PHY 151/201 — Spring 2022, 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.)

________ persevere	(a) concise and exact use of words
________ contend	(b) an inclination to behave in a particular way
________ condensation	(c) referring to Aristotle's practice of walking around while teaching.
________ jurisprudence	(d) indiscriminate or casual
________ induction	(e) the action of coming together
________ conspire	(f) a ratio inexpressible as a ratio of integers
________ propensity	(g) unable to be changed
________ shrewd	(h) a departure from the main subject
________ subterranean	(i) enabling a person to learn something themself
________ incommensurable	(j) the conversion of a vapor or gas to a liquid
________ heuristic	(k) the inference of a law from particular instances
________ parallax	(l) seem to be planning or working together
________ congress	(m) continue even in the face of difficulty
________ Euclidean	(n) the power or scope to act as one pleases
________ allegory	(o) faithfulness to a person, cause, or belief
________ brevity	(p) having or showing sharp powers of judgment
________ promiscuous	(q) a story or picture with a hidden meaning
________ fathom	(r) a system of geometry dealing with ordinary experience
________ immutable	(s) occurring beneath earth's surface
________ peripatetic	(t) assert something as a position in an argument
________ liberty	(u) the theory or philosophy of law
________ digression	(v) a unit of length equal to six feet
________ corollary	(w) a feeling of repulsion
________ abhorrence	(x) a proposition derived from one already proved
________ fidelity	(y) when an object's position appears different when viewed from different positions

Section 2. Multiple choice (15 pts.)

1. In order to double the volume 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

2. A 1000 kg race car travels around a circular track at a constant speed of 50 meters per second. The radius of the track is 1000 meters. The frictional force between the tires and the road provides the centripetal force keeping the car moving in a circle. What is the minimum coefficient of friction, μ, required to do so?
   - (a) 1/4
   - (b) 1/3
   - (c) 1/2
   - (d) 3/4
   - (e) none of the above

3. A projectile is launched at a 45 degree angle above a flat horizontal surface. The horizontal component of its muzzle velocity is 20 m/s. What is its horizontal range?
   - (a) 15 meters
   - (b) 30 meters
   - (c) 45 meters
   - (d) 80 meters
   - (e) 90 meters

4. Aluminum has a specific gravity of about 3. How much upward force (in grams) does it take to suspend a 1 cubic centimeter aluminum cube underwater?
   - (a) 0; it floats
   - (b) 1
   - (c) 2
   - (d) 3
   - (e) 4

5. According to Einstein's theory of relativity
   - (a) light slows down a bit when it travels from air into water
   - (b) energy is conserved but mass is not necessarily conserved
   - (c) massless particles, such as photons of light, have momentum
   - (d) all of the above
   - (e) none of the above

6. 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
7. The hydrostatic pressure at the bottom of a cylinder of water is 1 Pascal. If the cylinder is now placed in an elevator that is accelerating upward, the hydrostatic pressure on the bottom would
   (a) increase
   (b) decrease
   (c) remain the same
8. There was a lunar eclipse on Sunday, May 15. At the moment of the eclipse,
   (a) the sun could not be seen from Earth because the moon was blocking it.
   (b) the sun and the moon were in conjunction.
   (c) the sun and moon were in opposition.
   (d) the moon was in its "new" phase.
   (e) wait a minute! There was no lunar eclipse on Sunday, May 15.
9. The forces acting on a submerged sphere—weight, drag, and buoyancy—balance in such a way that the net force acting on the sphere is zero. Therefore
   (a) the object is stationary
   (b) the object is falling at a constant velocity
   (c) the object is rising at a constant velocity
   (d) all of the above are, in fact, possible
   (e) the object is accelerating
10. In order to sharpen the note played by a stretched string by one octave, one might
    (a) halve the length of the string
    (b) double the tension in the string
    (c) halve the weight of the string
    (d) all of the above
    (e) none of the above
11. Based on his spinning bucket experiment, Newton argued that
    (a) one can discern absolute rotational motion, therefore absolute space is experimentally verifiable
    (b) one can discern absolute linear motion, therefore absolute space is experimentally verifiable
    (c) the surface of water in a bucket remains level regardless of its state of motion
    (d) the speed of light is the same for all observers, regardless of their motion
    (e) none of the above

12. A cylindrical beam protrudes horizontally from a vertical wall. If the scale of the beam is tripled (that is: its length and its diameter are both tripled), what happens?

   (a) its weight triples
   (b) its resistance to *longitudinal* fracture triples
   (c) the breaking moment (torque) caused by its weight triples
   (d) all of the above
   (e) none of the above

13. In water, tiny air bubbles rise more slowly than large air bubbles because

   (a) drag affects the tiny bubbles more
   (b) large bubbles experience a larger buoyant force
   (c) both of the above
   (d) neither of the above
   (e) air bubbles don't rise in water

14. If the force of gravity was an inverse-cube law (instead of an inverse square law), then the relationship between the period of orbit of a planet, T, and the orbital radius, r, would be:

   (a) $T \propto 1/r$
   (b) $T \propto r$
   (c) $T \propto r^2$
   (d) $T \propto r^{3/2}$ (Kepler's third law)
   (e) $T \propto r^3$

15. A projectile is launched vertically at a speed of 30 m/s. What is its maximum height?

   (a) 15 meters
   (b) 30 meters
   (c) 45 meters
   (d) 80 meters
   (e) 90 meters

Section 3. Ramp problem (5 pts.)

A 3 kg mass, A, is placed on a horizontal frictionless ramp. The ramp is then elevated to an angle $\theta = 30$ degrees above the horizontal. To keep it from sliding down the ramp, a string is tied to mass A. The string is stretched over a pulley at the top of the ramp, and attached to a second mass, B, which is suspended from the string. (This is a bit like what you did in lab.)

1. Draw a free body diagram depicting all the forces acting on mass A.

2. What must be the weight (in Newtons) of mass B in order to keep A from sliding down the ramp?

3. What is the normal force exerted by the ramp on mass A?

4. If the string is now cut, what is the acceleration of mass A?

5. How much time would it take for mass A to slide a distance of 2 meters down the ramp?

Section 4. Collision problem (5 pts.)

A cart of mass $M_A = 3$ kg slides *forward* along a frictionless track at a constant velocity of 2 m/s. It strikes another initially stationary cart of mass $M_B = 9$ kg. The collision lasts about 10 milliseconds. Just after the collision, cart A is traveling *backwards* down the track at a speed fo 1 m/s.

1. What is the speed of cart B just after the collision?

2. Make a sketch of the force acting on cart A as a function of time during the time of the collision. Label your axes.

3. What is the area under the curve you just sketched? What are the units of this quantity?

4. What is the average force acting on cart A during the collision? And what is the average force on cart B during the collision?

5. What is the speed of the center of mass of this pair of carts after the collision? Is it different from before the collision? Explain.

Section 5. Special relativity problem (5 pts.)

A cylindrically shaped cluster of electrons is traveling in a straight line down an evacuated tunnel with a constant velocity of $v = 0.6c$. The cluster smashes into an electron detector at the end of the tunnel. The time between when the first electron and the last electron in the cluster strikes the detector is 2 nanoseconds (2×10^{-9} sec.). This is measured by a scientist, K, who is at rest with respect to the electron detector.

1. TRUE or FALSE: The scientist who is at rest with respect to the detector measures the "proper time" (Δt_0) between when the first and last electrons in the cluster struck the detector.

2. TRUE or FALSE: By "proper time," we really mean the correct time—that is: any other observer, moving at a different velocity and hence measuring a different time interval, would in fact be *incorrect.*

3. TRUE or FALSE: The observer at rest with respect to the detector measures the "proper length" (L_0) of the cluster.

4. What is the length of the cluster (in centimeters) as measured by the scientist, K, who is at rest with respect to the detector?

5. What is the length of the cluster (in centimeters) as would be measured by a (hypothetical) observer K' who is moving along with the electron cluster at $v = 0.6c$ compared to the scientist, K?

6. TRUE or FALSE: K and K' measure the the same length of the electron cluster. If FALSE, which one measures the correct length? Explain your answer.

7. TRUE or FALSE: K and K' measure the the same *relative speed* of the electron cluster and the detector ($0.6c$). If FALSE, which one measures the correct speed? Explain.

Section 6. Newton's theory of gravity essay (5 pts.)

Answer the following essay prompt using neat handwriting, logical and relevant argumentation, and correct grammar, spelling and punctuation.

1. Newton never directly measured the gravitational forces acting on the moon, Earth, or any planets. Nonetheless, he theorized that all objects are attracted to one another by a universal gravitational force. How was he able to arrive at this conclusion? Provide a brief (but accurate) outline of how Newton arrived at his universal law of gravitation, citing specific and relevant laws and/or principles. Do you find his proof convincing?