SOLUTIONS

Physics 204– First Hour Exam
Sunday, March 1, 2009
Prof. George Horton

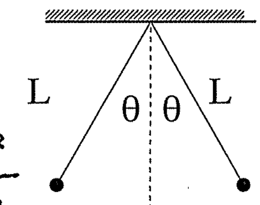
Your name sticker ⇒ [ ]

with exam code

1. The exam will last from 8:10 to 9:30 P.M. Use a #2 pencil to make entries on the answer sheet. Enter the following id information now, before the exam starts.
2. In the section labelled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
3. Under STUDENT # enter your 9-digit Rutgers ID number.
4. Enter 204 under COURSE, and your section number under SEC.
5. Under CODE enter the exam code given above.
6. During the exam, you may use a calculator and are allowed one $8\frac{1}{2} \times 11$ inch sheet of paper with whatever you want hand-written on it. Xeroxed or printed sheets are **not permitted** and will be confiscated.
7. The exam consists of 17 multiple choice questions. For each multiple choice question mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess.
8. Turn off any cell phone or other communication device, and pack it away in a place clearly inaccessible. You may not use your cell-phone as a clock or in any other way during the exam.
9. Before starting the exam, make sure that your copy contains all 17 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.
10. A proctor will check your name sticker and your student ID when you turn in the exam. Please have them ready.
11. You are not allowed to give help to any other student, ask for help from anyone but a proctor, or change your seat without permission from a proctor. Doing so will result in a zero score for the exam.
12. Please hand in the answer sheet. You may take the question paper with you when you leave.
13. Some constants are given on the last page.

Distance between charges is $r = 2L\sin\theta = 2(.3)\sin 30° = .3\ m$
Let T = tension in each thread.

1. Two small spheres, each of mass 0.005 kg and carrying equal charge q are suspended from a common point by massless threads of length $L = 0.3\ m$. What is q, if the threads make an angle $\theta = 30°$ with the vertical?



a) $7.9 \times 10^{-7}\ C$
b) $7.5 \times 10^{-2}\ C$
c) $6.3 \times 10^{-13}\ C$
→ d) $5.3 \times 10^{-7}\ C$
e) $1.8 \times 10^{-7}\ C$

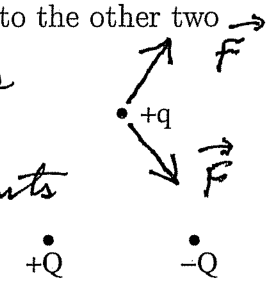
$T\sin\theta = \frac{kq^2}{r^2}$

$T\cos\theta = mg$

Dividing, $\tan\theta = \frac{kq^2}{r^2 mg}$

$\Rightarrow q = \sqrt{\frac{r^2 mg \tan\theta}{k}} = 5.3 \times 10^{-7}\ C.$

2. Three charges $+q, +Q, -Q$ are placed at the corners of an equilateral triangle as shown. The net electrical force on charge $+q$ due to the other two charges is

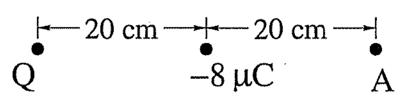


a) vertically up
b) vertically down
c) zero
d) horizontally to the left
→ e) horizontally to the right

Same magnitude for both forces. Vertical components cancel.

3. In the figure, the electric field at point A is zero. What is the charge Q?

→ a) $+32\ \mu C$
b) $-32\ \mu C$
c) The electric field cannot be zero for any value of Q
d) $+16\ \mu C$
e) $+16\ \mu C$



$E_A = \frac{kQ}{(.4)^2} + \frac{k(-8\ \mu C)}{(.2)^2} = 0$

$Q = \frac{(8\ \mu C)(.4)^2}{(.2)^2} = +32\ \mu C.$

4. A charge $+Q$ is located inside a styrofoam ball of radius R. The net electric flux through the ball's surface is Φ. What is the value of the net electric flux through the ball's surface if the charge inside is doubled, and the ball's radius is tripled?

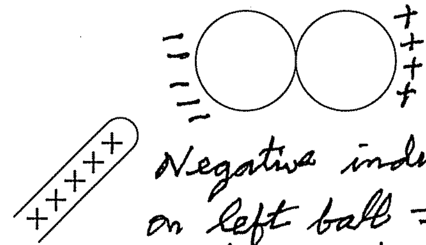
a) Φ
→ b) 2Φ
c) $9\Phi/2$
d) $2\Phi/9$
e) $4\Phi/9$

$\Phi = E \cdot A = \frac{kQ}{R^2} \cdot 4\pi R^2 = 4\pi k Q.$

$\Phi_{NEW} = 4\pi k(2Q) = 2\Phi.$

5. A positively charged insulator is brought near two conducting spheres that are in contact. Subsequently the balls roll apart a bit. Then the ball on the right will have

a) no net charge
→ b) a positive charge
c) a negative charge
d) either a positive or a negative charge
e) none of the other answers



Negative induced charge on left ball ⇒ positive induced charge on right ball

6. The voltage between the cathode and the screen of a television set is 22 kV. If an electron leaves the cathode with an initial speed of zero, what will be its speed just before it hits the screen?

a) $2.8 \times 10^6\ m/s$
b) $6.2 \times 10^7\ m/s$
→ c) $8.8 \times 10^7\ m/s$
d) $7.7 \times 10^{15}\ m/s$
e) $5.3 \times 10^7\ m/s$

$qV = \frac{1}{2} m v^2$

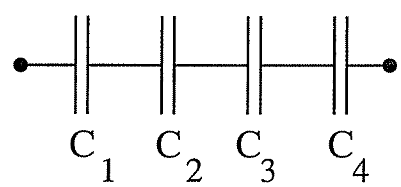
$(1.6 \times 10^{-19})(22 \times 10^3) = \frac{1}{2}(9.11 \times 10^{-31}) v^2$

Solving, $v = 8.8 \times 10^7\ m/s$.

7. If $C_1 < C_2 < C_3 < C_4$, the equivalent capacitance of this combination of capacitors

→ a) is less than C_1
b) is more than C_4
c) is between C_2 and C_3
d) could be any value depending on the values of the four capacitances
e) could be any value depending on the applied voltage

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}$ is even greater than $\frac{1}{C_1}$, so C must be less than C_1.



8. A 4 μF capacitor is charged to 150 V. How much additional energy must be added to charge it to 300 V?

a) $6.00 \times 10^{-4}\ J$
→ b) $1.35 \times 10^{-1}\ J$
c) $1.80 \times 10^{-5}\ J$
d) $0.30 \times 10^{-3}\ J$
e) $2.80 \times 10^{-1}\ J$

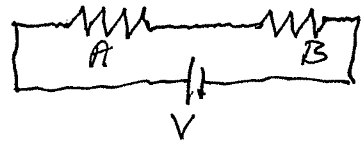
$E_1 = \frac{1}{2} C V_1^2 \qquad E_2 = \frac{1}{2} C V_2^2$

$E_2 - E_1 = \frac{1}{2} C (V_2^2 - V_1^2)$

$= \frac{1}{2}(4 \times 10^{-6})[(300)^2 - (150)^2] = 0.135\ J$

9. Two resistors are connected in series across a potential difference. Resistor A has twice the resistance of resistor B. If the current carried by resistor A is I, what is the current carried by resistor B?

a) 2I
b) I/2
c) 4I
d) I/4
→ e) I

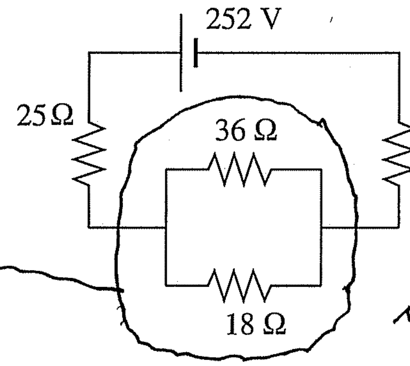


"Series" ⇒ same current in both resistors.

10. In the circuit shown, the power dissipated in the 18 Ω resistor is

a) 150 W
→ b) 98 W
c) 33 W
d) 160 W
e) None of the other answers

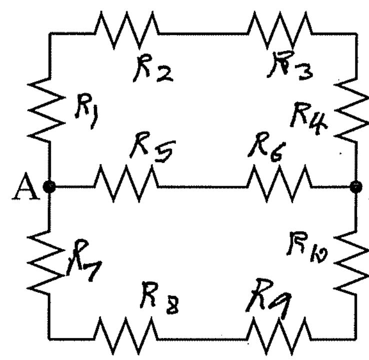
$\frac{1}{R} = \frac{1}{36} + \frac{1}{18}$ ⇒ $R = 12\ \Omega$



$R_{TOT} = 25 + R + 35 = 72\ \Omega$ since $12\ \Omega$ is value of R as shown at left.
$I_{TOT} = \frac{252}{72} = 3.5$ A.
Voltage across 18 Ω is $I_{TOT} \cdot R = (3.5)(12) = 42$ V,
so $P = \frac{V^2}{R} = \frac{(42)^2}{18} = 98$ W.

11. What is the effective resistance between terminals A and B for the circuit shown? Each resistor is 10 Ω.

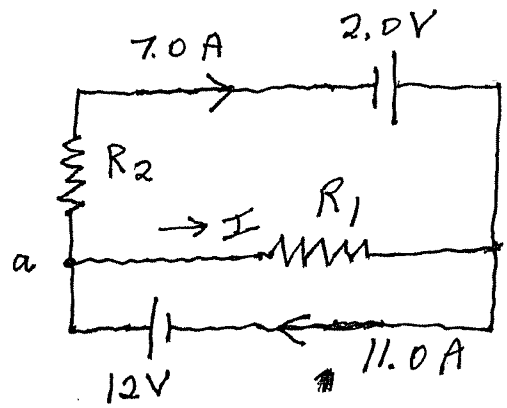
a) 1 Ω
b) 0.5 Ω
→ c) 10 Ω
d) 5 Ω
e) None of the other answers



$R_{1234} = R_{78910} = 4 \times 10 = 40\ \Omega$.
$R_{56} = 20\ \Omega$.
These combos are in parallel, so $\frac{1}{R} = \frac{1}{40} + \frac{1}{40} + \frac{1}{20} = \frac{1}{10}$.
⇒ $R = 10\ \Omega$.

12. In the circuit shown, what is the value of R_1? Hint: First apply Kirchhoff's junction rule (sometimes also called the point rule).

a) 0.29 Ω
b) 1.7 Ω
c) 1.1 Ω
→ d) 3.0 Ω
e) 0.67 Ω



Junction rule at "a":
$11 = 7 + I$
⇒ $I = 4$ A.
Loop rule for lower loop: Traversing clockwise:
$12 - 4R_1 = 0$
⇒ $R_1 = 3\ \Omega$.

13. A 6.0 μF capacitor, initially uncharged, is connected to a 10 $k\Omega$ resistor and a 9.0 V battery, in series. What is the initial current in this circuit?

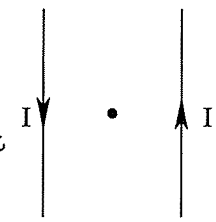
a) 6.0×10^{-2} A
→ b) 9.0×10^{-4} A
c) 5.4×10^{-5} A
d) 0.90 A
e) 6.0×10^{-5} A

Capacitor is initially uncharged. So the initial current I is given by
$V - IR = 0 \Rightarrow I = \frac{9.0}{10 \times 10^3} = 9.0 \times 10^{-4}$ A.

14. Two wires lie in the plane of the paper and carry equal currents in opposite directions, as shown. At a point midway between the wires, the magnetic field is

a) zero
b) into the page
→ c) out of the page
d) towards the top or bottom of the page
e) towards one of the two wires

By right-hand rule, $\vec{B}$ due to each wire is out of the page at the point indicated.



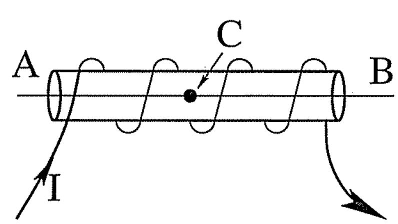
15. An electron has an instantaneous velocity of 2.5×10^5 m/s in the positive x-direction in a region where there is a uniform magnetic field of 0.45 T directed at 35° to the x-axis in the horizontal plane. What is the magnitude and direction of the force on the electron?

a) 1.8×10^{-14} N up
b) 1.5×10^{-14} N down
c) 1.5×10^{-14} N up
→ d) 1.0×10^{-14} N down
e) 1.0×10^{-14} N up

$|\vec{F}| = |q| v B \sin\theta$
$= (1.6 \times 10^{-19})(2.5 \times 10^5)(.45) \sin 35°$
$= 1.0 \times 10^{-14}$ N. Direction is down by using right-hand rule and negative charge of electron.

16. A solenoid carries a current I as shown. An electron is inserted with velocity v along the axis AB of the solenoid. When the electron is at C, it experiences a force that is

→ a) zero
b) not zero and along AB
c) not zero and along BA
d) not zero and perpendicular to AB
e) None of the other answers



$|\vec{F}| = |q| v B \sin\theta$
Here $\theta = 180°$, so $F = 0$.

17. An α-particle, charge $3.204 \times 10^{-19}\ C$ and mass $6.64 \times 10^{-27}\ kg$, is moving at right angles to a uniform magnetic field of 1.20 T. The radius of curvature of the track of the α-particle is 0.20 m. What is its momentum?

See below.

a) $3.1 \times 10^{-19}\ kg \cdot m/s$
b) $0.77\ kg \cdot m/s$
c) Cannot be determined, because the α-particle's speed is not given
d) $7.7 \times 10^{-22}\ kg \cdot m/s$
→ e) $7.7 \times 10^{-20}\ kg \cdot m/s$

Some Constants

acceleration due to gravity g	$9.8\ m/s^2$
electromagnetic permittivity ϵ_0	8.854×10^{-12} C^2/N-m^2
electromagnetic constant $k_e \equiv \frac{1}{4\pi\epsilon_0}$	8.9875×10^9 N-m^2/C^2
magnitude of electron charge	1.602×10^{-19} C
electron mass	9.11×10^{-31} kg
proton mass	1.67×10^{-27} kg
magnetic permeability μ_0	$4\pi \times 10^{-7}$ T·m/A
speed of light in vacuum	2.998×10^8 m/s
atomic mass unit	u = 1.6605×10^{-27} kg = 931.5 MeV/c^2

Magnetic force provides centripetal acceleration.

So $q v B \sin 90^\circ = \frac{m v^2}{r}$. $\sin 90^\circ = 1$.

$\Rightarrow m v = q B r$ and mv is momentum, so

$p = m v = (3.204 \times 10^{-19})(1.20)(0.20)$

$= 7.7 \times 10^{-20}$ kg · m/s.