Instructor(s):

PHYSICS DEPARTMENT

PHY 2005, Spring 2016 Final Exam April 28, 2016

Name (print, last first): _____ Signature: _____

On my honor, I have neither given nor received unauthorized aid on this examination.

YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

(1) **Code your test number on your answer sheet (use lines 76–80 on the answer sheet for the 5-digit number)**. Code your name on your answer sheet. **DARKEN CIRCLES COMPLETELY**. Code your UFID number on your answer sheet.
(2) Print your name on this sheet and sign it also.
(3) Do all scratch work anywhere on this exam that you like. **Circle your answers on the test form.** At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout.
(4) **Blacken the circle of your intended answer completely, using a #2 pencil or blue or black ink**. Do not make any stray marks or some answers may be counted as incorrect.
(5) **The answers are rounded off. Choose the closest to exact. There is no penalty for guessing. If you believe that no listed answer is correct, leave the form blank.**
(6) Hand in the answer sheet separately.

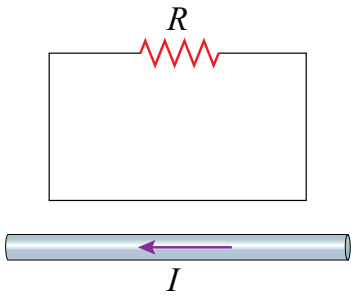
Physical Constants:

$g = 9.8$ m/s^2	$m_e = 9.11 \times 10^{-31}$ Kg $= 0.51$ MeV	$m_p = 1.67 \times 10^{-27}$ Kg $= 938$ MeV
$\mu_o = 4\pi \times 10^{-7}$ T·m/A	$e = 1.6 \times 10^{-19}$ C	$\varepsilon_o = 8.85 \times 10^{-12}$ C^2/Nm^2
Speed of light in vacuum $c = 3 \times 10^8$ m/s	constant k in Coulomb's Law: $k = 8.99 \times 10^9$ Nm^2/C^2	
$h = 6.6 \times 10^{-34}$ Js	$R = 1.097 \times 10^7$ m^{-1}	$1\ eV = 1.6 \times 10^{-19} J$

1. A double slit is illuminated with monochromatic light of wavelength 600 nm. The m = 0 and m = 1 bright fringes are separated by 3.0 cm on a screen which is located 4.0 m from the slits. What is the separation between the slits? (in m)

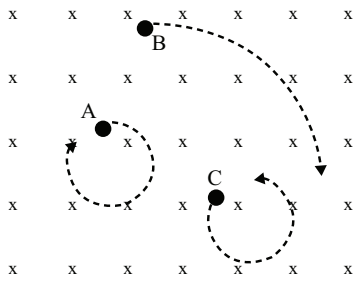
(1) 8.0×10^{-5} (2) 4.0×10^{-5} (3) 1.2×10^{-4} (4) 2.0×10^{-5} (5) 1.6×10^{-4}

2. The drawing shows a straight wire carrying a current I. Above the wire is a rectangular loop that contains a resistor R. The current I is decreasing in time. Which of the following statement(s) is(are) correct?
(a) An induced current flows through the resistor R from left to right.
(b) The magnetic field produced by the loop current always has a direction that is opposite to the direction of the magnetic field produced by the current I.
(c) The total flux penetrating through the loop doe not change and therefore no current flows through the resistor R.
(d) An induced current flows through the resistor R from right to left.
(e) The total flux penetrating through the loop increases.



(1) a only (2) a and b (3) d and e (4) b and d (5) c only

3. Three particles have the same mass and the same magnitude of charge. Which of the following statements are correct based on the figure showing the trajectories of three particles in a uniform magnetic field.
(a) A and B have the same sign of charge.
(b) A has positive charge and C has negative charge.
(c) The speed of A is larger than B.
(d) The speed of C is smaller than A.
(e) B has negative charge but C has positive charge.



(1) a and e (2) a and c (3) b and e (4) a, b, and c (5) c and e

4. Which one of the following statement(s) is(are) consequence(s) of Special Relativity?
   (a) Clocks that are moving run slower than when they are at rest.
   (b) The length of a moving object is larger than it was at rest.
   (c) Light is a particle.
   (d) Mass of an object is constant regardless of the speed of the object.
   (e) The speed of light emitted from an object moving with a uniform speed v is (c + v).

   (1) a only (2) a and b (3) c only (4) a, d, and e (5) d and e

5. Photons of energy 6 eV cause electrons to be emitted from a certain metal with a maximum kinetic energy of 2 eV. If photons of twice the wavelength are incident on this metal which one of the following statements is true?

   (1) No electrons will be emitted.
   (2) Electrons will be emitted with a maximum kinetic energy of 1 eV.
   (3) Electrons will be emitted with a maximum kinetic energy of 8 eV.
   (4) Electrons will be emitted with a maximum kinetic energy of 10 eV.
   (5) Electrons will be emitted with a maximum kinetic energy of 20 eV.

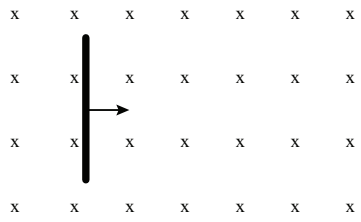
6. An electron and a proton have the same kinetic energy and are moving at speeds much less than the speed of light. Determine the ratio of the de Broglie wavelength of the electron to that of the proton.

   (1) 42.8 (2) 0.023 (3) 1 (4) 1831 (5) 529

7. An electron is in the ground state of a hydrogen atom. A photon is absorbed by the atom and the electron is excited to the n = 2 state. What is the energy in eV of the photon? (in eV)

   (1) 10.2 (2) 13.6 (3) 3.40 (4) 6.80 (5) 0.64

8. A straight wire is moving sideways with a constant speed perpendicular to a magnetic field (see figure). Which of the following statement(s) is(are) true?
   (a) The wire feels a force in the direction perpendicular to its motion (into the page).
   (b) A potential difference is induced across the wire and the top of the wire has the higher potential.
   (c) Free electrons in the wire will be accumulated in the middle of the wire.
   (d) 1.2 A of current flows through the wire throughout the motion.

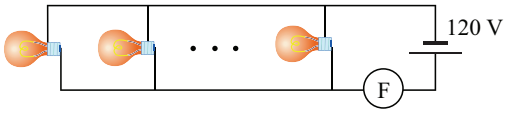


   (1) b only (2) c and d (3) b and d (4) a and c (5) a only

9. Which of the following phenomena does not involve refraction of light waves?
   (a) A far-sightedness can be corrected by using a converging lens.
   (b) Sunlight passed through a prism reveals its rainbow spectrum.
   (c) An inverted real image made by a concave mirror.
   (d) Light transmitted through a bent optical fiber.
   (e) Total eclipse of the sun.

   (1) c and e only (2) e only (3) b, c, and d only (4) all except a (5) none

10. Some light bulbs are connected in parallel to a 120 V source as shown in the figure. Each bulb dissipates an average power of 60 W. The circuit has a fuse F that burns out when the current in the circuit exceeds 9 A. Determine the largest number of bulbs, which can be used in this circuit without burning out the fuse.



   (1) 17 (2) 9 (3) 25 (4) 36 (5) 13

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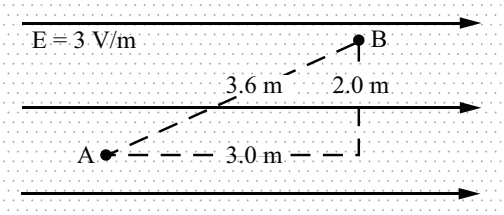
11. A $+1.0\ \mu$C point charge is moved from point A to B in the uniform electric field as shown. The E-field strength is 3 V/m. Which one of the following statements is necessarily true concerning the potential energy of the point charge?



(1) It decreases by 9.0×10^{-6} J.
(2) It increases by 9.0×10^{-6} J.
(3) No change.
(4) It increases by 6.0×10^{-6} J.
(5) It decreases by 10.8×10^{-6} J.

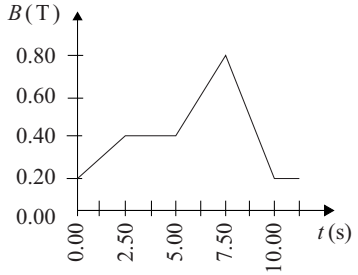
12. It is desired to use a 60-cm focal length diverging lens to form a virtual image of an object. The image is to be one-third as large as the object. Where should the object be placed and what will be the image distance in cm?

(1) (120, −40) (2) (−165, −45.2) (3) (55, −22.5) (4) (−155, 41.3) (5) (55, 22.5)

13. A thin film of polymer used in an antireflective coating has an index of refraction of 1.5. If light of frequency 5.5×10^{14} Hz is incident on the film, but is found to be entirely transmitted and not reflected, what is a possible thickness x of the film (in m)?

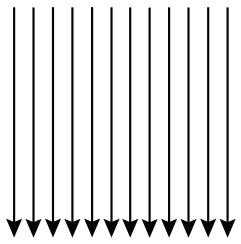
(1) 9.1×10^{-8} (2) 1.8×10^{-7} (3) 1.3×10^{-7} (4) 0 (5) 3.6×10^{-7}

14. A circular coil of wire has 25 turns and has a *radius* of 0.075 m. The coil is located in a variable magnetic field whose behavior is shown on the graph. At all times, the magnetic field is directed to the normal to the plane of a loop. What is the average magnitude of EMF induced in the coil in the time interval from $t = 5.00$ s to 7.50 s? (in mV)



(1) 70.7 (2) 140 (3) 49 (4) 180 (5) 92

15. Uniform parallel electric field is set up in space as shown in the figure. Particle #1 has +3 mC charge and a 3 mg-mass and Particle #2 has -10 mC charge and a 10 mg-mass. These particles are released in the field region. Which of the following statements is wrong? Ignore gravity and consider the electric force and the Newton's second law.



(1) Particle #2 has the larger magnitude of acceleration.
(2) Particle #1 and #2 move in the opposite direction.
(3) Particle #1 will feel the smaller magnitude of force than Particle #2 does.
(4) The magnitude of the force cannot be determined since the field strength is not given.
(5) The forces acting on the particles are in the opposite direction.

16. The yellow light from a sodium lamp has a wavelength of 589 nm in vacuum. When this light is propagating through mineral oil with an index of refraction $n = 1.52$, what is its wavelength in nm?

(1) 387.5 (2) 895 (3) 589 (4) 439.7 (5) 282

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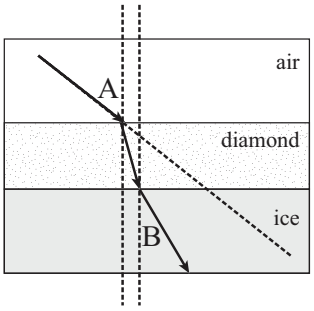
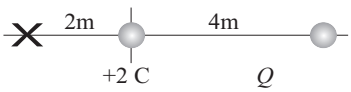
17. As a beam goes through layers of different materials (air, diamond, and ice), it bends as shown in the figure. The numbers in the figure indicate the angles formed by each beam and vertical line. When the angle A (angle of incidence) is 45°, what is the angle B (angle of refraction in ice) in degree?

Material	Index of Refraction (n)
air	1.00
diamond	2.42
ice	1.31



(1) 32.7 (2) 51.2 (3) 45 (4) 61 (5) 42.1

18. A charge of +2 C is at the origin. When charge Q is placed at 4 m along the positive x axis, the electric field at 2 m along the negative x axis becomes zero. What is the value of Q?



(1) −18 C (2) −8 C (3) −10 C (4) −4 C (5) +12 C

PH4205

Final Exam Solns S16

(1)

$n\lambda = d\sin\theta$ for constr. interference

Here $n=1$ (1st max),

$$\text{So} \quad d = \frac{\lambda}{\sin\theta} = \frac{6\times10^{-7}\,m}{\sin\theta}$$

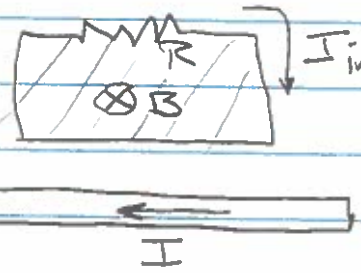
From diagram, $\tan\theta = \frac{0.03}{4}$

So $\theta = \arctan 0.0075 = 0.429^\circ$

$\sin\theta = 0.00748$ ($\tan\theta \simeq \sin\theta$ for small angles)

$$\Rightarrow \quad d = \frac{6\times10^{-7}}{0.0075} = 8\times10^{-5}\,m$$

(2)



B from wire points into the page, but is decreasing with time. Lenz's law $\Rightarrow$ current must flow in the loop to oppose this change, i.e. to increase the flux into the paper. This requires that the induced current flow clockwise by rh rule. So current flows left to right through the resistor.

(3) Force on a moving charge is

$F_M = qvB$ in a direction given by rh rule.

(a) From their trajectories A and B are experiencing a force to their right relative to direction of travel $\Rightarrow$ same charge. (a) is correct.

(b) might be correct since A and C are circling in different directions, but if A were positive, rh rule gives force to left, opposite for C — wrong

(c) Tricky: You might think if v is bigger, force is bigger and circle should be "tighter". But the particle also has more momentum, + therefore is harder to push away from a straight line trajectory. Recall the particle goes in a circle; therefore

$$qvB = \frac{mv^2}{R}$$

$$\text{So} \quad R = \left(\frac{m}{qB}\right)v \quad \propto v$$

So A is slower and (c) is wrong

(d) wrong for same reason as (c)

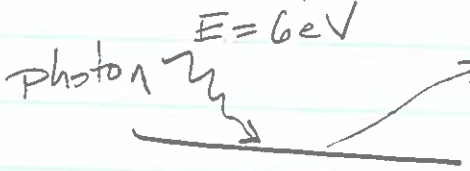
(e) rh rule for B says $\vec{v} \times \vec{B}$ points to left relative to trajectory, but particle is curving to right. Therefore charge must be negative. C goes the other way, so it is positive. (e) is correct

So (1) a and e is correct,

(4) (a) is time dilation - correct
(b) opposite of length contraction - incorrect
(c) correct (sort of), but not a consequence of relativity
(d) incorrect acc. to Albert: Mass increases with speed
(e) incorrect acc. to Albert: nothing can go faster than c.

(1) a only is right

(5)



This means the binding potential energy must be 4eV. A photon of twice the wavelength will have 1/2 the energy since $E = \frac{hc}{\lambda}$

Thus the photon we are asked to consider has $E = 3\,eV$. This is no longer enough to overcome the binding potential energy barrier and kick an electron out. So (1) is correct.

(6) $\frac{1}{2} m_e v_e^2 = \frac{1}{2} m_p v_p^2 \Rightarrow \frac{v_p}{v_e} = \sqrt{\frac{m_e}{m_p}}$

de Broglie wavelength is $\lambda = \frac{h}{p} = \frac{h}{mv}$

Ratio electron : proton is $\frac{\lambda_e}{\lambda_p} = \frac{m_p v_p}{m_e v_e}$

$$= \frac{m_p}{m_e}\sqrt{\frac{m_e}{m_p}} = \sqrt{\frac{m_p}{m_e}} = \sqrt{\frac{1.67 \times 10^{-27}\,kg}{9.11 \times 10^{-31}\,kg}}$$

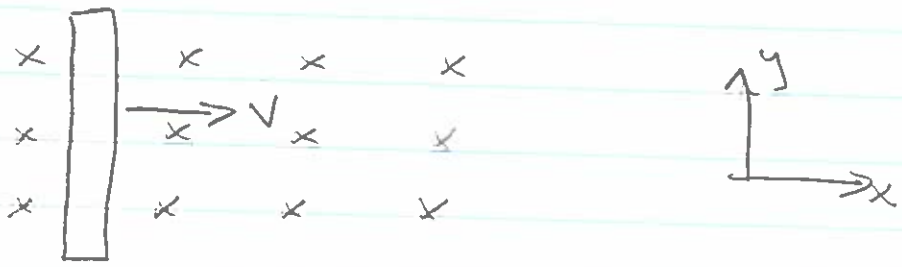
$$= 42.8$$

(7) Bohr energies $E_n = -\frac{13.6}{n^2}\,eV \quad n = 1, 2, \ldots$

Transition between $n = 2$ and $n = 1$ is therefore

$$\frac{-13.6}{4} + 13.6 = 10.2\,eV$$

(8)



Electrons in wire feel a force because they

are moving in a magnetic field (to right, with wire on the average). $\vec{v} \times \vec{B}$ is by rh rule up (y direction). However electrons are negative so magnetic force $\vec{F}_m = q\vec{v} \times \vec{B}$ is down (-y) ((a) is wrong) The electron can move, or flow, so positive charge will accumulate at the top of the wire, which therefore has a higher potential ((b) is correct). No reason for them to accumulate in the middle (c) is wrong. (d) is wrong because (i) the charge separation must eventually stop, and (ii) we weren't given any numbers!

(9) Lenses involve refraction: (a)
Optical fibers use total internal reflection which is due to index of refraction (d)
Prism bends light of different λ differently => refraction (b)

Neither mirrors (c) nor eclipses (e) (which are shadow phenomena) use refraction

c and e only is correct

(10) Resistances in parallel:

$$\frac{1}{R_{eff}} = \underbrace{\frac{1}{R} + \frac{1}{R} + \cdots}_{N \text{ bulbs}} = \frac{N}{R}$$

$R_{eff} = \frac{R}{N}$

What is R? Use $P = 60\,W = \frac{V^2}{R}$

$$\Rightarrow R = \frac{120^2}{60} = 240\,\Omega$$

If we have $I = 9A = \frac{120V}{(240/N)} = \frac{N}{2}A$

$N = 18$ for 9A, but then circuit will blow, so we need 1 fewer $= 17$

(11) $PE = qEd$ (d along field)

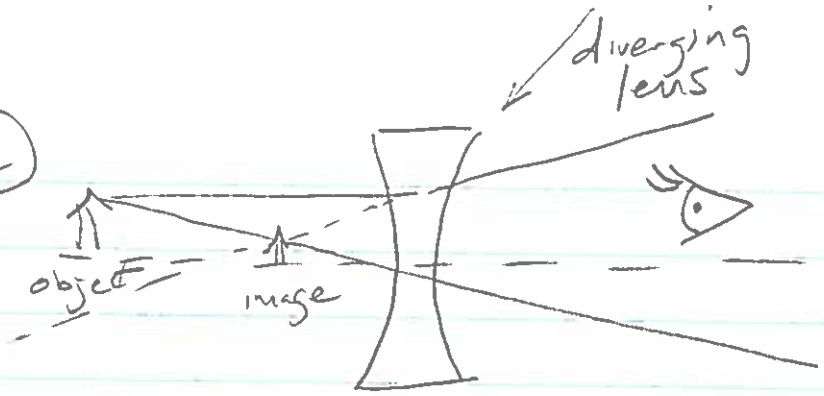
Note we can ignore the 2.0m displacement, because it is $\perp$ to field

So since the + charge is moved 3m in the direction of the field ("downhill") its PE decreases by

$$(1\mu C)(3\,V/m)(3m) = 9\times10^{-6}\,J$$

(7)

(12)



$f = -60\,cm$ ← diverging

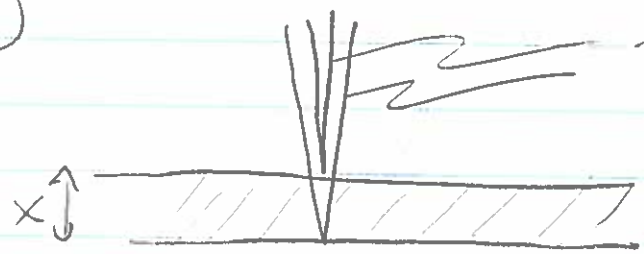
$$M = \frac{-q}{p} = \frac{h_i}{h_o} = \frac{1}{3}$$

$$\frac{1}{p} = \frac{-1}{q} + \frac{1}{f} = \frac{3}{p} \quad \frac{-1}{60}$$

$$-\frac{2}{p} = -\frac{1}{60} \Rightarrow \boxed{p = 120}$$

$$q = -\frac{p}{3} = \boxed{-40}$$

(13)



two outgoing rays interfere destructively

Path difference $= 2x$ should be $\frac{1}{2}$-integer multiple of wavelength $\frac{\lambda_f}{2}, \frac{3\lambda_f}{2}, \frac{5\lambda_f}{2}$ ... for destructive interference (anti reflective)

$$\boxed{2x = \frac{\lambda_f}{2}}$$ ← we need to use wavelength of light in the film λ_0

$$\boxed{\lambda = \frac{c}{f}} \qquad \boxed{\lambda_f = \lambda / n}$$

$$x = \frac{\lambda_f}{4} = \frac{\lambda}{4n} = \frac{3 \times 10^8}{4 \cdot 1.5\,(5.5 \times 10^{14})} = \underline{9.1 \times 10^{-8}\ m}$$

25 turns

(14) 

$r = 0.075\,m$

$$V_{ind} = -N\frac{\delta\Phi}{\delta t} = -NA\frac{\delta B}{\delta t}$$

$$= -25\left(\pi\, 0.075\,m^2\right)\left(\frac{0.8-0.4\,T}{2.5\,s}\right)$$

$$= 0.071\,V = 71\,mV$$

(15) $F_E = qE \qquad a = F_E/m = \frac{q}{m}E$

(1) $\frac{q_2}{m_2} = \frac{-10}{10} = -1\frac{C}{g} \qquad \frac{q_1}{m_1} = \frac{-3}{3}$

So accelerations are the same

(2) correct because they have opp. q

(3) correct because $q_1 < q_2$

(4) correct

(5) correct, see (2)

(16) $\lambda_{med} = \lambda_{vacuum}/n$

$$\frac{589\,nm}{1.52} = 387.5\,nm$$