PHY 152/202: General Physics 2
Electricity, Magnetism and Light
Dec. 13, 2023 Final exam
No books, notes, or electronic devices
Exam, Form: A

Name: _____

Student Number: _____

TA: _____

Date: _____

Section 1. Matching of scientific terms and concepts (6 pts.)

_____ appreciable
_____ candour
_____ corpuscle
_____ latent
_____ decant
_____ palpable
_____ fissile
_____ cessation
_____ elucidate
_____ interpose
_____ fatigue
_____ ponderous
_____ corona
_____ manifest
_____ undulate
_____ turbid
_____ austral
_____ progeny
_____ gilt
_____ vulgar
_____ nautical
_____ impetus
_____ luminous
_____ congeries

(a) characteristic of or belonging to the masses
(b) covered thinly with gold leaf or gold paint
(c) cloudy, opaque, or thick with suspended matter
(d) relating to the southern hemisphere
(e) the force or energy with which a body moves
(f) move with a wave-like motion
(g) easily split
(h) place or insert between one thing and another
(i) offspring:
(j) bright or shining
(k) the fact or process of ending or being brought to an end
(l) a disorderly collection; a jumble
(m) hidden; not manifest
(n) a minute particle regarded as the basic constituent of matter or light
(o) the quality of being open and honest in expression; frankness
(p) large or important enough to be noticed
(q) a small circle of light seen around the sun or moon, due to diffraction by water droplets
(r) make (something) clear; explain
(s) clear or obvious to the eye or mind
(t) to tire, exhaust, or weaken
(u) concerning sailors or navigation
(v) burdened because of great weight
(w) plain to see or comprehend
(x) gradually pour a liquid from one container into another,

Section 2. Multiple choice (30 pts.)

1. You hold a long bar magnet in your hands in front of you. The north end is in your right hand; the south end is in your left hand. Flexing your muscles, you snap the magnet by pulling your two hands apart from each other. When a magnetic compass needle is placed directly between the two halves, the north end of the compass needle will point

   (a) to the right

   (b) to the left

   (c) up (toward the sky)

   (d) down (toward the earth)

   (e) away from your belly

2. In his *De Magnete*, Gilbert attributes magnetism to a *formal* cause. Which of the following is -not- one of Aristotle's four causes?

   (a) formal cause

   (b) efficient cause

   (c) material cause

   (d) proximate cause

   (e) final cause

3. In the laboratory, a plastic tube is rubbed with rabbit fur, making the tube negatively charged. The tube is brought very near to one side of an uncharged metal sphere mounted atop an insulating plastic rod. At the same time, a small (initially uncharged) proof plane is touched momentarily to the opposite side of the metal sphere. When the proof plane is now removed and placed into a faraday ice pail, it is found that the proof plane is

   (a) positively charged

   (b) negatively charged

   (c) uncharged

   (d) magnetized

   (e) colder than before

4. Benjamin Franklin found that the electrical charge stored in a Muschenbroek bottle was stored in

   (a) the glass

   (b) the cork in the top

   (c) the liquid in the bottle

   (d) the metal pin piercing the cork

   (e) all of the above

5. A 3 kilo-volt power supply is used to charge a small metal sphere of capacitance 1 micro-Farad. This sphere is then touched momentarily to a second metal sphere with twice the radius (and hence twice the capacitance) of the first sphere. What is the final charge remaining on the first sphere after this process is complete?

   (a) 1 micro-Coulomb

   (b) 1 milli-Coulomb

   (c) 2 milli-Coulomb

   (d) 3 milli-Coulomb

   (e) none of the above

6. The lightning rod was invented by
   (a) Gilbet
   (b) Franklin
   (c) Coulomb
   (d) Oersted
   (e) Ampere

7. Consider two charges placed along the x-axis: $q_1 = +1$ coulomb is placed at $x = 0$. $q_2 = -2$ coulomb is placed at $x = 2$. When a third charge $q_3 = +3$ coulomb is placed at $x = 3$, the net force on q_3 will be
   (a) in the $+x$ direction
   (b) in the $-x$ direction
   (c) perpendicular to the x-axis
   (d) zero
   (e) infinite

8. A conducting wire carries a large current, I, from east to west. When you hold a magnetic compass needle *above* the wire, the tip of the needle that initially pointed northward (toward canada) will now deflect
   (a) eastward
   (b) westward
   (c) south
   (d) in fact, it will just remain pointing northward
   (e) it will act like a motor, and just keep spinning around

9. Based on his experiments with current-carrying wires, Ampere suggested that
   (a) electrical currents circulate inside of permanent bar magnets
   (b) electrical tension can be used to generate an electrical current
   (c) electrical currents can be used to communicate across vast distances
   (d) electrical currents in wires eventually reach a terminal velocity due to resistance
   (e) all of the above

10. Suppose that an electrical current flows counter-clockwise around the perimeter of this sheet of paper as it lies on your desk. A strong magnetic field is then applied from left to right. As a result,
   (a) the left side of the paper will tend to rise off the desk
   (b) the right side of the paper will tend to rise off the desk
   (c) the paper will tend to lie flat but rotate clockwise
   (d) the paper will tend to lie flat but rotate counter-clockwise
   (e) none of the above

11. In his experimental researches, Michael Faraday aimed to demonstrate that
   (a) electrical currents can generate a noticeable effect on magnetic compass needles
   (b) ordinary magnets can be used to generate electrical currents
   (c) the north pole of a bar magnet is positively charged
   (d) iron bars can be magnetized by heating
   (e) all of the above

12. You have in your possession a 2 Ohm resistor and a 6 Ohm resistor. These can be used separately, in series, or in parallel. Which of the following is -not- a possible resistance you can make?

    (a) 8 Ohms

    (b) 6 Ohms

    (c) 2 Ohms

    (d) $1\frac{1}{2}$ Ohms

    (e) $\frac{2}{3}$ Ohms

13. A wire is connected between the terminals of a 10-volt battery. The wire has a length of 1 meter, a cross-sectional area of 1 square cm, and a resistivity of 1 ohm-meter. How much current flows through the wire?

    (a) 1 micro-Ampere

    (b) 1 milli-Ampere

    (c) 100 milli-Ampere

    (d) 1 Ampere

    (e) none of the above

14. A 10 volt battery drives electrical current through a 10 ohm resistor. How much heat is generated in ten seconds?

    (a) 1 Joule

    (b) 10 Joules

    (c) 100 Joules

    (d) 1000 Joules

    (e) none of the above

15. Two flat mirrors are placed so that one edge is touching an a 45-degree angle is made between their reflecting surfaces (like in lab). A pin is placed between the reflecting surfaces. How many images of pins are formed behind the mirrors?

    (a) 2

    (b) 3

    (c) 4

    (d) 5

    (e) more than 5

16. A ray of light strikes the face of a transparent glass cube at an angle of 30 degrees with respect to the normal. It enters the glass and then exits through the opposite face of the cube. What angle does the exiting light ray make with respect to a normal to the opposite face?

    (a) much less than 30 degrees

    (b) less than 30 degrees

    (c) exactly 30 degrees

    (d) more than 30 degrees

    (e) much more than 30 degrees

17. An object is placed 2 cm in front of a double-convex lens that has a focal length of 6 cm. Where on the opposite side of the lens is the image of the object formed?

    (a) 1 cm

    (b) 2 cm

    (c) 3 cm

    (d) 6 cm

    (e) in fact, the image forms on the *same* side of the lens, not the opposite side

18. According to Christiaan Huygens,

    (a) all natural effects must be understood in terms of the mechanical motions of tiny particles

    (b) each point on a wave-front can be treated as a spherical source of waves

    (c) light requires a medium for propagation: the aether

    (d) light is a longitudinal wave, like sound

    (e) all of the above

19. The speed of light was first measured by

    (a) Olaf Roemer

    (b) Rene Descartes

    (c) Galileo Galilei

    (d) Christian Huygens

    (e) Albert Michelson

20. The speed of light

    (a) can be calculated from ϵ_o and μ_o

    (b) is approximately 300,000 km / sec

    (c) is the same in all directions

    (d) is slower in glass than in air

    (e) all of the above

21. X-rays have a wavelength of about 0.1 nanometers. What is the frequency of such x-rays?

    (a) about 3×10^{18} Hertz

    (b) about 1×10^{15} Hertz

    (c) about 1×10^{12} Hertz

    (d) about 3×10^{9} Hertz

    (e) about 1×10^{6} Hertz

22. Sound of wavelength λ passes through a hole in a barrier of width a. As a result, it spreads out or "diffracts." To *increase* the diffraction angle, one could

    (a) decrease λ

    (b) increase a

    (c) both of these would increase the diffraction

    (d) neither of these would increase the diffraction

    (e) wait a minute, sound waves don't diffract

23. Iceland spar

    (a) is birefringent

    (b) was studied carefully by both Isaac Newton and Christian Huygens

    (c) naturally cleaves (or breaks) in the form of an oblique parallelpiped

    (d) was instrumental in understanding the transverse polarization of light

    (e) all of the above

24. If you were to use blue light (instead of red light) to measure the diameter of your hair in lab this semester, you would probably find that

    (a) the spacing between the observed fringes would remain the same

    (b) the spacing between the observed fringes would increase

    (c) the measured hair diameter would decrease

    (d) the measured hair diameter would increase

    (e) none of the above

25. A thin film of transparent material ($n = 1.25$) coats a plate of glass ($n = 1.5$). A beam of white light falls upon the thin film from above. What is the minimum thickness such that the film appears green ($\lambda = 500$ nm), when viewed from above?

    (a) 100 nm

    (b) 400 nm

    (c) 900 nm

    (d) 1300 nm

    (e) none of the above

26. A hemispherical glass lens is placed, curved side down, atop a flat glass plate. The lens is illuminated from above by monochromatic ight. When viewed from above, the observed interference fringes

    (a) are concentric and equally spaced

    (b) are concentric and most widely spaced at the center

    (c) are concentric and most widely spaced at the periphery

    (d) form equally spaced straight lines that intersect at the center

    (e) in fact, there are no interference fringes formed by the reflecting light

27. In the Brewster's angle lab, if you had used water ($n = 1.3$) instead of glass ($n = 1.5$), Brewster's angle would have

    (a) increased

    (b) decreased

    (c) remained the same

28. The sunset appears reddish because

    (a) The atmosphere acts as a thin film, causing red light to experience constructive interference.

    (b) Red sunlight passes through the atmosphere more readily than blue light.

    (c) Red light is refracted by the atmosphere more than other colors.

    (d) Light becomes polarized when scattering from the atmosphere.

    (e) The sun is made of blood.

29. Suppose you had overestimated your value of μ_0 by a factor of 9. Your calculated vale of the speed of light would be

    (a) underestimated by a factor of 9

    (b) underestimated by a factor of 3

    (c) overestimated by a factor of 3

    (d) overestimated by a factor of 3

    (e) none of the above

30. Consider a motorboat that is capable of traveling at a speed of three miles per hour in still water. What is the time required for this boat to go one mile upstream in a river flowing at a speed of two miles per hour.

    (a) less than twenty minutes

    (b) about half an hour

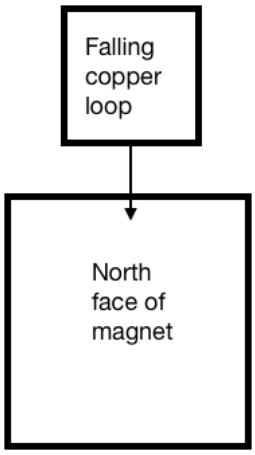
    (c) about an hour

    (d) about an hour and a half

    (e) about three hours

Section 3. Falling loop problem (6 pts.)

Consider a square loop of copper wire whose area is four square centimeters and whose mass is 100 grams. The loop is suspended vertically and then dropped. After falling five meters, it passes in front of the north face of a bar magnet, as shown below. The strength of the magnetic field is 0.1 Tesla. As an approximation, let's assume that the magnetic field strength is zero everywhere except directly in front of the magnet's face.



1. First, let's calculate the speed of the falling loop at the moment it begins to pass in front of the magnet. If the bottom edge has fallen exactly five meters at the moment it begins passing in front of the face of the magnet, what is its speed at this instant? (Hint: you can use conservation of energy.)

2. By the way, what is the kinetic energy of this loop of copper (in milli-joules) at this instant?

3. Just as flux starts to penetrate the loop, in which direction is current induced? Clockwise or counter-clockwise (from our perspective)?

4. At this instant, what is the the electromotive force (in milli-volts) that generates this current? (Hint: you can use faraday's law...)

5. If the resistance of the loop is 0.04 ohms, then what is the magnitude of the electric current (in milli-amps) induced in the loop at this instant?

6. At this instant, what is the drag force (in milli-newtons) acting on the bottom edge of the loop? (Hint: use the lorentz force law). Is this drag force larger or smaller than the force of gravity?

Section 4. Electric Field mapping (4 pts.)

Suppose that a parallel plate capacitor is formed by placing two large metal plates 5 cm apart. The left plate is positively charged, the right plate is negatively charged.

1. First, in the space below, make a sketch of these parallel plates. Make them fairly large and separated by about 5 cm

2. On the same diagram, sketch four equipotential lines in the region between the plates. Make these dashed lines.

3. Again, on the same diagram, sketch a few electric field lines. Make these solid lines. Be sure to draw arrows indicating the direction of the force that a positively charged particle would feel if placed on one of these lines.

4. **PHY 202 students only (1 more point):** If the capacitor plates are charged using a 500 volt power supply, what is the strength of the electric field in the region between the plates?

Section 5. PHY 202 students only: Maxwell's equations (4 pts.)

1. What is Gauss's law? Write down the formula, and then explain using clear English text, the meaning of both the left and right hand sides of the equation.

2. How about Faraday's law? Again: write down the formula and the meaning of the equation.

3. Now do the same for the Ampere-Maxwell law. Also: which part of this equation did Maxwell himself introduce?

4. Finally, write down the "no-name" law and its meaning. How would this formula be changed if there were "magnetic monopoles" (that is: if you could separate a north pole from a south pole)

5. Which of these two equations was used by Maxwell to compute the speed of an electromagnetic wave?

Section 6. Essay question (4 pts.)

1. Explain in about one page of clear and concise writing the content of Hermann von Helmholtz's essay "On the Conservation of Force." In particular: what was the main point he made, and what specific evidence did he provide to support this point? In this essay, I am looking for clarity of thought and for correct grammar, punctuation, and spelling.