PHY 201: Space, Time and Motion
Spring 2018, Final exam
May 16, S109, 8:00 - 9:45 a.m.
Use $g = 10$ m/s^2
No calculators.

Name: _____

Student Number: _____

TA: _____

Date: _____

Exam, Form: $\boxed{\text{A}}$

## Section 1. Matching of scientific terms and concepts (5 pts.)

_____ encompass

_____ advent

_____ oblige

_____ disdain

_____ prejudice

_____ incidental

_____ lucidity

_____ parity

_____ oscillate

_____ allude

_____ epitomize

_____ perpetual

_____ vain

_____ centrifugal

_____ treatise

_____ vortex

_____ continuum

_____ quiescent

_____ spurious

_____ traverse

(a) occurring by chance in connection with something else

(b) in a state or period of inactivity or dormancy

(c) never ending or changing

(d) moving or tending to move away from a center

(e) make (someone) legally or morally bound to an action or course of action

(f) be a perfect example of

(g) producing no result; useless

(h) clarity of expression; intelligibility

(i) surround and have or hold within

(j) suggest or call attention to indirectly; hint at

(k) the arrival of a notable person, thing, or event

(l) travel across or through

(m) the feeling that someone or something is unworthy of one's consideration or respect; contempt

(n) a continuous sequence in which adjacent elements are not perceptibly different from each other, although the extremes are quite distinct

(o) a written work dealing formally and systematically with a subject

(p) preconceived opinion that is not based on reason or actual experience

(q) a mass of whirling fluid or air, especially a whirlpool or whirlwind

(r) vary in magnitude or position in a regular manner around a central point

(s) the state or condition of being equal

(t) apparently but not actually valid

Section 2. Multiple choice (23 pts.)

1. A beam projects horizontally from a vertical wall. The weight of the beam produces a moment (torque) which attempts to break the beam. If the length of the beam is now doubled (everything else remaining the same) then the breaking moment is increased by a factor of

   (a) 2

   (b) $\sqrt{2}$

   (c) 4

   (d) 8

   (e) none of the above

2. A bead of mass m is hung by a string from the ceiling. A second bead of mass m is hung by an identical string from the first bead. A third bead of mass m is likewise hung from the second bead. What is the tension in the string connecting the first and second beads?

   (a) mg

   (b) $1.5\ mg$

   (c) $2\ mg$

   (d) $2.5\ mg$

   (e) none of the above

3. According to the theory of relativity,

   (a) moving particles lose mass.

   (b) a rod moving rapidly is lengthened.

   (c) a clock moving rapidly ticks more quickly.

   (d) all forms of energy have mass-like properties.

   (e) momentum is not conserved in high-speed collisions.

4. An airplane flies at a constant speed in a straight line. Which of the following must be true?

   (a) the weight of the plane must be zero

   (b) the buoyant force on the plane must be zero

   (c) the drag on the plane must be zero

   (d) the net force on the plane must be zero

   (e) none of the above are true

5. A bucket of water is placed in an elevator. An ice cube floats in the water, with 90% of the cube submerged. During the time that the elevator moves upward at a constant speed,

   (a) more than 90% of the cube will be submerged

   (b) 90% of the cube will still be submerged

   (c) less than 90% of the cube will be submerged

6. Which of the following was *not* a character participating in Galileo's *Dialogues Concerning Two New Sciences*

   (a) Salviati

   (b) Simplicio

   (c) Sagredo

   (d) Stevinus

   (e) All of the above were characters.

7. Two smooth identical diameter solid spheres, one made of copper the other made of glass, are released in an aquarium. The copper sphere falls faster because it experiences

    (a)   a smaller drag

    (b)   a smaller buoyant force

    (c)   a greater gravitational force

    (d)   all of the above

    (e)   actually, the two balls fall at the same rate

8. A ball is tossed upwards at a speed of 20 m/s. How high does it get at the peak of its flight?

    (a)   15 m

    (b)   20 m

    (c)   25 m

    (d)   30 m

    (e)   45 m

9. Mars is one-tenth as massive as Earth and is one-half the radius of earth. Based on this data, what is the acceleration of gravity, g, on the surface of Mars (compared to on Earth)?

    (a)   about 1/8 that of Earth

    (b)   about 2/5 that of Earth

    (c)   about 3/4 that of Earth

    (d)   about 11/2 that of Earth

    (e)   none of the above

10. A *positron* is a positively charged electron: it has the same mass but the *opposite charge* as the electron. In the medical diagnostic technique known as *positron emission tomography* (PET), a radioactive isotope is injected into the blood of a person. This radioactive isotope undergoes a reaction called "positron emission decay", in which a proton transforms into a neutron and a positron. The locations of the emitted positrons can then be detected by an image scanner. Consider the following reaction which involves Carbon-11 decaying into Boron-11, a positron (e^+), and a neutrino (ν):

$$^{11}_{6}\text{C} \longrightarrow {}^{11}_{5}\text{B} + e^+ + \nu + \text{kinetic energy}$$
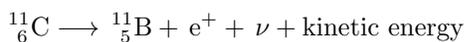
How many *neutrons* go into, and come out of, this positron emission decay reaction?

    (a)   5 in, 6 out

    (b)   11 in, 11 out

    (c)   6 in, 5 out

    (d)   17 in, 16 out

    (e)   it is impossible to tell from this equation

11. With which of the following statements would Newton agree?

    (a)   It is necessary that God exists, and that he exists *always* and *everywhere.*

    (b)   Blind metaphysical necessity cannot produce the variety of things we see around us.

    (c)   Gravity really exists, and is responsible for the motions of celestial bodies and our seas.

    (d)   The parts of animals' bodies move at the command of the will, that is, by the vibrations of the Spirit.

    (e)   All of the above.

12. Approximately how fast does Earth's moon move in its orbit around Earth?

   (a)   800,000 km/day

   (b)   80,000 km/day

   (c)   8000 km/day

   (d)   800 km/day

   (e)   80 km/day

13. A mass suspended from a string swings back and forth in a vacuum (no drag). Make a force (free-body) diagram for the mass at the moment it passes through the bottom of its swing in the space below. The net force on the mass at this instant is

   (a)   zero

   (b)   upward

   (c)   downward

   (d)   forward (in the same direction it's swinging)

   (e)   backward (opposite to the direction it's swinging)

14. Which of the following statements must be true for a moving body, M, which experiences a force directed toward a fixed point S.

   (a)   The orbit of M about S lies in an unaltered flat plane.

   (b)   For any two equal intervals of time during its orbit, equal areas are swept out by a line drawn from S to M.

   (c)   Kepler's third law of planetary motion does not necessarily apply to mass M.

   (d)   The speed of M is large when it is closer to (and slower when it is farther from) S.

   (e)   All of the above are, in fact, true.

15. Which of the following observations did Newton *not* use to support his universal law of gravity?

   (a)   Saturn's moons obey Kepler's third law of planetary motion.

   (b)   Jupiter's moons obey Kepler's third law of planetary motion.

   (c)   Earth's moon obeys Kepler's third law of planetary motion.

   (d)   The six known planets obey Kepler's third law of planetary motion.

   (e)   Actually, Newton used all of these to support his universal law of gravity.

16. A cannon is fired horizontally from the top of a 45 meter tall cliff with a muzzle velocity of 40 m/s. Neglecting air resistance (drag) what is its speed when it strikes the ground?

   (a) $10\sqrt{2}$ m/s

   (b) $20\sqrt{2}$ m/s

   (c)   40 m/s

   (d)   50 m/s

   (e)   none of the above

17. A 2 kg block rests on a ramp with a 45-degree incline. A cord attached to the back of the block stretches over a pulley at the top of the ramp, and a 1-kg block is hung from the other end of the cord. Make a force (free-body) diagram for the mass on the ramp in the space below. What is the acceleration of this block down the ramp?

    (a) $\frac{2}{\sqrt{2}}g$

    (b) $\frac{2}{3}g$

    (c) $\frac{1}{2}g$

    (d)   zero (it doesn't accelerate)

    (e)   actually, the block accelerates up the ramp

18. In proving that a body subject to a centripetal force must sweep out an area proportional to time, Newton employed his

    (a)   first law of motion alone

    (b)   first and third laws of motion alone

    (c)   first and second laws of motion alone

    (d)   second and third laws of motion alone

    (e)   first, second and third laws of motion

19. Which of the following is a restatement of the *principle of induction*?

    (a)   We should admit no more causes in nature than are both true and sufficient to explain appearances.

    (b)   To the same effects, we should assign the same causes, insofar as possible.

    (c)   The laws of nature can be obtained by generalizing from many individual observations.

    (d)   The results of experiments can be deduced logically from correct axioms

    (e)   Nature is inanimate and hence cannot strive toward final causes.

20. A copper coin and an aluminum coin are balanced on opposites sides of a scale. When the humidity of the air increases,

    (a)   the copper coin tends to sink and the aluminum coin tends to rise.

    (b)   the aluminum coin tends to sink and the copper coin tends to rise.

    (c)   the coins remain balanced.

21. A treasure chest filled with Spanish gold bullion sits on the bottom of a crystal-clear lagoon in the Caribbean sea, at a depth of about 64 feet. If the chest has no water in it (you may assume that it is full of atmospheric-pressure air from when the treasure was put in), then about how much force would be required to open the 10 inch× 10 inch lid (which has an area of 100 square inches)?

    (a)   2,800 pounds

    (b)   280 pounds

    (c)   28 pounds

    (d)   2.8 pounds

    (e)   0 pounds

22. Which of the following observations can not be made by an observer standing in Milwaukee?

    (a)   a full moon setting at midnight
    (b)   a crescent moon in opposition to the sun
    (c)   Jupiter in a crescent phase
    (d)   all of the above observations could, in fact, be made by an observer in Milwaukee
    (e)   actually, none of the above observations could be made by an observer in Milwaukee

23. Two stretched guitar strings are the same length and are made of the same material. String A is found to vibrate at a higher frequency than string B. This might be because

    (a)   string B has a smaller diameter.
    (b)   string B has a larger diameter.
    (c)   string B is under a greater tension.
    (d)   all of the above are possible explanations.
    (e)   none of the above can explain this curious phenomenon.

Section 3. Binary star system (6 pts.)

The brightest star in the night sky is Sirius, the so-called "dog-star." Sirius is actually comprised of two stars (Sirius A and Sirius B) which are orbiting each other about their common center of mass. In this problem, we will study the orbital motion of such a binary star system. Suppose that there are two stars, A and B. Star A is twice as massive as our sun ($M_A = 2M$) and star B has the same mass as our sun ($M_B = M$). Also: the distance, d between the center of star A and the center of star B is $d = 3R$, where R is some large unit of length.

1. First, make a sketch of this binary-star system with appropriate labels. Place an X at the position of the center of mass of this system. How far (in terms of R) is the center of mass position X from star A? From star B?

2. Now, make two force (free body) diagrams: one for star A and one for star B. How many forces are acting on star A? On star B?

3. Use Newton's second law to determine the speed of star A (v_A) and the speed of star B (v_B). Your answer should be expressed in terms of G, M_s and R. Hint: you may assume that each star is moving at a constant speed in a circle around the center of mass.

4. Which of the two stars is moving faster? Which of the two stars takes longer to go around in a circle?

5. Which of the two stars feels a greater force?

6. Do the two stars obey Kepler's third law of planetary motion, assuming that they are orbiting around the center of mass position? Explain.

Section 4. Cart problem (6 pts.)

Think back to the lab experiment in which you studied the conservation of momentum while working with colliding carts on a track. In this problem, let's begin by refreshing our memory about conservation of momentum. Suppose that two carts, A and B are placed on the track. Cart A has a mass $M_A = 2$ kg; cart B has a mass $M_B = 1.5$ kg. A stiff spring is placed between them and they are gently pressed together, compressing the spring. When the carts are released, they move apart in opposite directions down the track. You may neglect friction between the carts and the track when you answer the following questions.

1. If the speed of cart A is 6 meters per second relative to the track, then what is the speed of cart B relative to the track? What principle or law did you use in arriving at your answer?

2. If the center of mass of the system is initially at the center of the track, where is the center of mass of the two-cart system 1 second after the carts are released?

3. What is the kinetic energy of this system before releasing the spring? What about after releasing the spring? Has energy been created?

4. Now, let's redo our previous analysis, but let's take into account Einstein's theory of relativity! To make our calculations easier (so we don't have to use a calculator), assume that the speed of light, c, is just 10 meters per second. (You should recall that the relativistic momentum is now $p = \gamma m_0 v$, rather than just $p = m_0 v$, as Newton taught.) So: if the speed of cart A is 6 meters per second relative to the track, then what is the speed of cart B relative to the track?

5. Suppose that a little gnome rides on each of the carts. What is the speed of cart B as measured by the gnome on cart A? (You should round your values to the nearest whole number to simplify your calculations.) From the perspective of cart A, is cart B moving faster than the speed of light? Is this surprising?

6. Suppose the gnomes have identical watches. Each sees his own watch tick once every second. What is the approximate time between ticks of gnome A's watch, as measured by gnome B? Again, feel free to round numbers to make calculations easier...

Section 5. Essay questions (5 pts.)

Answer of the following essay question. Be sure to use correct grammar and spelling, clear and logical reasoning, and graceful and convincing style.

1. **Newton and Einstein** In ancient times, people believed in geo-centrism: that the Earth was at rest at the center of the universe. Later, people began to believe in helio-centrism: that the Sun was at rest at the center of the universe. What do you think: is it possible to know whether some thing (whether the Earth or the Sun) is truly at rest? Your answer to this question should provide a mature view which draws on your understanding of both Newton's *Principia* and Einstein's *Relativity*.