PHY202 Electricity, magnetism and light
Fall 2017 Final Exam
No calculators.
Dec. 13, 8:00 - 9:45 a.m. S113
Exam, Form: A

Name: _____

Student Number: _____

TA: _____

Date: _____

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

_____ savant
_____ venture
_____ confute
_____ inference
_____ incredulity
_____ confer
_____ gross
_____ tawny
_____ trite
_____ isosceles
_____ effluvia
_____ elucidate
_____ conjecture
_____ dictum
_____ periphrasis
_____ chromatic
_____ incipient
_____ explication
_____ turbid
_____ ascertain
_____ candour
_____ terrestrial
_____ discontinuity
_____ calico
_____ league

(a) the state of being unwilling or unable to believe something
(b) make sure of
(c) cloudy, opaque, or thick with suspended matter
(d) the use of indirect and circumlocutory speech or writing
(e) analyze and develop (an idea or principle) in detail
(f) of, on, or relating to the earth
(g) about three miles
(h) a short statement that expresses a general truth or principle
(i) dare to do or say something that may be considered audacious
(j) in an initial stage; beginning to happen or develop
(k) an orange-brown or yellowish-brown color
(l) large-scale; not fine or detailed
(m) an opinion or conclusion formed on the basis of incomplete information
(n) grant or bestow (a title, degree, benefit, or right)
(o) of, relating to, or produced by color
(p) a learned person, esp. a distinguished scientist
(q) the quality of being open and honest in expression; frankness
(r) overused and consequently of little import; lacking originality or freshness
(s) a conclusion reached on the basis of evidence and reasoning
(t) a distinct break in physical continuity or sequence in time

(u) printed cotton fabric

(v) an unpleasant or harmful odor, secretion, or discharge

(w) prove (a person or an assertion) to be wrong

(x) (of a triangle) having two sides of equal length

(y) make (something) clear; explain

Section 2. Multiple choice (32 pts.)

1. An anti-reflection coating ($n = 1.2$) is spread on a glass window ($n = 1.5$). What is the minimum thickness it must be so that no red light ($\lambda = 600$ nm) is reflected?

   (a) 200 nm
   (b) 250 nm
   (c) 300 nm
   (d) 500 nm
   (e) none of the above

2. A charged particle is placed next to (but outside of) a blown-up balloon. The total electric flux through the surface of the balloon is

   (a) q/ϵ_0
   (b) $q/4\pi\epsilon_0$
   (c) $q/16\epsilon_0$
   (d) it depends on the radius of the balloon
   (e) 0

3. A 100 gram magnet falls, under the influence of gravity, through an aluminum tube which is 1 meter long. Electrical currents are generated in the aluminum tube, which die away after the magnet leaves the tube. Assuming that the magnet falls at a constant speed while inside the tube, how many joules of heat will have been generated in the tube by these electrical currents by the time the magnet leaves the bottom of the tube?

   (a) 1
   (b) 2
   (c) 10
   (d) 20
   (e) 200

4. An electrical current flows clockwise around the outer edge of this sheet of paper resting on your desk. If a uniform magnetic field is directed horizontally from right to left, then

   (a) the left edge of the paper will attempt to rise from the surface of the desk
   (b) the right edge of the paper will attempt to rise from the surface of the desk
   (c) the top edge of the paper will attempt to rise from the surface of the desk
   (d) the bottom edge of the paper will attempt to rise from the surface of the desk
   (e) none of the above

5. Vector $\vec{a}$ has a length of 9; vector $\vec{b}$ has a length of 3; vector $\vec{c}$ has a length of 2. What is the dot product $\vec{b} \cdot \vec{c}$?

   (a) 0
   (b) 1
   (c) 6
   (d) 27
   (e) it is impossible to tell from the information provided

6. Suppose that an antenna receives electromagnetic waves with a frequency of 10 MHz. What is the approximate wavelength of these waves?

   (a) 3 cm
   (b) 30 cm
   (c) 3 meters
   (d) 33 meters
   (e) 330 meters

7. Which of the following formulae describes an electromagnetic wave traveling along the $+z$ axis and polarized along the x axis?

   (a) $\vec{E}(z,t) = E_0 \sin\left(\frac{2\pi t}{\tau} - \frac{2\pi z}{\lambda}\right)\hat{x}$
   (b) $\vec{E}(x,t) = E_0 \sin\left(\frac{2\pi t}{\tau} - \frac{2\pi x}{\lambda}\right)\hat{z}$
   (c) $\vec{E}(z,t) = E_0 \sin\left(\frac{2\pi t}{\tau} + \frac{2\pi z}{\lambda}\right)\hat{x}$
   (d) $\vec{E}(z,t) = E_0 \sin\left(\frac{2\pi t}{\tau} + \frac{2\pi x}{\lambda}\right)\hat{z}$
   (e) none of the above

8. Vector $\vec{a}$ has a length of 9; vector $\vec{b}$ has a length of 3; vector $\vec{c}$ has a length of 2. What is the smallest possible length of the vector sum $\vec{a} + \vec{b} + \vec{c}$?

   (a) 0
   (b) 3
   (c) 4
   (d) 14
   (e) it is impossible to tell from the information provided

9. Consider a Michelson interferometer, such as the one you used in lab. By slowly lengthening one of the arms of the interferometer by one centimeter, the detector goes from a maximum to a minimum and back to a maximum reading. What is the wavelength of the electromagnetic waves used by the interferometer?

   (a) 5 mm
   (b) 1 cm
   (c) 2 cm
   (d) 4 cm
   (e) none of the above

10. The speed of sound in air is 330 m/s. If the density of air is quadrupled (everything else remaining the same) the speed of sound will be changed by a factor of

   (a) 4
   (b) 2
   (c) 1/2
   (d) 1/4
   (e) actually, the speed of sound will be unchanged

11. 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.
12. A laser beam is reflected from the top of a glass plate lying flat on a lab bench. The incidence angle of the beam is exactly Brewster's angle. Now a vertically oriented polarizing filter is placed between the laser and the glass. As a result, the reflected laser beam will
    (a) disappear
    (b) get brighter
    (c) remain unchanged
    (d) change color
13. Which of Maxwell's four equations were used to demonstrate that electromagnetic waves travel at the speed $c = 1/\sqrt{\mu_o \epsilon_0}$?
    (a) Faraday's law and the Ampere-Maxwell law
    (b) Gauss' law and the no-name law
    (c) Gauss' law and Faraday's law
    (d) The Lorentz force law and the Ampere-Maxwell law
    (e) Actually, Maxwell had to use all four of his equations to demonstrate this
14. Suppose that you push the north pole of a bar magnet away from you and into a helical coil of wire. From your perspective, an electric current is generated in the coil
    (a) clockwise
    (b) counterclockwise
    (c) away from you
    (d) towards you
    (e) actually, no current is generated
15. Suppose that Gilbert was wrong, and that a small magnet could be broken in such a way as to isolate a pure north magnetic pole. This would imply a violation of
    (a) $\int \vec{E} \cdot d\vec{A} = q/\epsilon_o$
    (b) $\int \vec{E} \cdot d\vec{s} = -\frac{d}{dt} \int \vec{B} \cdot d\vec{A}$
    (c) $\int \vec{B} \cdot d\vec{s} = \mu_o I + \mu_o \epsilon_o \frac{d}{dt} \int \vec{E} \cdot d\vec{A}$
    (d) $\int \vec{B} \cdot d\vec{A} = 0$
    (e) Coulomb's law

16. Based on experiments with his newly developed interferometer, Michelson argued that
    (a) atoms are smoke-ring-like vortices made from the aether
    (b) a displacement of the aether corresponds to an electric current
    (c) there must be a medium whose function it is to transmit light waves
    (d) all phenomena of the physical universe are different manifestations of the various modes of motion of one all-pervading substance
    (e) all of the above
17. A standing wave traveling through a medium
    (a) consists of two counter-propagating waves having the same frequency
    (b) exhibits locations where there is no displacement of the medium
    (c) can be produced by reflecting microwaves from a zinc plate
    (d) all of the above
    (e) none of the above
18. A wire carries a current of one ampere. What is the line integral of the magnetic field calculated on a circular path centered on the wire?
    (a) μ_0 amperes
    (b) $\mu_0/2\pi$ amperes
    (c) $4\pi\mu_0$ amperes
    (d) none of the above
    (e) it depends on the radius of the circular path
19. A lightning bolt strikes a flag pole, causing electrical current to flow down the pole. A compass, located north of the flag pole will momentarily deflect
    (a) eastward.
    (b) westward.
    (c) southward.
    (d) downward.
    (e) upward.
    (f) Actually, it will remain unaffected.
20. When the slit spacing in a young's two-slit experiment is doubled (all other things remaining equal), the separation between the interference fringes
    (a) is quartered
    (b) is halved
    (c) remains the same
    (d) is doubled
    (e) is quadrupled

21. A tungsten wire is placed across the terminals of a battery, causing a current to flow through the wire. In order to double 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) halve the cross-sectional area of the wire
    (e) all of the above

22. With which of the following would Newton and Huygens agree?

    (a) when light reflects, the angle of incidence equals the angle of reflection
    (b) light beams travel in straight lines
    (c) iceland crystal is birefringent
    (d) the speed of light is finite
    (e) all of the above

Section 3. Electric fields near a capacitor (4 pts.)

Suppose that a parallel plate one micro-farad capacitor is hooked up to an adjustable power supply. The voltage is turned to 10 volts and after a few brief moments, the capacitor is fully charged up.

1. How much charge is residing on the capacitor after it is has been fully charged?

2. Carefully sketch the equipotential lines (dashed lines) and the electric field lines (solid lines) in the region between the capacitor plates. Are there any regions between the plates where the electric field is zero? Explain.

3. Now suppose that a small metal sphere is inserted into the region midway between the capacitor plates. Make another sketch the equipotential lines (dashed lines) and the electric field lines (solid lines) in the region between the capacitor plates. Are there any regions between the plates where the electric field is zero? Explain.

4. What happens to the metal sphere if the power supply voltage is slowly increased? (No need to do any calculations here. Just explain what, if anything, happens.)

Section 4. 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_p and charge q_p) orbited at a distance r by a negatively charged electron (mass m_e and charge q_e).

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 q_p, ϵ_o, *etc.* (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 ($F = m_e a$), 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 and the distance it travels in a circle. The units of electrical current is coulombs per second.)

4. You may recall that a loop of current acts like a little magnet: a magnetic dipole. The magnetic dipole moment, m, of a loop of current is defined as the current times its area: $m = Ia$. What is the magnetic dipole moment of our hydrogen atom, which consists of an electron orbiting a proton? Also: make a drawing of the hydrogen atom and sketch the magnetic field lines in its vicinity.

5. Now: suppose our hydrogen atom is exposed to an external magnetic field B_e 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 $\frac{dB_e}{dt}$ for a time Δt. Assuming that the radius of the electron orbit does not change, what happens to the motion of the electron? Does its speed (v) increase, decrease, or remain constant? If it changes, then by how much does it change? Be as mathematically precise as you can.

6. Does the magnetic dipole moment (m) of the hydrogen atom change as a result of the external magnetic field? If so, by how much?

Section 5. Action-at-a-distance essay (3 pts.)

Use clear and concise prose, neat handwriting, and correct grammar, spelling and punctuation to answer the following question.

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.