8$  seconds
- (e)  $10^{18}$  seconds

**7. (5 points)** Which of the following is a physics mistake in *The Algebraist*?

- (a) Gravity going down to zero at the center of a large planet
- (b) Spaceships that can travel faster than half the speed of light
- (c) Worrying about relativistic mass increase when towing a wormhole at high speed
- (d) The existence of a gas giant planet that is larger than Jupiter
- (e) Being able to build a craft that dives into the high pressure areas deep in a gas giant

**8. (5 points)** Which of the following technologies relies on our understanding of quantum physics?

- (a) Modern consumer electronics
- (b) Heavier than air flight
- (c) Warp drive
- (d) Bridges with large spans
- (e) Internal combustion engines

**9. (5 points)** If the total force on an object is non-zero, which of the following will change?

- (a) Its distance to the center of the Earth
- (b) Its electrical energy
- (c) Its acceleration
- (d) Its amplitude
- (e) Its velocity

**10. (5 points)** Which of the following represents an area of physics that is not properly understood yet?

- (a) The nature of temperature
- (b) Line spectra
- (c) Radioactive decays
- (d) Quantum gravity
- (e) Magnetism

**11. (5 points)** In our universe, which of the following measurements does *not* change relative to an observer?

- (a) The speed of massive objects
- (b) Mass
- (c) Length
- (d) Time intervals
- (e) The speed of light

**12. (5 points)** Which is *not* true according to Aristotelian physics?

- (a) The Earth is flat
- (b) Earth is at the center of the universe
- (c) The natural place of air is higher than that of water
- (d) The Earth is subject to change and decay, but not the heavenly spheres
- (e) Without a force, moving objects slow down

**13. (5 points)** For what phenomena that we encountered in the lab was the weak nuclear force responsible?

- (a) Microwave cavities
- (b) Beta decay
- (c) Atomic spectra
- (d) Friction
- (e) Lens focusing

**14. (5 points)** According to Heisenberg's uncertainty principle, an object's location and speed cannot be determined simultaneously. Why do we not notice this uncertainty with a car driving down the road?

- (a) We do not have a good theory of quantum gravity
- (b) Our experimental equipment cannot measure such huge uncertainties
- (c) The binding energies of the car's particles damp down the uncertainties
- (d) Everyday automobiles move too slow compared to the speed of light
- (e) A car is very massive, so the uncertainties are extremely small

**15. (5 points)** If you were in a spaceship far from any external gravitational influences, accelerating at " $2g$ ," what would you feel? ( $g$  is the acceleration due to gravity of the surface of the Earth.)

- (a) As if your mass had doubled
- (b) As if your weight had doubled
- (c) No different, because  $h$  is always constant
- (d) No different, because you're still beyond the event horizon
- (e) Nothing, because you'd be immediately squashed to death

**16. (5 points)** As the Earth orbits the Sun, in what direction does the total force on the Earth point?

- (a) Toward the Sun
- (b) Away from the Sun
- (c) Forward along Earth's orbit
- (d) Backward along Earth's orbit
- (e) The total force on earth is zero

- 17. (5 points)** We are able to analyze the composition of distant stars because
- (a) We have sent small robots to the stars and retrieved samples
  - (b) We can break apart the gravitational waves we detect from the stars into alpha-forms
  - (c) We can do spectroscopy and look for the line patterns of different elements
  - (d) All stars are alike, so if we know the composition of the sun, we know all others as well
  - (e) The spot pattern on star surfaces depend on the chemicals they are made of
- 18. (5 points)** Most of the matter/energy in the observed universe
- (a) Consists of charged neutrinos
  - (b) Is in the form of iron
  - (c) Has no gravitational effect
  - (d) Is “dark”—little is known about it
  - (e) Produces lethal muon showers throughout the universe
- 19. (5 points)** A rocket blasts off from the surface of the Earth and heads off into space. The gravitational attraction between the rocket and the Earth will
- (a) remain constant
  - (b) remain constant until the distance of the moon, but then abruptly become zero
  - (c) decrease regularly with distance, and become zero shortly beyond the moon
  - (d) decrease regularly with distance, but never become exactly zero
  - (e) increase until the distance of the moon, then gradually decrease
- 20. (5 points)** If you were to dive deeper and deeper into a liquid moon, which of the following would you observe?
- (a) Weight increases, pressure increases
  - (b) Weight decreases, pressure decreases
  - (c) Weight decreases, pressure increases
  - (d) Weight is constant, pressure decreases
  - (e) Weight increases, pressure is constant

21. (15 points) You know the following bits of physics:

- The bond energies in biological molecules are close to the energies of ultraviolet photons.
- A molecular bond is broken if a molecule absorbs a single energetic photon—not by gradually absorbing multiple photons. (Remember the photoelectric effect.)
- Ultraviolet photons have higher frequencies than visible photons, and red is the lowest frequency visible light.
- For photons,  $E = hf$ .
- Cells can turn cancerous if their genetic material is damaged.

Use these facts to put together an explanation for why exposure to ultraviolet radiation increases your risk of skin cancer, while you can sit around bathed in very bright red light and it will not cause cancer. (Though it might drive you bananas.)



**23. (15 points)** Three questions about revolutionary transitions in the history of physics:

(a) Give an example of an idea from Aristotelian physics that was later superceded by Newtonian physics. Explain why the Newtonian idea works better.

(b) Give an example of an idea from Newtonian physics that was later superceded by relativity. Explain why the relativistic idea works better.

(c) Give an example of an idea from Newtonian physics that was later superceded by quantum physics. Explain why the quantum idea works better.

**24. (20 points)** Two conceptual questions about quantum randomness:

(a) When each radioactive nucleus will decay is unpredictable—physicists can only give a certain probability it will decay or survive within a certain time period. Use an everyday example, such as a class of students flipping coins, to explain the concept of the *half life* of a large population of radioactive atoms.

(b) Say a friend tells you that the notion that the world works in a fundamentally random manner does not make sense. After all, randomness means anything could happen! But we live in an orderly universe. If physicists say quantum physics is fundamentally random and also talk about “the laws of physics” they are inconsistent. Set this friend straight—explain how there is no inconsistency here.

**25. (15 points)** Say you want to correct the misunderstanding of someone who thinks that since gravitational attraction decreases as a rocket gets farther away from Earth, weight should *increase* as we go down closer to the center of the Earth. How would you convince them that the weight at the center is zero, without resorting to "physicists say so?" For example, saying that the gravitational attraction of a spherical shell is zero if you're on the inside does not count, because you're just taking my word for that. (*Hint:* if you felt gravity at the center of the earth, in which direction would you be pulled?)

**26. (20 points)** Many scientists today are convinced that Artificial Intelligence (AI) is possible, that achieving machine sentience is possible within our current understanding of physics. No one has achieved anything close to a genuine AI yet, but many scientists judge the *prospects* for AI to be good in the long run. But then, there are also some who disagree. Their reasons vary; they can involve anything from a suspicion that consciousness has something to do with unsolved problems of quantum gravity to convictions that something like a “soul” as understood in spiritual belief systems is required and that the soul has to be an entity wholly beyond physics.

Answer the following. *I'm not looking for set answers, but some intelligent discussion. My ideal is that a student who succeeds in a liberal arts science course should have something sensible to say when discussing such matters.*

(a) Give some reasons you think the pro-AI people might be correct.

(b) Give some reasons you think the anti-AI people might be correct.

(c) What's your position on the AI question? Explain. (It'll have to be speculative, but that's OK.)

(d) What would it take (particularly in the way of evidence or argument) to convince you that you were *wrong* about your position?

(e) In what way did what you have learned in this course influence your answers, considering that AI is not directly a physics question? (In other words: Why is physics relevant here?)