PHY 151/201 Spring 2020, Final exam

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

Due: upload your hand-written solutions to MyWLC by 12:30, Monday, May 11!

Honesty: you may use the textbook, but nothing (and nobody) else.

Have a good exam week and a blessed Summer!

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

_____ quicksilver
_____ profane
_____ innate
_____ syzygy
_____ laden
_____ celerity
_____ immutable
_____ disparity
_____ null
_____ relinquish
_____ counterpoise
_____ endeavor
_____ egress
_____ proverbial
_____ chord
_____ spurious
_____ manifest
_____ aperture
_____ inappreciable
_____ rancor

(a) inborn; natural
(b) a great difference
(c) swiftness of movement
(d) try hard to do or achieve something
(e) a straight line joining the ends of an arc
(f) unchanging over time or unable to be changed
(g) go out of or leave (a place)
(h) voluntarily cease to keep or claim; give up
(i) secular rather than religious:
(j) a conjunction or opposition, especially of the moon with the sun
(k) an opening, hole, or gap
(l) bitterness or resentfulness
(m) clear or obvious to the eye or mind
(n) too small or insignificant to be valued or perceived
(o) a factor, force, or influence that balances or neutralizes another
(p) the liquid metal mercury
(q) not being what it purports to be; false or fake
(r) well known, especially so as to be stereotypical
(s) heavily loaded or weighed down
(t) having or associated with the value zero

Section 2. Multiple choice (25 pts.)

1. 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.

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 half 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. 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

4. A dropped ball falls how far *during* its third second of fall (from $t = 2$ to $t = 3$)?
   (a) 5 meters
   (b) 10 meters
   (c) 15 meters
   (d) 20 meters
   (e) 25 meters

5. 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

6. 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

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 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

9. 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

10. 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

11. Which of Aristotle's four causes did Descartes (as well as Galileo and many other modern scientists after Descartes) explicitly reject as "explaining nothing"

    (a) material
    (b) formal
    (c) efficient
    (d) final
    (e) all of the above

12. 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

13. 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

14. The *Pequod*, a whaling ship from Nantucket, sails due west at 1 km/hr with respect to the sea. Moby Dick, the great white whale, swims westward at a speed of 5 km/hr with respect to the *Pequod*. What is the speed of Moby Dick with respect to Captain Ahab, who hobbles westward across the deck of the *Pequod* at 1 km/hr, shaking his fist and cursing?

    (a) 7 km/hr eastward
    (b) 3 km/hr eastward
    (c) 3 km/hr westward
    (d) 7 km/hr westward
    (e) none of the above

15. 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

16. 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

17. A body with mass two and speed three approaches a stationary body of mass five. What is the speed of the center of gravity of this two-body system?

    (a) 1/3
    (b) 1/2
    (c) 3/2
    (d) 3/4
    (e) none of the above.

18. 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.

19. Newton argued that a violation of his third law of motion would necessarily imply a violation of

    (a) the principle of induction
    (b) Newton's first law of motion
    (c) Newton's second law of motion
    (d) Kepler's first law of planetary motion
    (e) the constancy of the speed of light

20. Newton's proof that a moving body remains in the same plane when it is subject to only a centripetal force (Book I, Section II, Proposition I) relies on

    (a) Kepler's second law of planetary motion
    (b) Kepler's first law of plenary motion
    (c) Archimedes' principle
    (d) the principle of inertia
    (e) all of the above

21. Consider the 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. 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

22. 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

23. 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

24. Consider the orbit of the moon around the Earth. According to Newton's analysis: in one minute, the moon falls approximately

    (a) 15 inches
    (b) 15 feet
    (c) 32 feet
    (d) actually, it falls about 15 feet in one second
    (e) The moon is not falling.

25. 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

Section 3. Ramp problem (5 pts.)

A 2 kg mass is placed near the top of a very long frictionless ramp with a gradual (30 degree) slope. The block is released from a state of rest at time $t = 0$.

1. Sketch this situation, and then (next to it), draw a free body diagram representing all of the forces acting on the block.

2. For each of these forces, describe, in clear language, the equal and opposite force (in the sense of Newton's third law). Do these forces act on the block itself?

3. Is there a net force on the block? If so, then what is the block's acceleration? If not, then why not?

4. What is the speed of the block at time $t = 2$? What is its location at this time?

Section 4. **PHY 151 students only:** Train game problem (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, half a second later, when it falls back into your hand.

1. How much time does the apple take to reach its maximum height?

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

3. Suppose that the moment you release the apple, the train conductor suddenly slams on the breaks, causing the train to undergo uniform deceleration for three 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?

4. What is the final speed of the train relative to the tracks, after the deceleration has ended?

Section 5. **PHY 201 students only** Gas centrifuge problem (5 pts.)

A gas centrifuge is a tall vertical cylindrical tube which spins rapidly about its central axis. It can be used to separate substances of different densities (such as different isotopes of uranium from a mixed uranium gas). How does it do this?

Recall how in our final laboratory experiment, the acceleration of the elevator made a hanging weight feel heavier. That is: an upward acceleration could be interpreted as a downward force, or an "effective weight," acting on the mass.

Similarly, in a spinning centrifuge, the inward centripetal acceleration that is keeping the gas in a circular orbit can be interpreted as an outward force, or "effective weight" acting on the gas filling the tube. We sometimes call this apparent outward weight a "centrifugal force".

Now, suppose that a particular gas centrifuge tube has a radius R and spins with a rotational period T (it spins around once every T seconds). Also, assume that the gas inside spins around like a solid body, That is: all the gas inside the tube spins around at the same frequency as the tube itself.

1. Write down an equation for the speed, $v(r)$, of a tiny bit of gas of mass which is rotating around at a distance r from the tube's axis. Hint: how far does this bit of gas travel in a circle, and how long does it take to go that far?

2. Write down an equation for the centripetal acceleration, a_c, of this tiny bit of gas. In which direction is it accelerating? Hint: remember how the formula for centripetal acceleration depends on speed and orbital radius!

3. Recall that the hydrostatic pressure at a depth, r, beneath a fluid depends on the weight of all the fluid above it. Similarly, in our gas centrifuge, a bit of gas spinning at radius r feels a pressure that depends on the "effective weight" of all the fluid that is at smaller radius. So: what is the hydrostatic pressure of the fluid at a distance r from the axis of rotation? (Hint: you may need to integrate the equation for hydrostatic pressure, since the centripetal acceleration is a function of r).

4. What is the net force exerted by the surrounding fluid on a tiny element of fluid of mass m and volume V at distance r from the axis of rotation? Hint: find the pressure on the top and bottom faces of the fluid element.

5. In a gas consisting of several different isotopes of some element, what do you think happens to gas isotopes which have the lowest density? In particular, where do they tend to accumulate, at the center of the tube or at the periphery? Why?

Section 6. Final essay (5 pts.)

1. What was the most interesting thing that you learned in PHY 151/201 this semester? Explain clearly, using specific references to the text and/or the lectures. You will be graded not only on how interesting and relevant your essay is, but also on the correctness of your grammar, the logical coherence of your arguments, and the rhetorical style of your writing.