PHY 152/202 , Fall 2020 Final Exam
Electricity, magnetism and light
Dec. 9, 8:00 - 9:45 a.m.
No books, notes, or electronic devices
Just you and your pen/pencil

Exam, Form: A

Name: _____

Student Number: _____

TA: _____

Date: _____

Section 1. Matching of scientific terms and concepts (6 pts.); note: some definitions may be on the next page!

_____ explication
_____ ascertain
_____ zodiac
_____ celestial
_____ latent
_____ feign
_____ effluvia
_____ torrid
_____ tawny
_____ incipient
_____ savant
_____ wainscot
_____ turbid
_____ chromatic
_____ ferruginous
_____ opacity
_____ sully
_____ nautical
_____ retina
_____ appellation
_____ prodigious
_____ candour

(a) a learned person, esp. a distinguished scientist
(b) very hot and dry
(c) of or concerning sailors or navigation; maritime
(d) damage the purity or integrity of; defile
(e) of, relating to, or produced by color
(f) cloudy, opaque, or thick with suspended matter
(g) remarkably or impressively great in extent, size, or degree
(h) pretend to be affected by
(i) containing iron oxides or rust
(j) an orange-brown or yellowish-brown color
(k) in an initial stage; beginning to happen or develop
(l) analyze and develop (an idea or principle) in detail
(m) a belt of the heavens near the ecliptic, including all apparent positions of the sun, moon, and most familiar planets
(n) a layer at the back of the eyeball containing cells that are sensitive to light
(o) (of a quality or state) existing but not yet developed or manifest; hidden; concealed
(p) find (something) out for certain; make sure of
(q) the condition of lacking transparency or translucence; opaqueness
(r) the quality of being open and honest in expression; frankness
(s) an unpleasant or harmful odor, secretion, or discharge

(t) a name or title

(u) an area of wooden paneling on the lower part of the walls of a room

(v) belonging or relating to the sky or heaven

Section 2. Multiple choice (30 pts.)

1. The south magnetic pole of a magnetized compass needle
   (a) must be positively electrically charged
   (b) must be negatively electrically charged
   (c) always points towards the north pole star
   (d) all of the above
   (e) none of the above
2. A small uncharged cork-ball is attracted to the metal wire projecting from a Leyden jar if
   (a) the wire is positively charged
   (b) the wire is negatively charged
   (c) either of these would cause it to be attracted
   (d) the wire is uncharged
   (e) actually, an uncharged cork-ball cannot be attracted to anything
3. Suppose that the charging probe from the positive terminal of a 1 kV power supply is touched very briefly to two different balls. Immediately afterwards, the larger ball has
   (a) a larger voltage, and a larger charge, than the smaller ball.
   (b) a larger voltage than, but the same charge as, the smaller ball.
   (c) an equal voltage to, but a larger charge than, the smaller ball.
   (d) an equal voltage to, and the same charge as, the smaller ball.
   (e) none of the above
4. When the spacing between two opposite charges is doubled, the force of attraction
   (a) is quartered
   (b) is halved
   (c) is doubled
   (d) is quadrupled
   (e) Wait a minute: opposite charges don't attract, they repel.
5. Consider your coulomb's law experiment. Which of the following modifications would make the apparatus more sensitive to small electrical forces?
   (a) making the horizontal rod supporting the movable ball a bit shorter
   (b) increasing the tension in the torsion wire
   (c) making the torsion wire thinner
   (d) none of the above
   (e) all of the above
6. Consider the current balance you used in the laboratory. The magnets between which the flat aluminum counterweight passed
   (a) attracted the counterweight
   (b) repelled the counterweight
   (c) slowed down the counterweight
   (d) accelerated the counterweight
   (e) had no purpose whatsoever

7. The magnetic field at a point near a long, straight copper wire can be increased by
   (a) increasing the current in the wire
   (b) moving the wire closer to the point
   (c) surrounding the wire by a substance having a larger magnetic permeability
   (d) all of the above
   (e) none of the above
8. A straight copper wire carries an electrical current from east to west. When you hold a magnetized compass needle *below* the wire, the tip of a compass needle having a north magnetic polarity will point
   (a) northward
   (b) southward
   (c) eastward
   (d) westward
   (e) the compass needle will retain whatever position it originally had
9. A positively charged particle traveling (initially) due northwards at a high speed enters a chamber in which a magnetic field points due eastwards. The charge will deflect
   (a) upwards
   (b) downwards
   (c) westwards
   (d) eastwards
   (e) actually, it will not change course
10. The quantity of work which will raise a gram of water through temperature of one degree centigrade is approximately the same as the work which a gram weight would perform in falling through a distance of
   (a) half a millimeter
   (b) half a meter
   (c) fifty meters
   (d) half a kilometer
   (e) one kilometer
11. According to Huygens, light is like sound in that it
   (a) obeys what is now known as Huygens' principle
   (b) needs a medium for propagation
   (c) consists of longitudinal waves
   (d) all of the above
   (e) none of the above
12. An increase in the humidity of the air near Earth's surface causes the peak of a distant tall tower to appear
   (a) a bit higher
   (b) a bit lower
   (c) unchanged

13. When light slows down upon entering a medium, it bends away from the normal. This
    (a) is known as Snell's law.
    (b) was first observed by Newton.
    (c) is only true for exotic materials, such as calcspar.
    (d) is evidence for the electromagnetic theory of light.
    (e) is false.

14. When an unpolarized ray of light passes from air into water at an oblique angle,
    (a) its frequency remains unchanged
    (b) it refracts towards the normal
    (c) its wavelength decreases
    (d) it may become polarized
    (e) all of the above

15. Newton's rings are a consequence of
    (a) interference.
    (b) refraction.
    (c) incontinence.
    (d) dispersion.
    (e) birefringence

16. Suppose that an unpoloarized beam of red light passes through a piece of Iceland spar. The two beams which emerge each pass through another piece of Iceland spar which is aligned in the same orientation as the first. How many separate beams of light emerge?
    (a) 0
    (b) 1
    (c) 2
    (d) 3
    (e) 4

17. Which ordering of scientists is in the correct chronological order (earliest first)
    (a) Coulomb, Helmholtz, Newton
    (b) Gilbert, Huygens, Maxwell
    (c) Faraday, Franklin, Gilbert
    (d) Oersted, Tyndall, Franklin
    (e) none of the above

18. Consider your lab in which you measured the thickness of your hair using a laser beam. A beam of sound cannot be effectively used in a similar manner to measure the width of your hair because
    (a) sound does not produce an interference pattern
    (b) the wavelength of sound is too long
    (c) sound is not a transverse wave
    (d) sound is not loud enough
    (e) sound is invisible

19. In a vacuum, about how many wavelengths of violet light fit in one centimeter?

    (a) 25 billion

    (b) 25 million

    (c) 25 thousand

    (d) 250

    (e) 25

20. A beam of light ($\lambda = 500$ nm in vacuum) falls upon a thin, uniform, film of soap ($n = 1.25$) suspended in the air. What is the minimum thickness such that the film appears bright, when viewed from the direction in which the light is incident on the film?

    (a) 100 nm

    (b) 125 nm

    (c) 200 nm

    (d) 500 nm

    (e) none of the above

21. Which of the following would -not- be observed if light consisted of longitudinal waves?

    (a) reflection

    (b) refraction

    (c) interference

    (d) birefringence

    (e) actually, all of the above would still be observed

22. When a ray of unpolarized light strikes the surface of glass at Brewster's angle, the reflected and refracted rays of light

    (a) travel in directions perpendicular to one another

    (b) are both unpolarized

    (c) cannot be observed

    (d) are reversed

    (e) none of the above

23. Suppose that an initially unpolarized laser beam, traveling northward, passes through a horizontally aligned polaroid filter before striking a vial filled with milk. The light scattered toward the east is

    (a) unpolarized

    (b) vertically polarized

    (c) horizontally polarized

    (d) east-west polarized

    (e) actually, no light is scattered eastward

24. Why does the sky overhead often appear blue in color?

    (a) The atmosphere acts as a thin film which causes blue light to experience constructive interference.

    (b) Blue sunlight is scattered from the atmosphere more readily than other colors.

    (c) Blue sunlight passes through the atmosphere more readily than other colors.

    (d) Blue sunlight is refracted by the atmosphere more readily than other colors.

    (e) Actually, the sky overhead is never blue.

25. A tungsten wire is placed across the terminals of a battery, causing a current to flow through the wire. In order to halve the electric current, you could

    (a) halve the diameter of the wire

    (b) halve the length of the wire

    (c) double the resistivity of the wire

    (d) double the cross-sectional area of the wire

    (e) all of the above

26. Suppose that a ten-gram bar magnet is dropped down a one meter long aluminum pipe. If the south pole is facing downward, then when looking down the tube, an electrical current is induced in the pipe

    (a) clockwise

    (b) counterclockwise

    (c) down the tube

    (d) up the tube

    (e) actually, no current is induced in the tube

27. Suppose that a ten-gram bar magnet is dropped down a one meter long aluminum pipe. Its speed upon leaving the bottom is the same as the speed upon entering the top. About how much heat is generated in the aluminum pipe?

    (a) 0.01 Joules

    (b) 0.1 Joules

    (c) 1 Joules

    (d) 10 Joules

    (e) none of the above

28. Lenz's law states that

    (a) a current is induced in a loop of wire so as to counteract any change in the magnetic flux through the loop.

    (b) a force is exerted by a magnetic field on a charge moving parallel to the magnetic field lines.

    (c) the total energy of the universe can never be increased or decreased

    (d) you cannot have your cake and eat it too

    (e) diversity is our greatest strength

29. Which of the following is cited as strong evidence, provided by Maxwell, supporting the concept of *action-at-a-distance*?

    (a) the ringing of a bell by a string

    (b) sound waves traveling through air

    (c) the ringing of a bell by an electrical circuit

    (d) the attraction of a light suspended object toward a spinning disk

    (e) the shifting of Newton's rings when pressure is applied to the hemispherical lens.

30. Consider the lab in which you measured the force between two current-carrying wires. If you were to thereby *underestimate* your value of μ_o by a factor of four, your calculation of c would have been

(a) too big by a factor of four

(b) too big by a factor of two

(c) too small by a factor of two

(d) too small by a factor of four

(e) none of the above

Section 3. **PHY 152 students only:** Particle accelerator problem (4 pts.)

Suppose an electron, having charge q and mass m, is placed between two oppositely charged parallel capacitor plates which are separated by a small distance d. The plates are maintained at a voltage difference, V, by a high-voltage power supply. The electron is released from position, $x = 0$, very near the negatively charged plate. Suppose the strength of the (constant) electrical force pushing the electron towards the positively charged plate is given by the equation $F = qV/d$.

1. How much work does the electrical force do on the electron by the time it strikes the positively charged capacitor plate at $x = d$? HInt: what is the definition of work? You should express your answer in terms of the variables given above (*e.g.*, m, q, V, *etc.*)

2. What is the speed, v, of the electron just before it strikes the positively charged capacitor plate? (Again, express your answer in terms of the variables given above.)

3. Now some numbers: the charge and mass of an electron are (approximately) 2×10^{-19} Coulombs, and 8×10^{-31} kg, respectively. So what voltage difference, V, is required to accelerate the electron to one-third the speed of light? (The speed of light is about $c = 3 \times 10^8$ m/s.)

Section 4. **PHY 202 students only:** Planetary model of the hydrogen atom (6 pts.)

According to the planetary model of the atom, a hydrogen atom consists of a positively charged proton (mass M and charge q) orbited at a distance r by a negatively charged electron (mass m and charge q).

1. Write down a formula for the strength of the force, F, exerted by the proton on the orbiting electron. Do not plug in any numbers; just leave your answer in terms of variables such as the charge (q) and the coulomb constant (k). (Hint: don't make this harder than it is. Just write down coulomb's law for the force acting on the electron)

2. Now, let's find the speed, v, of the orbiting electron. To do this, simply combine (i) the coulomb force law (from above), (ii) Newton's 2nd law ($F = ma$), and (iii) the fact that an object orbiting in a circle experiences a centripetal (inwardly directed) acceleration ($a = v^2/r$).

3. The orbiting electron can be thought of as an electrical current going around the proton. Find a mathematical expression for the electrical current, I, going around the proton. (Hint: you know the speed of the electron, v, the distance around a circle of radius r; and that the units of electrical current is coulombs per second.)

4. You may recall that a loop of current acts like a little magnet. The so-called "magnetic dipole moment", μ, of a loop of current is defined as the current around the loop times the area of the loop: $\mu = Ia$. What is the magnetic dipole moment of our hydrogen atom, which consists of an electron orbiting a proton? Simplify your answer as much as possible. Also: make a little drawing of the hydrogen atom and sketch the magnetic field lines in its vicinity. When drawing the magnetic field lines, don't forget that the electron is negatively charged....

5. Now: suppose our hydrogen atom is exposed to an external magnetic field, B, which is directed in the same direction as the magnetic field which was caused by the orbiting electron. This external magnetic field increases at a constant rate $\frac{dB}{dt}$. Supposing that the radius of the electron orbit does not change, what do you think happens to the motion of the electron? Do you think its speed increases, decreases, or remain constant? Does the magnetic dipole moment of the hydrogen atom get get larger or smaller?

6. If the electromotive force, ε, generated by the changing magnetic field does an amount of work on the orbiting electron given by the formula $W = \varepsilon q$. By how much does the kinetic energy of the electron change?

Section 5. **PHY 202 students only:** Action-at-a-distance essay (3 pts.)

1. Based on your readings from this semester, argue either *for* or *against* the concept of *action-at-a-distance.* You should cite specific logical and experimental evidence which supports your position. Your essay should display correct thinking, neat handwriting, and perfect grammar, spelling and punctuation.