PHY 151/201 Spring 2023, Final exam

Name: $g = 10$ m/s^2 or 32 ft/sec^2

Section 1. Matching of scientific terms and concepts; some definitions on next page (5 pts.)

______ disparity	(a) conceal from view
______ subsist	(b) based on observation or experience, rather than pure logic
______ perforce	(c) used to express necessity or inevitability
______ aphelion	(d) moving or tending to move away from a center
______ tacit	(e) voluntarily cease to keep or claim; give up
______ occult	(f) clear or obvious to the eye or mind
______ propensity	(g) agreement or harmony
______ metaphor	(h) remain alive
______ devoid	(i) clarity of expression; intelligibility
______ ebony	(j) heavily loaded or weighed down
______ aperture	(k) representative or symbolic of something else
______ empirical	(l) action or speech that deliberately makes someone annoyed or angry
______ manifest	(m) zero
______ oblique	(n) an opening, hole, or gap
______ celerity	(o) a tendency to be too ready to believe that something is real or true
______ confound	(p) swiftness of movemen
______ relinquish	(q) entirely lacking or free from
______ laden	(r) a difference in level or treatment
______ centrifugal	(s) an inclination to behave in a particular way
______ lucidity	(t) inclined at other than a right angle
______ accord	(u) heavy blackish or very dark brown timber from a mainly tropical tree
______ null	(v) the action of going out of or leaving a place
______ egress	(w) cause surprise or confusion
______ credulity	(x) understood or implied without being stated
______ provocation	(y) the point in an orbit furthest from the sun

Section 2. Multiple choice (22 pts.)

1. A projectile is fired in a vacuum from a flat surface with an initial horizontally speed of 40 m/s and a vertical speed of 30 m/s. What is the speed of the projectile at the apogee (highest point) of its flight?

   (a) 0 m/s
   (b) 30 m/s
   (c) 40 m/s
   (d) 50 m/s
   (e) none of the above

2. A pendulum on the Earth's surface has a period of one heartbeat. What would be the period of the same pendulum when placed on the surface of a planet having twice Earth's mass (all other things remaining the same)?

   (a) $1/\sqrt{2}$ heartbeat
   (b) 1 heartbeat
   (c) $\sqrt{2}$ heartbeat
   (d) 2 heartbeats
   (e) none of the above

3. A half-moon might appear directly overhead to an observer standing on Earth

   (a) around sunset
   (b) at midnight
   (c) around mid-day
   (d) any of the above are, in fact, possible
   (e) never

4. The descent of stones in Europe and in America have the same cause. This follows from

   (a) Newton's first rule of reasoning.
   (b) Newton's second rule of reasoning.
   (c) Newton's first law of motion.
   (d) Newton's second law of motion.
   (e) Archimedes' principle

5. In order to increase the weight which can be hung from the end of a (weightless) beam protruding horizontally from a wall by a factor of eight one can

   (a) double the length of the beam
   (b) halve the length of the beam
   (c) quarter the length of the beam
   (d) double the diameter of the beam
   (e) halve the diameter of the beam

6. Two forces, ten newtons and four newtons, act simultaneously on a two kilogram mass. What is the minimum acceleration of this mass?

   (a) zero
   (b) 3 m/s^2
   (c) 5 m/s^2
   (d) 7 m/s^2
   (e) none of the above

7. A solid body submerged in a fluid displaces its own volume of this fluid. This is

   (a) the principle of inertia
   (b) the principle of induction
   (c) archimedes' principle
   (d) the principle of relativity
   (e) none of the above

8. A syringe at sea level is attached to one end of a clear plastic tube, whose other end is dipped into a bucket of mercury. When the syringe is drawn upwards, the mercury will be drawn upward to a maximum height of approximately

   (a) 10 cm
   (b) 70 cm
   (c) 76 cm
   (d) 96 cm
   (e) it depends on the diameter of the tube

9. Two syringes are attached by a thin plastic tube. The plunger of one syringe has a diameter of 1 mm; the other has a diameter of 1 cm. The entire apparatus—both syringes and the tube— are filled with water. When a 2 Newton force is applied to the plunger of the smaller syringe, the plunger of the larger syringe feels a force of

   (a) 0.2 Newton
   (b) 2 Newton
   (c) 20 Newtons
   (d) 200 Newtons
   (e) none of the above

10. Two pebbles of the same shape and material (but different sizes) are dropped in a pool of water. Which will fall more slowly through the water?

   (a) The small one, because drag affects it more.
   (b) The small one, because the buoyant force is greater.
   (c) The large one, because drag affects it more.
   (d) The large one, because the buoyant force is greater.
   (e) Neither: they will both fall at the same speed.

11. According to Pascal, which of the following were errors which rendered a correct understanding of the adhesion of bodies absolutely impossible?

    (a) air has no weight
    (b) elements (such as water) have no weight (when submerged) in themselves
    (c) fluids may be raised to any height whatsoever by means of a pump
    (d) all of the above
    (e) none of the above

12. Consider a "planetary model" of the atom in which several electrons orbit around a positively charged atomic nucleus. The force holding each electron in its orbit is a $1/r^2$ attractive force. One can conclude that the orbital periods of the electrons are then proportional to the ratio of their orbital radii to the

    (a) first power.
    (b) 3/2 power.
    (c) second power.
    (d) 5/2 power.
    (e) none of the above

13. The mass of Mercury is about 5% that of Earth; its radius is about 40% that of earth. What would be the acceleration of a rock dropped near Mercury's surface?

    (a) about 1 m/s^2
    (b) about 3 m/s^2
    (c) about 10 m/s^2
    (d) about 30 m/s^2
    (e) it depends on the rock's mass

14. A 4 kg mass is spun in a circle of radius 4 cm at a speed of 2 cm per second. How much centripetal force is required?

    (a) 2 milli-Newtons
    (b) 3 milli-Newtons
    (c) 4 milli-Newtons
    (d) 6 milli-Newtons
    (e) none of the above

15. The driver of a front-wheel drive Subaru, sitting patiently at a stop sign, suddenly hits the gas pedal. The frictional force which the road exerts on the wheels is now

    (a) forward on the front wheels and forward on the back wheels
    (b) forward on the front wheels and backward on the back wheels
    (c) backward on the front wheels and forward on the back wheels
    (d) backward on the front wheels and backward on the back wheels

16. Consider the crucifixion of Jesus. Which of the following statements is consistent with an *Aristotelian* approach to understanding this historical event?

    (a) the *material* cause was metal nails and a wooden cross
    (b) the *formal* cause was the crucifixion of Jesus itself
    (c) the *efficient* cause was the Jewish leaders plotting to have Jesus sentenced to death
    (d) the *final* cause was the redemption of the world from sin
    (e) all of the above are consistent with an Aristotelian understanding of Jesus' crucifixion

17. A spaceship flies toward a planet at 0.5 c. It fires a rocket at the planet at 0.5 c with respect to its cannon. According to Einstein's theory of relativity, what is the speed of the rocket compared to the planet?
   (a) 1.16 c
   (b) 1.00 c
   (c) 0.80 c
   (d) 0.50 c
   (e) none of the above
18. In order to double the surface area of a cube, its edge length must be increased by a factor of
   (a) $2^{1/3}$
   (b) $2^{1/2}$
   (c) $2^{2/3}$
   (d) 2^2
   (e) none of the above
19. By means of his rotating bucket thought-experiment, Newton argued that
   (a) time passes at different rates according to different people
   (b) absolute rotational motion is sometimes measurable
   (c) moving objects are shorter than stationary objects
   (d) absolute linear motion is sometimes measurable
   (e) only relative motion is ever measurable
20. If a ball falls one unit of distance during its first second of fall, then how many units of distance does it fall during its fourth second of fall?
   (a) 1
   (b) 2
   (c) 3
   (d) 4
   (e) none of the above
21. Consider a system consisting of two bodies which approach each other and collide. The momentum of this system remains unchanged so long as
   (a) the bodies remain intact
   (b) the bodies do not stick together
   (c) the bodies' gravitational attraction is ignored
   (d) there are no external forces acting on the bodies
   (e) actually, the momentum of this system can *never* change.
22. A canoe floats in a pool of water. A rock rests in the bottom of the canoe. A red line marks the water level on the side of the pool. When the rock is removed from the canoe and thrown into the pool, the water level
   (a) rises above the red line
   (b) remains at the level of the red line
   (c) falls below the red line

Section 3. Free body diagrams(5 pts.)

A 5 kg mass is suspended from a cord attached to the ceiling of an elevator. A 10 kg mass is suspended by a second cord from the bottom of this 5 kg mass. The elevator is initially stationary.

1. Draw a free body diagram for the 10 kg mass. As always, only include forces acting on this mass. Neglect the buoyant force due to air.

2. Now draw a free body diagram for the 5 kg mass. Again, only include forces acting on this mass.

3. What is the tension in the top cord? The bottom cord?

4. Now suppose the elevator begins to accelerate upward at 3 m/s^2. What are the tensions in each cord? Which is more likely to break?

5. If you were riding in the elevator, could you determine if the elevator was *accelerating* or not? If so, how?

Section 4. Train game (5 pts.)

Suppose that you are riding on a train at constant speed over smooth, level tracks. It is a long ride. To amuse yourself, you are tossing an apple straight up in the air, and catching it, one second later, when it falls back into your hand.

1. How much time does the apple take to reach its maximum height? Don't overthink this.

2. What is the maximum height that the apple reaches (in feet)? (Use $g = 32$ ft/ sec^2).

3. What was the vertical speed of the apple when it leaves your hand (in feet per second)?

4. Suppose, now, that the moment you release the apple, the train conductor suddenly slams on the breaks, causing the train to undergo uniform deceleration for two seconds (note that this is a *horizontal* deceleration!). This time, instead of landing in your hand, the apple falls into the lap of a passenger 5 feet in front of you, ending your amusing game. What was the deceleration of the train?

5. If the train comes to a complete stop in two seconds, what was the initial speed of the train at the moment the breaks were hit?

Section 5. Carts problem (4 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? Explain.

4. Now, for the PHY 201 students: 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, show that the speed of cart B relative to the track is $v_B = \sqrt{50}$ m/s, or about 7 m/s.

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? Use the speeds given above (6 and 7); round your answer to one significant figure. From the perspective of the gnome on cart A, is cart B moving faster than the speed of light?

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, just round your answer to one significant figure to do the calculations.

Section 6. PHY 151/201 essay (4 pts.)

Answer the following essay prompt using neat handwriting, logical and relevant argumentation, and correct grammar, spelling and punctuation. You will be graded on how clear, well-written and informative your essay is.

1. What was the most interesting thing that you learned in PHY 151/201 this semester?