Instructor(s): *Z. Qiu*

PHYSICS DEPARTMENT

PHY 2005, Spring, 2015 Final Exam April 22, 2015

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

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

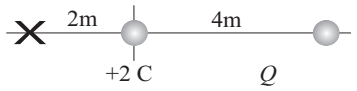
YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

(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	$m_p = 1.67 \times 10^{27}$ kg
$e = 1.6 \times 10^{-19}$ C	constant k in Coulomb's Law: $k = 8.99 \times 10^9$ Nm^2/C^2	
$\mu_o = 4\pi \times 10^{-7}$ N/A^2	$\varepsilon_o = 8.85 \times 10^{-12}$ C^2/Nm^2	$h = 6.63 \times 10^{-34}$J·s

1. 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?

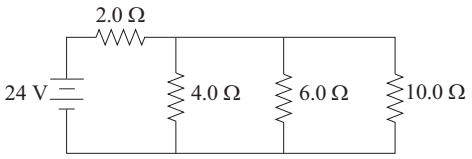


(1) −18 C (2) −8 C (3) −10 C (4) −4 C (5) +12 C

2. Two capacitors with capacitances of 6.0 and 12.0μF, respectively, are connected in series. The system is connected to a 30-V battery. What charge accumulates on the 2.0-μF capacitor?

(1) 120μC (2) 180μC (3) 150μC (4) 30μC (5) 40μC

3. Three resistors connected in parallel have individual values of 4.0, 6.0 and 10.0Ω, respectively. If this combination is connected in series with a 24-V battery and a 2.0-Ω resistor, what is the current in the 10-Ω resistor?



(1) 1.2 A (2) 2.0 A (3) 3.1 A (4) 1.6 A (5) 2.4 A

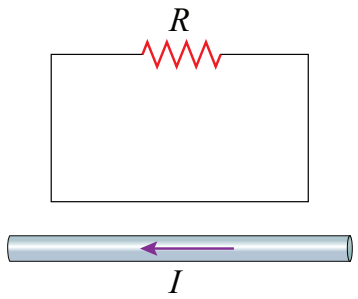
4. Two long parallel wires 60 cm apart carry currents of 2.5 A and 4.0 A in the same direction. Is there any point between the two wires where the magnetic field is zero?

(1) yes, 36.9 cm from the 4-A wire
(2) yes, 23 cm from the 4-A wire
(3) yes, midway between the wires
(4) no
(5) yes, 47.6 cm from the 4-A wire

5. A planar loop consisting of four turns of wire, each of which encloses 200 cm^2, is oriented perpendicularly to a magnetic field that increases uniformly in magnitude from 10 mT to 25 mT in a time of 5.0 ms. What is the resulting induced current in the coil if the resistance of the coil is 1.25Ω?

(1) 48 mA (2) 12 mA (3) 0.24 mA (4) 60 mA (5) 9.6 mA

6. 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

7. 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

8. 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

9. Two converging thin lenses with focal lengths 30.0 cm and 20.0 cm are aligned on a common axis, running left to right, the 30-cm lens being on the left. A distance of 100.0 cm separates the lenses. An object is located at a distance of 120.0 cm to the left of the 30-cm lens. Where will the final image appear as measured from the 20-cm lens?

(1) +30 cm (2) −30 cm (3) −60 cm (4) +70 cm (5) +120 cm

10. A Young's double slit has a slit separation of 2.0×10^{-5}m on which a monochromatic light beam is directed. The resultant bright fringes on a screen 1.50 m from the double slit are separated by 3.45×10^{-2}m. What is the wavelength of this beam? (1 nm =10^{-9}m)

(1) 460 nm (2) 554 nm (3) 373 nm (4) 237 nm (5) 292 nm

11. A puddle of water ($n = 1.33$) is covered with a very thin layer of oil ($n = 1.20$). How thick is the oil in the region that strongly reflects light with a wavelength of 650 nm?

(1) 271 nm (2) 245 nm (3) 458 nm (4) 650 nm (5) 325 nm

12. If a proton with mass 1.67×10^{-27}kg moves in an accelerator such that its total energy is three times its rest energy, what is its speed? ($c = 3.00 \times 10^8$m/s)

(1) 2.83×10^8m/s (2) 1.41×10^8m/s (3) 2.12×10^8m/s (4) 1.00×10^8m/s (5) none of the others

13. What is the wavelength of the line in the Balmer series of hydrogen that is comprised of transitions from the $n = 8$ to the $n = 2$ level? ($R = 1.097 \times 10^7 \text{m}^{-1}$ and 1 nm = 10^{-9}m)

(1) 389 nm (2) 486 nm (3) 523 nm (4) 430 nm (5) 675 nm

14. In the year 2213 an astronaut wears an antique, but accurate, "quartz" wristwatch on a journey at a speed of 2.0×10^8 m/s. According to the watch, the trip lasts 23.9 hours. How long was the trip as measured by the mission control in Houston? (in hr)

(1) 32.1 (2) 42.9 (3) 23.9 (4) 18.1 (5) 26.6

15. A muon has rest energy 105 MeV. What is its kinetic energy when its speed is 0.85c? (in MeV)

(1) 94 (2) 27 (3) 541 (4) 181 (5) 46

16. A uniform electric field, with a magnitude of 450 N/C, is directed parallel to the positive x-axis. If an electron is released from rest at $x = 4.0$ m, what is its speed as the electron reaches $x = 0$? (in m/s)

(1) 2.51×10^7 (2) 0.69×10^7 (3) 1.56×10^7 (4) 4.18×10^6 (5) 3.75×10^6

17. A conducting sphere has a net charge of -5×10^{-17} C. How many excess electrons are on the surface of the sphere?

(1) about 310 (2) about 190 (3) about 370 (4) about 620 (5) about 440

18. Which one of the following statements concerning the magnetic force on a charged particle in a magnetic field is true?

(1) It depends on the component of the particle's velocity that is perpendicular to the field.
(2) It is a maximum if the particle is stationary.
(3) It is zero if the particle moves perpendicular to the field.
(4) It is a maximum if the particle moves parallel to the field.
(5) It acts in the direction of motion for a positively charged particle.

19. An object is held at a distance of 24 cm from a convex mirror creating an image that is 1/4 the object size. What is the focal length of the mirror?

(1) −8.0 cm (2) −6.0 cm (3) −9.0 cm (4) −12 cm (5) 15 cm

20. 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

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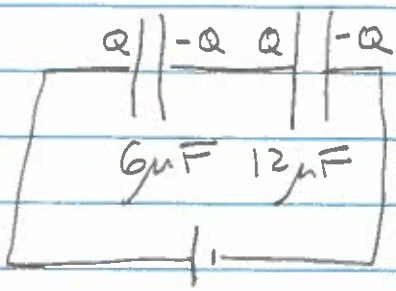
(1) $E = \frac{2C}{(2m)^2} + \frac{Q}{(6m)^2} = 0$

$\Rightarrow \quad Q = -2C\left(\frac{6}{2}\right)^2 = \boxed{-18C}$

(2)



series capacitors Q = same

$Q = CV \Rightarrow$

$Q = (6\mu F)V_1$

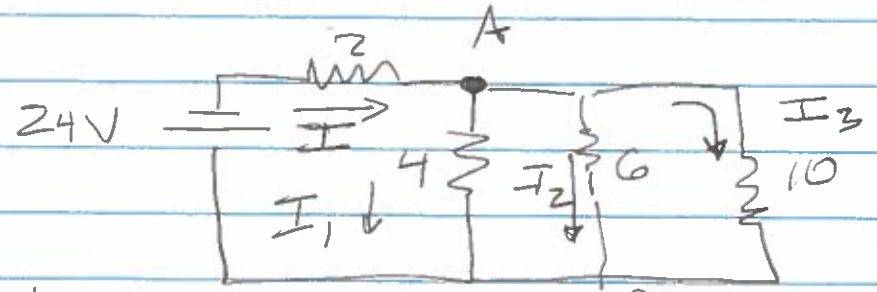
$Q = (12\mu F)V_2$ } $\boxed{\frac{V_1}{V_2} = 2}$

$V_1 + V_2 = 30V$

$\Rightarrow \quad V_1 + \frac{V_1}{2} = \frac{3}{2}V_1 = 30 \Rightarrow V_1 = 20$

$\Rightarrow \quad Q = (6\mu F)(20V) = \boxed{120\mu F}$

(3)



Effective resistance $R_{||}$ of 4, 6, 10 Ω is

$\frac{1}{R_{||}} = \frac{1}{4} + \frac{1}{6} + \frac{1}{10} = \frac{15}{60} + \frac{10}{60} + \frac{6}{60} = \frac{31}{60}$

$R_{||} = \frac{60}{31} = 1.93 \qquad R_{tot} = 2 + 1.93 = 3.93$

$I = \frac{24V}{3.93} = 6.1A$

Voltage at pt. A is $24 - (2\Omega)(6.1A)$
$= 11.9\,V$

I through 10Ω resistor is then

$$\frac{(11.9\,V)}{10\Omega} = 1.19\,A$$

or, use K's laws: $24 - 2I - 4I_1 = 0$ a)

$24 - 2I - 10I_3 = 0$ b)

$24 - 2I - 6I_2 = 0$ c)

$I - I_1 = I_2 + I_3$ d)

a), b) $\Rightarrow$ $I_3 = \frac{2I_1}{5}$

a), c) $\Rightarrow$ $I_2 = \frac{2I_1}{3}$

d) $\Rightarrow$ $I - I_1 = \underbrace{\left(\frac{2}{3} + \frac{2}{5}\right)}_{\frac{16}{15}} I_1$

$$I_1 = \frac{15}{31} I$$

a) $\Rightarrow$ $24 - 2I - \frac{60}{31} I$

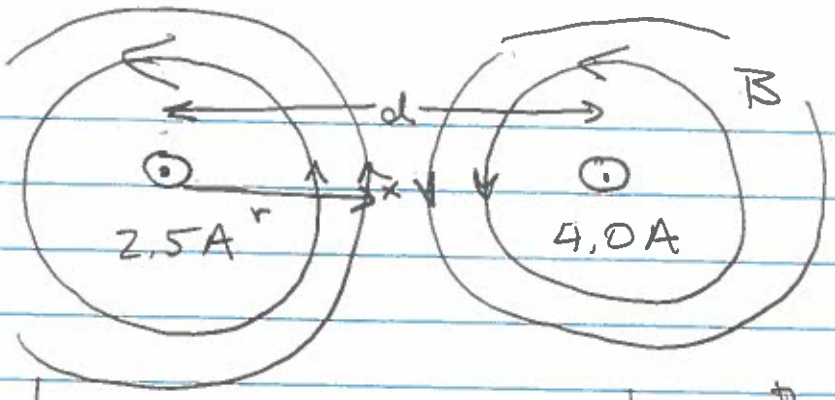
$$24 = \frac{122}{31} I \Rightarrow I = \frac{31}{122} \cdot 24 = 6.1\,A$$

$$I_3 = \frac{2}{5}\frac{15}{31}(6.1) = 1.19\,A$$

Not easier!

3

4



B's can cancel somewhere!

$$B_{2.5} = \frac{\mu_0 2.5}{2\pi r} = \frac{\mu_0 4.0}{2\pi(d-r)}$$

$$\frac{2.5}{r} = \frac{4.0}{(d-r)} \qquad 2.5(d-r) = 4r$$

$$2.5d = 6.5r \Rightarrow r = d \cdot \frac{2.5}{6.5}$$

$$= (60\,cm)\frac{2.5}{6.5} = 23.1$$

So $d - r = 60 - 23.1 = 36.9\,cm$

5

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

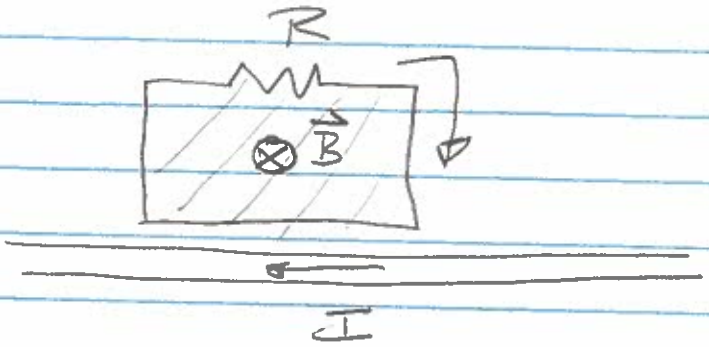
$$= -4 \cdot (200 \cdot 10^{-4}) \underbrace{\left(\frac{25\times10^{-3} - 10\times10^{-3}}{5\times10^{-3}}\right)}_{3\ T/s}$$

$$= -0.24\ V$$

$$I = \frac{V_{ind}}{1.25\Omega} = 192\ mA$$

NB: probably meant 1.25 Ohm/turn, in which case coil resistance is 5 Ohm, which means I=0.24/5=48 mA

(6)



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

(7) Only a) is correct.

Note: c) light is a particle is a prediction of quantum mechanics, not relativity

Others are incorrect

(8) De Broglie wavelength: $\lambda = h/p$

$$\frac{1}{2} m_e v_e^2 = \frac{1}{2} m_p v_p^2 \qquad \frac{v_e}{v_p} = \sqrt{\frac{m_p}{m_e}}$$

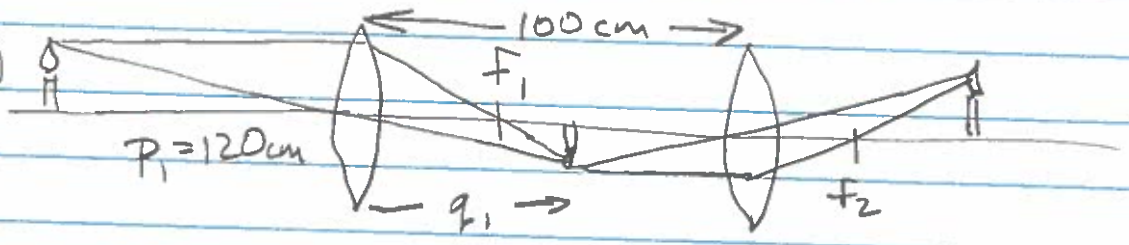
$$\frac{p_e}{p_p} = \frac{m_e v_e}{m_p v_p} = \frac{m_e}{m_p}\sqrt{\frac{m_p}{m_e}} = \sqrt{\frac{m_e}{m_p}}$$

$$= \sqrt{\frac{9.1\times10^{-31}}{1.7\times10^{-27}}} = \sqrt{5.45\times10^{-4}}$$

$$= 2.33\times10^{-2}$$

$$\frac{\lambda_e}{\lambda_p} = \frac{p_p}{p_e} = \frac{1}{2.33\times10^{-2}} = 42.9$$

(9)



$f_1 = 30$ cm $f_2 = 20$ cm

Apply lens eqn. twice.

$$\frac{1}{p_1} + \frac{1}{q_1} = \frac{1}{f_1} \Rightarrow \frac{1}{q_1} = \frac{1}{30} - \frac{1}{120} = \frac{1}{40}$$

$$\Rightarrow q_1 = 40.$$

Treat image at q_1 as object for 2nd lens. So p_2 is $100 - q_1 = 60$ cm

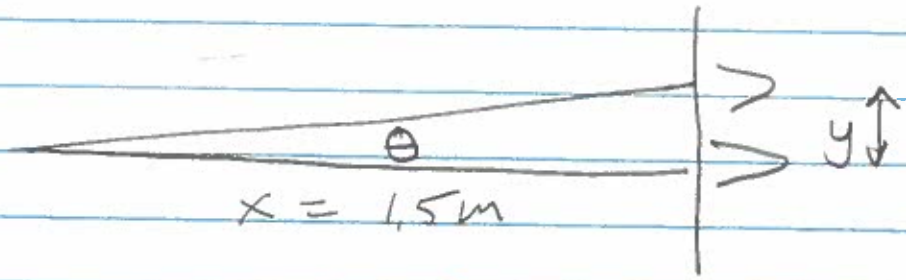
$$\frac{1}{q_2} = \frac{1}{f_2} - \frac{1}{p_2} = \frac{1}{20} - \frac{1}{60} = \frac{1}{30}$$

$$\Rightarrow q_2 = 30\text{ cm to right of}$$

(10) Bright fringes $n\lambda = d\sin\theta$

$n=0 \Rightarrow \theta = 0$

$n=1 \Rightarrow \theta = \theta_1 \quad \lambda = d\sin\theta_1$



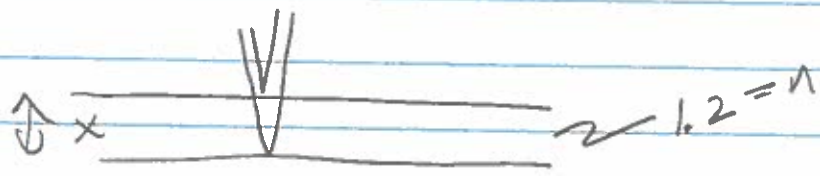
$$\theta = \arctan\frac{y}{x} = \arctan\frac{3.45\times10^{-2}}{1.5}$$

$$= 1.31^\circ$$

$$\Rightarrow \lambda = d\sin\theta = (2\times10^{-5})(0.022)$$

$$= 460\ nm$$

(11) "strongly reflects light" $\Rightarrow$ constructive interference



Path difference $= 2x = \lambda_f = \frac{\lambda}{n}$

$$x = \frac{650\times10^{-9}\ m}{(1.20)\cdot 2} = 271\ nm$$

(12) $E = mc^2 = \dfrac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} = 3 m_0 c^2$

$$\Rightarrow \frac{1}{1-\frac{v^2}{c^2}} = 9 \Rightarrow \frac{1}{9} = 1 - \frac{v^2}{c^2}$$

$$\frac{v}{c} = \sqrt{\frac{8}{9}} \qquad v = 2.83 \times 10^8 \text{ m/s}$$

(13) Balmer series

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{8^2}\right)$$

$$= 1.097 \times 10^7 \left(\frac{1}{4} - \frac{1}{64}\right) = 2.57 \times 10^6 \text{ m}^{-1}$$

$$\lambda = 389 \text{ nm}$$

(14) $\gamma = \dfrac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \dfrac{1}{\sqrt{1-\left(\frac{2}{3}\right)^2}} = 1.34$

Trip is longer by this amount

$$(1.34)(23.9 \text{ hr}) = 32.1 \text{ hr}$$

(15) $m_0 c^2 = 105 \text{ MeV}$

relativistic KE $= (m - m_0)c^2 = (\gamma - 1) m_0 c^2$

$\gamma = 1/\sqrt{1 - v^2/c^2} = 1/\sqrt{1 - 0.85^2} = 1.90$

$KE = (1.90 - 1)\, 105 \text{ MeV} = 94.5 \text{ MeV}$

(16) $E = 450\ N/C \longrightarrow$

Electric pot. energy $= qEd =$

$(1.6 \times 10^{-19})(450)(4_M) = 2.88 \times 10^{-16}\ J$

transformed into KE $\Rightarrow$

$\frac{1}{2} m_e v^2 = 2.88 \times 10^{-16}\ J$

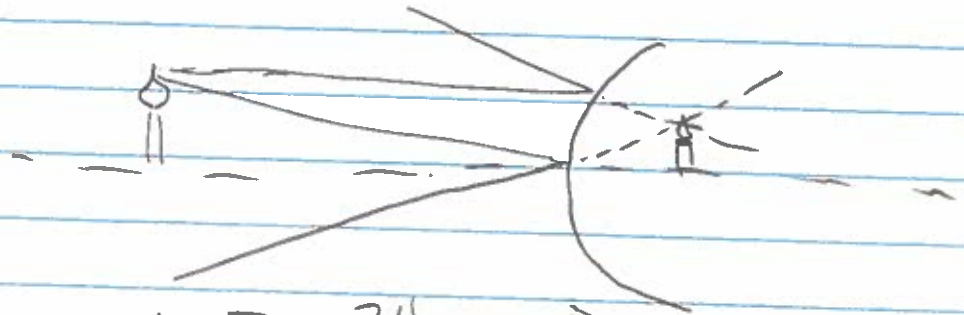
$v = \sqrt{\frac{2(2.88 \times 10^{-16})}{9.11 \times 10^{-31}}} = 2.51 \times 10^{7}\ \frac{m}{s}$

(17) $\frac{-5 \times 10^{-17}\ C}{(1.6 \times 10^{-19}\ C/e)} = 313$ electrons

(18) $F_M = q v B_\perp = q v_\perp B$

(1) is true

(19)



$\leftarrow p = 24\ cm \rightarrow$

$\frac{1}{F} = \frac{1}{q} + \frac{1}{p}$ $\quad M = \frac{-q}{p} = \frac{1}{4}$

$$q = -\frac{p}{4} = -6 \text{ cm}$$

$$\frac{1}{f} = \frac{1}{-6} + \frac{1}{24} = \frac{-1}{8}$$

$$f = -8 \text{ cm} \quad \text{(convex mirror)}$$

(20) Mirrors and shadows (eclipse) do not involve refraction. Therefore c) and e) are both correct.