Final Exam vers. 0001 - Physics 1120 - Fall, 2007

NAME (print legibly, please)__________________________________________
Student ID #__________________________________________________
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Please do not open the exam until you are told to.

Your exam should have pages numbered 1-17 (questions begin on page 3)
This exam consists of 42 multiple-choice questions. Each is worth the same.
Fill in the bubble sheet with a #2 pencil.

PLEASE follow all directions carefully.
Print and bubble in your name on the bubble sheet.
Print and bubble in your student Identification Number.
Print and bubble in your Exam version, 0001 or 0002, in the upper left of your bubble sheet in the area marked 1234.

Erase mistakes as thoroughly as possible. Ask for a fresh bubble sheet if you fear you cannot thoroughly erase mistakes. Check that you have bubbled carefully!!!

By handing in this exam, you agree to the following statement: "On my honor, as a University of Colorado Student, I have neither given nor received unauthorized assistance on this work"

Signature______________________________________________

Possibly Useful Constants and formulas:
e = -1.6E-19 C, \( \epsilon_0 = 8.85 \times 10^{-12} \) (SI units), \( \mu_0 = 4\pi \times 10^{-7} \) (SI units),
1eV (electron-Volt) = 1.6E-19 J

Gauss' Law: \( \oiint \mathbf{E} \cdot d\mathbf{A} = Q(\text{enc})/\epsilon_0 \)
Gauss' Law for Magnetism: \( \oiint \mathbf{B} \cdot d\mathbf{A} = 0 \)
Ampere's Law: \( \oint \mathbf{B} \cdot d\mathbf{L} = \mu_0 I(\text{through}) + \mu_0 \epsilon_0 d\Phi_{\text{elec}}/dt \)
Faraday's Law: \( \oint \mathbf{E} \cdot d\mathbf{L} = -d\Phi_{\text{mag}}/dt \)
Lorentz Force Law: \( \mathbf{F} = q\mathbf{E} + q\mathbf{v} \times \mathbf{B} \)

Relax. Budget your time. Your neighbors also think this is a long, hard exam.

Oh, and by the way, "none of these" really IS the correct answer - at LEAST once on this exam, perhaps more than once!
1. A balloon of mass $M$ has been positively charged (its charge is $+Q$) and is held up to the ceiling. The ceiling polarizes, so the balloon sticks to it. The friction coefficient between the balloon and the ceiling is $\mu$, and we will assume that the electric field, $E$, created by the ceiling is uniform and directed upwards. What is the (minimum) magnitude $E$ of this electric field?

A) $E = \frac{\mu Q}{Mg}$  
B) $E = \frac{Mg}{\mu Q}$  
C) $E = \frac{\mu Mg}{Q}$  
D) $E = \frac{Q}{Mg}$  
E) $E = \frac{Mg}{Q}$

The next two questions refer to this situation:

Two positively charged particles, labeled 1 and 2, are placed a distance $R$ apart in empty space and are released from rest. Particle 1 has mass $m$ and charge $+Q$; particle 2 has mass $2m$ and charge $+Q/2$. Each particle feels only the static Coulomb force due to the other particle. (There is no gravity, no friction, nor any other forces in this problem.)

2. How do the magnitudes of the initial accelerations of the two particles compare?  
[\text{a}_1 = \text{magnitude of initial acceleration of particle 1}, \quad \text{a}_2 = \text{magnitude of initial acceleration of particle 2}]  
A) $a_1 = 2 a_2$  
B) $a_1 = \frac{1}{2} a_2$  
C) $a_1 = 4 a_2$  
D) $a_1 = a_2$  
E) None of these.

3. As the particles continue to move apart after their release, the speed of each particle...
A) decreases as time goes by  
B) increases as time goes by  
C) stays the same.
The following two questions refer to this situation:
Two negative charges are each located a distance r from the origin, as shown.
Note that the upper charge is twice as strong as the one to the right. (-2Q compared to -Q)

4. At the origin, the direction of electric field is ...

A) Up and right at exactly a 45 degree angle to the +x axis.
B) Down and left at exactly a 45 degree angle to the -x axis.
C) Straight up the page
D) The field has no direction, because the field is zero
E) None of these: the field points in some other direction than the choices given above.

5. (Assume, as usual, that Voltage is zero at infinity.) At the origin, given the charge configuration above, the VOLTAGE is ....

A) \(+kQ/r\)
B) \(-kQ/r\)
C) \(-2kQ/r\)
D) \(-3kQ/r\)
E) None of these choices is correct

6. A small plastic bead has a +q charge on its bottom side and a –q charge on its top side (it’s a permanent electric dipole).
The bead is placed in an electric field represented by the field line diagram shown.
At the instant shown in the diagram, what is the direction of the net force on the bead due to this Electric field?

A) the net force is zero
B) right \(\rightarrow\)
C) left \(\leftarrow\)
D) down \(\downarrow\)
E) up \(\uparrow\)
7. Point P is located exactly midway between two charged objects, each of which has identical charge $+Q$. The object on the left is a thin insulating rod, oriented vertically. This rod has its total charge ($+Q$) spread out uniformly along it. The object on the right is a simple pointlike charge, $+Q$. Point P is on the centerline, as shown.

What is the direction of the electric field at point P, midway between the rod and the point?

A) No direction, because the E-field is zero at point P  
B) to the right $\rightarrow$  
C) to the left $\leftarrow$  
D) None of the above: the correct direction is not given.

8. You have two objects (labeled #1 and #2), both with charges $-Q$, fixed on the x-axis at $x=-d$ and $x=+d$ respectively. (Define voltage to be zero off at infinity)  
There are no other charges anywhere. At the origin, halfway between the charges, what can you say about the magnitude of the electric field, and the voltage?

A) $|E| = 0, \ V = 0$  
B) $|E|$ is not zero, $\ V = 0$  
C) $|E| = 0, \ V$ is not 0  
D) $|E|$ is not zero, $\ V$ is not 0  
E) Not enough information to decide.

9. An ohm-meter measures the resistance between points a and b in the arrangement of 4 resistors shown. All four resistors are identical, with $R=6.0 \ \Omega$. What is the measured resistance between a and b?

A) The meter would read infinity, because this is not a complete circuit.  
B) The meter would read 0 $\ \Omega$, this is not a complete circuit.  
C) 24 $\ \Omega$  
D) 8.0 $\ \Omega$  
E) 6.5 $\ \Omega$
The next TWO problems refer to the circuit at right. There are two ideal batteries (voltage V each), and three identical ideal bulbs. Initially the capacitor is uncharged, and the switch is open.

10. **Immediately after** the switch is closed, the absolute value of the voltage difference **across bulb #1** is equal to:
   A) 2V  
   B) 4V/3  
   C) V  
   D) 2V/3  
   E) zero

11. **A very long time after** the switch is closed, the absolute value of the potential difference **across the capacitor** is equal to
   A) 2V  
   B) 4V/3  
   C) V  
   D) 2V/3  
   E) zero

12. An ideal battery is attached to three identical ideal bulbs, as shown in the circuit to the right. A switch in parallel with bulb 3 is originally open and is then closed. When the switch is closed, what happens to the brightness of bulbs 1 and 2?
   A) #1 brightens, #2 brightens  
   B) #1 brightens, #2 stays same  
   C) #1 stays same, #2 stays same  
   D) #1 stays same, #2 brightens  
   E) None of these is correct
13. This circuit shown on the right has five identical ideal light bulbs (labeled 1-5). Rank the 5 bulbs from brightest to dimmest (hint: look carefully at the figure!)
(A) 1=5>2>3=4
(B) 1>2>3=4>5
(C) 1>2>5>3=4
(D) 1>2=3=4>5
(E) None of these is correct!

14. Which schematic diagram best represents the realistic circuit shown on the right

A) B) C) D) E) None of these four schematic circuit choices is equivalent to the "realistic" one!
15. The next two questions refer to this situation:
A cubical box of edge length L=2 meters is placed so that its edges are parallel to the coordinate axes, as shown.
The space in and around the box is filled with an electric field given by
\[ \vec{E} = A\hat{i} + B\hat{k} \]
where A = 1 N/C (newtons per coulomb), B= 3 N/C.
(i and k are usual unit vectors, pointing in x and z directions respectively)
In SI units, what is the magnitude of the electric flux through the top shaded surface (the surface at z = +2 m)?
A) zero   B) 3   C) 6   D) 12   E) None of these

16. The total electric charge enclosed by the cubical box is…
A) zero   B) positive   C) negative
D) Not enough information to answer the question!

17. In case (I) a positive charge +Q is surrounded by a spherical Gaussian surface of diameter R.
In case (II), two charges, each +Q, are enclosed by a spherical Gaussian surface of diameter 2R.
How does the electric flux through the surface in case (II) compare with the electric flux through the surface in case (I)?
\[ \Phi_E(\text{through surface II})/\Phi_E(\text{through surface I}) = ... \]
A) 1   B) 2   C) 4   D) 8   E) 16
18. A long straight wire, carrying a current $I$ to the right, is located below a stationary rectangular conducting loop. The straight wire and loop are in the same plane, and the entire straight wire is moving downward, away from the loop, with speed $v$, as shown.

The induced current in the stationary rectangular loop is

A) zero
B) clockwise
C) counter-clockwise

19. The same current $I$ is flowing through two long (ideal) solenoids, labeled A and B, which both have circular cross section.

Solenoid B has twice the diameter of A, half the length of A, and half as many turns (coils) as A.

What is the ratio of the total magnetic energy contained in solenoid B to that in solenoid A, that is, what is $U_B/U_A$? (Hint: for a solenoid $B = \mu_0 n I$)

A) 1 (total stored magnetic energy is same in each)
B) 2
C) 4
D) 8
E) None of these is correct

20. An electron and a proton, both with the same initial velocity $v_0$, enter a region with a uniform magnetic field $B$ into the page, as shown. Each one undergoes semi-circular motion in the field and exits the field some distance $d$ from the entry point.

(The diagram shows the path for just one of the two particles.)

Consider the following two statements, and decide if they are true or false

i) The particle shown in the picture must be the negative one (the electron)
ii) The distance "d" for the proton will be greater than "d" for the electron.

A) Both i and ii are true
B) i is true, but ii is false
C) i is false, but ii is true
D) Both i and ii are false
21. Three ideal polaroid filters, labeled 1, 2, and 3, are placed between a source of unpolarized light and an observer. As shown, the pass axes of the three filters are at angles of $0^\circ$, $60^\circ$, and $90^\circ$ relative to the vertical. The middle filter (2) is then removed. What does the observer see?

A) No light when filter 2 is present and some light when filter 2 is removed.
B) Some light when filter 2 is present and no light when filter 2 is removed.
C) No light when filter 2 is present and still no light when filter 2 is removed.
D) Some light when filter 2 is present and more light when filter 2 is removed.
E) Some light when filter 2 is present and the same amount of light when filter 2 is removed.

22. A very large (effectively infinite) plastic slab of thickness $T$ has a uniform positive charge density $\rho$ (charge per volume, C/m$^3$). A student wishes to compute the magnitude $E$ of the electric field at a distance $d$ ($d > T/2$) from the center of the slab. The student writes down Gauss’s Law $\oint \mathbf{E} \cdot d\mathbf{A} = Q(\text{enc})/\varepsilon_0$, and sketches the centered, cylindrical Gaussian surface shown (dashed). The cylinder has length $2d$ and end caps each of area $A=\pi r^2$. What is the correct expression for the charge $Q_{\text{enclosed}}$?

$Q_{\text{enclosed}} = \ldots$

A) $AT\rho$ 
B) $2A\rho$
C) $2A\,d\,\rho$
D) $2A\,T\,\rho$
E) $A\rho$
23. The equipotential surfaces in a region of space are indicated in the diagram below. A proton is released from rest at point X. What does the proton do? (neglect gravity)
A) accelerates to the right. B) accelerates to the left C) remains at rest. D) it drifts up (or down) along the line of constant voltage it starts on E) it accelerates down along the line of constant voltage it starts on.

24. A conducting wire loop with a light bulb (forming a simple closed circuit) is near a long, straight wire carrying a large current which is decreasing at a constant, steady rate (i.e. \( \frac{dl}{dt} = -\text{constant} \)), as shown. The loop and the straight wire are in the same plane. What can you say about the direction of current in the loop, and the brightness of the bulb (which is a visible measure of the current around the loop)?
A) Current is clockwise, brightness is decreasing with time
B) Current is clockwise, brightness is steady
C) Current is counter-clockwise, and brightness is decreasing with time
D) Current is counter-clockwise, and brightness is steady
E) There is no current flowing anywhere through the loop, the bulb is dark.

25. A long straight wire, carrying a current \( I \), passes through the center of a circular wire loop. The wire loop is in the plane of the page, and the straight wire is perpendicular to the page. The current is going into the page and is increasing. The current induced in the wire loop is ..
A) clockwise B) counter-clockwise C) zero.
26. A 1200W hairdryer (this refers to the average power of the hairdryer) is designed to be plugged into a standard 120V electrical outlet. What is the maximum number of such hair dryers that can be plugged in and turned on without tripping the breaker in a circuit that has a 15 A breaker switch?
Hint: A 15A breaker switch will interrupt the current if the total rms current exceeds 15A.

A) 80  B) 10  C) 4  D) 2  E) 1

The next two problems refer to this situation: a transformer at a power station is designed to step up the voltage from 120 V (RMS, AC) to 1200 V (RMS, AC).
The voltage oscillates with a frequency of 60 Hz.

27. If the primary (input) side is a coil with 100 turns, how many turns should the secondary (output) side have?

A) 10 turns          B) 20 turns  C) 1000 Turns  D) 1200 Turns  
E) None of these is correct!

28. If the station delivers an average power of 120 MW (that's MegaWatts), what is the maximum instantaneous current flowing out of the secondary side?
(Answer to two place precision)

A) 120 kA                  B) 71 kA      C) 100 kA  D) 140 kA 
E) None of these is correct!

29. If you halve the period, T of a traveling electromagnetic wave in vacuum, what happens to the wavelength of that wave?

A) wavelength is the same, it is independent of period. 
B) wavelength increases by a factor of 2.  
C) wavelength increases by a factor of 4 
D) wavelength decreases by a factor of 2 
E) wavelength decreases by a factor of 4.
30. A coil of wire with \( N = 100 \) turns and area \( A = 0.10 \text{ m}^2 \) is oriented so that its plane is perpendicular to a uniform magnetic field \( B \) which is increasing at a rate of 0.010 T/s. The coil is connected to a resistor \( R = 10\Omega \). What is the power dissipated in the resistor at the moment when \( B = 0.1 \text{ T} \)?

A) 0.1 W  
B) \( 10^{-2} \) W  
C) \( 10^{-3} \) W  
D) \( 10^{-4} \) W  
E) None of these.

31. A "coaxial cable" consists of a long inner solid wire with radius \( R \), and an outer (hollow) cylindrical wire with inner radius \( 2R \) and outer radius \( 3R \). The inner wire carries total current \( I \) into the page and the outer (hollow cylindrical) wire carries the same magnitude current \( I \) out of the page. Both wires have uniform current density. What is the magnitude of the magnetic field \( B \) at the surface of the outer wire, that is, at \( r = 3R \)?

A) \( \mu_0 I / 2\pi R \)  
B) \( \mu_0 I / 6\pi R \)  
C) \( \mu_0 I / \pi R \)  
D) zero  
E) None of these.

32. An electron (charge \(-e\)) is released from rest in a region where there is a uniform \( E \)-field and a uniform \( B \)-field, both are pointing along the +x-direction; that is, \( E = E_x \hat{i}, \ B = B_x \hat{i} \). What is the path of the electron after its release?

A) Left and curving upwards  
B) Left and curving downwards  
C) straight left ←, along the –x direction, forever  
D) straight right →, along the +x direction, forever  
E) Some other motion.
33. An end-on view of a solenoid is shown to the right. There is a decreasing clockwise current around the solenoid, causing a decreasing uniform B-field in its interior. What is the direction of the electric field at the point x inside the solenoid and directly below the solenoid’s central axis as shown in the diagram?

(A) left ←
(B) right →
(C) up ↑
(D) down ↓
(E) zero

34. A small elliptical shaped wire loop is carrying a current I which is increasing in time. Above it and below it are two small circular conducting loops, labeled 1 and 2, as shown. All three loops are FLAT and lie in the plane of the page. The currents induced in loops 1 and loop 2 are

A) Both clockwise
B) Both counterclockwise
C) Both zero
D) Clockwise in loop 1, but counterclockwise in loop 2
E) Counterclockwise in loop 1, but clockwise in loop 2.

35. Which one of the follow statements is correct (only one is correct!)?

A) The magnetic force on a charged particle may change its kinetic energy
B) A test charge released from rest will always initially move along a B-field line.
C) Where the B-field lines are most dense, the magnitude of the magnetic field is largest
D) The net magnetic flux through a closed surface may be non-zero
E) B-field lines may cross
36. Two charges, labeled 1 and 2, with charges $+Q$ and $-Q$, are a fixed distance apart. A metal cube, with no net charge on it, is placed between the charges, as shown in the diagram. What happens to the magnitude of the net force on charge 1 when the cube is placed between the charges.

A) net force on 1 is unchanged
B) net force on 1 decreases to zero
C) net force on 1 decreases (but remains non-zero)
D) net force on 1 increases
E) we cannot decide if we do not know the numerical magnitude of the charge $Q$.

The next three questions refer to this situation. A circuit consists of a battery, two resistors, an inductor and a switch as shown. Initially the switch is open and has been open for a long time.

37. The switch is closed. Immediately after the switch is closed, what is the magnitude of the current that flows through the battery?

A) 0 A  B) 0.5 A  C) 1. A  D) 2. A  E) None of these is correct!

38. After a very long time, what is the magnitude of the current through the battery?

A) 0 A  B) 0.5 A  C) 1. A  D) 2. A  E) None of these is correct!

39. After being left closed for a very long time, the switch is opened again. Immediately after the switch is re-opened, describe the current flowing the rightmost resistor, labeled $R_2$.

A) 1 A, flowing up $\uparrow$
B) 1 A, flowing down $\downarrow$
C) 2 A, flowing up $\uparrow$
D) 2 A, flowing down $\downarrow$
E) 0, no current flows through $R_2$ at that instant.
40. A long solenoid with many turns per length has a uniform magnetic field \( B \) within its interior. Consider the imaginary rectangular path of length "c" and width "a" with the bottom edge \textit{entirely within} the solenoid, as shown.

What is the integral of \( \int \mathbf{B} \cdot d\mathbf{L} \) around this rectangular path in the counterclockwise direction?

A) 0
B) 2 B c
C) 2 B (c+a)
D) B a c
E) B c

41. A coil of wire carrying current \( I \) can rotate freely about an axis in a uniform magnetic field. The coil is in the plane of the page, and the magnetic field is directed from left to right as shown.

If released from rest in the position shown, which way does it rotate?

(A) the right side will rotate out of the page
(B) the left side will rotate out of the page.
(C) the loop will not rotate at all, but it will feel a net force to the right
D) the loop will not rotate at all, and it will feel zero net force
E) the loop will not rotate at all, and it will feel a net force up the page.
42. An electromagnetic plane wave, given by $\vec{E}(x,y,z) = E_o \hat{z} \sin(kx + \omega t)$, propagates to the left.

The figure above represents this wave at a particular instant in time. Four points in space are labeled I, J, K, and L. All four points lie in the x-y plane and have the same x-coordinate.
(Note the orientation of the E- and B-fields: the E-field oscillates in the x-z plane; the B-field oscillates in the x-y plane)

For the instant shown, rank the magnitudes of the electric field at the four points, from largest to smallest.

A) $E_I > E_J > E_K > E_L$

B) $E_J > E_I > E_K > E_L$

C) $E_J > E_I = E_K > E_L$

D) $E_L > E_K > E_J > E_I$

E) $E_I = E_J = E_K = E_L$

Have a safe and excellent winter break. Both of us (Prof's Pollock and Gurarie) had a great time teaching you - we hope to see some of you in upcoming physics classes. Take a look around after this exam and think about all the places you see Maxwell's equations in action! (Maybe a harder thing to think about would be - where DON'T you?!)