Solutions

Physics 161
Makeup Exam
WEDNESDAY, DECEMBER 5TH, 2012

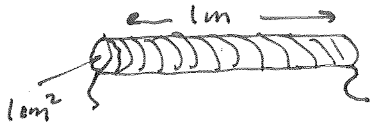
Directions: The exam consists of 25 multiple choice questions. Each question carries equal weight. Please circle the correct answer.

Note: Everyone will be given free credit on problems 10, 13, and 17.

Note: Formulae were put on blackboard: Thermo from Exam 1 in particular.

(1) A long solenoid has an inductance of 4π mH. If the solenoid's cross-sectional area is 1 cm^2, and its length is 1 m, what is the number of windings? (Assume that it is an air-core solenoid.)

(a) 1000
(b) 10000
(c) 100000
(d) 1000000



$B = \mu_0 N I / \ell$

$\Phi = NBA = \mu_0 N^2 I A / \ell$

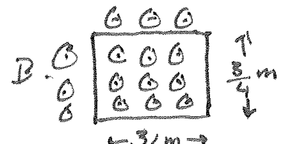
$L = \mu_0 N^2 A / \ell = \Phi / I$

$N^2 = \frac{4\pi \times 10^{-3} \cdot 1m}{\mu_0 \,(1 \times 10^{-4} m^2)}$

$N^2 = \frac{4\pi \times 10^{-3}}{4\pi \times 10^{-7}} \cdot 10^4 = 10^8$ $\quad N = 10^4$

(2) A closed loop of wire with fixed perimeter 3.0 m containing a 10 Ω resistor is bent in the shape of a square. It lies in the plane of the page, as shown in the figure. A uniform magnetic field $B = 1$ T is directed out of the page and passes through the loop. If the field strength is slowly increased to 17 T, how much charge passes through the resistor, and in which direction?

(a) 0.1 C clockwise
(b) 0.1 C counterclockwise
(c) 0.9 C clockwise
(c) 0.9 C counterclockwise



I will be clockwise, to create self-field to oppose increasing field. $\mathcal{E} = -\frac{d\Phi}{dt} = IR = R\frac{dQ}{dt}$

so $RQ = -\Delta\Phi = (\frac{3}{4}m)^2 16T = 9$

$Q = \frac{9}{10}$ C

(3) Two closed-loop circuits are magnetically coupled to one another via a transformer having $N_1 = 10$ turns in the primary circuit, and N_2 turns in the secondary circuit. If the emf across the transformer is 5000 Volts in the primary, and 200 kVolts in the secondary, what is N_2?

(a) 4
(b) 40.
(c) 400.
(d) 4000.

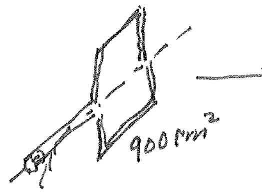
Recall, $\mathcal{E}_2 = \frac{N_2}{N_1}\mathcal{E}_1$, so $N_2 = 10 \cdot \frac{200 \times 10^3}{5 \times 10^3} = 10 \cdot \frac{2}{5} \times 10^2$

(for a transformer.) $= 0.4 \times 10^3 = 400$

(4) The armature of a generator rotates at the rate of 60 rpm (revolutions per minute) in a uniform magnetic field of 1.0 T. If the armature has an area of 900 cm^2 and supports 1000 windings, what is the maximum emf produced?

convert to rad/sec. $\rightarrow 60 \frac{rev}{min} \cdot \frac{1 min}{60 s} \cdot \frac{2\pi\, rad}{rev} = \omega\ (\frac{rad}{s})$

(a) 733 Volts
(b) 565 Volts
(c) 546 Volts
(d) 421 Volts



$\longrightarrow 1.0T = B$

$\Phi = NBA\cos(\omega t)$

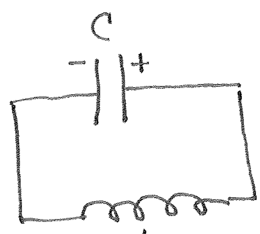
$\frac{d\Phi}{dt} = -(NBA\omega)\sin(\omega t)$

(maximum emf when $\sin = 1$ or -1.)

$\mathcal{E}_{max} = 10^3 \cdot 1 \cdot 900 \times 10^{-4} \cdot 60 \frac{rev}{min} \cdot \frac{1 min}{60 sec} \cdot \frac{2\pi\, rad}{rev} = 565$

(5) An inductor and a capacitor are placed in series in circuit as shown in the figure. The inductance is 2.0 mH and the capacitance is 2.0 mF. Which equation best describes the current in the inductor as a function of time?

(a) $\frac{d^2I}{dt^2} - (1.0\ \text{s}^{-2})\, I = 0$
(b) $\frac{d^2I}{dt^2} + (1.0\ \text{s}^{-2})\, I = 0$
(c) $\frac{d^2I}{dt^2} + (4.0 \times 10^{-6}\text{s}^{-2})\, I = 0$
(d) $\frac{d^2I}{dt^2} + (2.5 \times 10^{5}\text{s}^{-2})\, I = 0$



$\sum_{\text{Voltages}} = -\frac{Q}{C} - L\frac{dI}{dt} = 0$ and $\frac{1}{LC} = 2.5 \times 10^5 s^{-2}$.

$L\frac{dI}{dt} + \frac{Q}{C} = 0$

so $L\frac{d^2I}{dt^2} + \frac{1}{C}\frac{dQ}{dt} = 0$, $\frac{dQ}{dt} = I$

$\frac{d^2I}{dt^2} + \frac{1}{LC} I = 0$

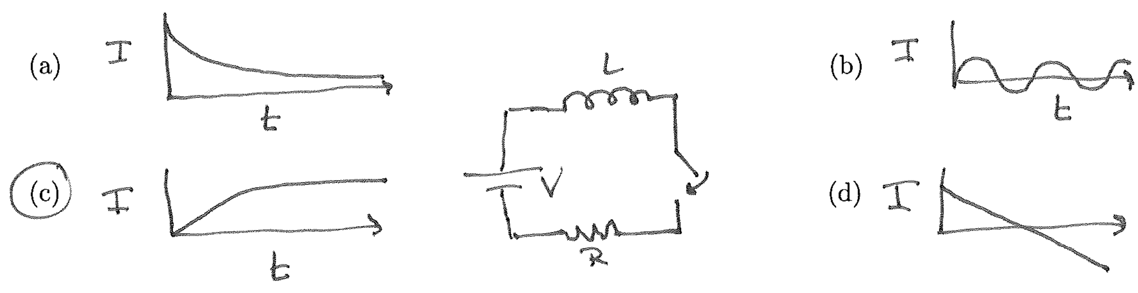
(6) Due to a plumbing mistake, a long straight cylindrical water pipe carries an electrical current of 1 Ampere across the ceiling in the men's locker room. What is the strength of the magnetic field a distance 1.0 meter from the center of the pipe? (Neglect the permeability of the ceiling tiles.)

(a) 1.0×10^{-7} T
(b) 2.0×10^{-7} T
(c) 3.0×10^{-7} T
(d) 4.0×10^{-7} T

$\oint \vec{B}\cdot d\vec{l} = B 2\pi r = \mu_0 I$

$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7})(1A)}{2\pi \cdot 1m} = 2\times 10^{-7}\,T$

(7) An inductor is placed in series with a resistor and a battery in a closed loop circuit, as shown in the figure. Which figure best describes the current versus time after the switch is closed?



(8) A parallel plate capacitor has a plate area of 1.0 cm^2 and a plate separation of 1.0 mm. The dielectric constant $\kappa = 3.0$ (plastic). If the breakdown field strength is 3.0×10^8 N/C, what is the maximum amount of charge that can be stored on this capacitor?

(a) 8×10^{-7} C.
(b) 5×10^{-6} C.
(c) 1×10^{-5} C
(d) 4×10^{-3} C.

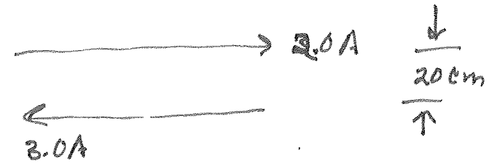
$E = \frac{\sigma}{\varepsilon} = \frac{\sigma}{\kappa\varepsilon_0} = \frac{Q}{A\kappa\varepsilon_0}$ $\qquad \frac{4\pi\varepsilon_0}{4\pi} = \frac{1}{4\pi\cdot 9\times 10^9}$

$Q = (3\times 10^8 N/C)\cdot(1\times 10^{-4} m^2)(3.0)\cdot\varepsilon_0$

$= 9\times 10^{8-4}\cdot\frac{1}{4\pi}\cdot\frac{1}{9}\times 10^{-9} = \frac{1}{4\pi}\times 10^{-5} = 8\times 10^{-7}\,C$

(9) Two long parallel wires each carry a steady current moving in opposing directions One wire carries a current of 2.0 A to the right, and the other wire carries a current of 3.0 A to the left. If the distance between the two wires is 0.20 meters, the magnetic force (per meter of wire) between them is

(a) 1×10^{-7} N/m (attractive).
(b) 2×10^{-7} N/m (repulsive).
(c) 6×10^{-6} N/m (repulsive).
(d) 9×10^{-5} N/m (repulsive).



$B_1 = \frac{\mu_0 I_2}{2\pi r_{12}}$ long wire

$\vec{F}_1 = I_1 \vec{l}_1 \times \vec{B}_1$ 1m

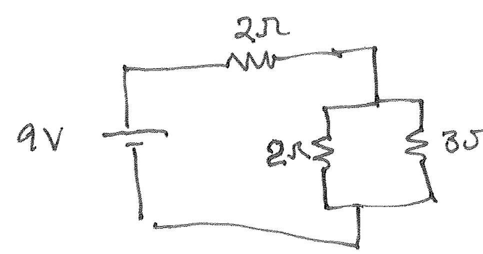
$|F_1| = \frac{\mu_0 I_1 I_2 \cdot l_1}{2\pi r_{12}} = \frac{2\times 10^{-7}\cdot 6}{(2\times 10^{-1})} = 6\times 10^{-6}$

(10) Consider the circuit shown below, consisting of two 2 Ω resistors, a 3 Ω resistor, and an 9 V battery. What is the power supplied by the battery? (Assume that the battery has no internal resistance.)

(a) 10 W
(b) 13 W
(c) ~~21 W~~ 25W
(d) 33 W

Mistake

closest Answer



$\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{3} = \frac{5}{6}$

$R_{eq} = 6/5\,\Omega$ $\qquad \frac{6}{5}\Omega + 2\Omega = \frac{16}{5}\Omega$

$\frac{(9V)^2}{(\frac{16}{5}\Omega)} = \left(\frac{81\cdot 5}{16}\right)$ Watts $= 25.3W$

(11) The following four equations describing all of the laws of electricity and magnetism are known as "Maxwell's equations", as they were summarized by him in 1865.

(a) $\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$
(b) $\oint \vec{E} \cdot d\vec{s} = -\frac{d}{dt} \int \vec{B} \cdot d\vec{A}$
(c) $\oint \vec{B} \cdot d\vec{A} = 0$
(d) $\oint \vec{B} \cdot d\vec{s} = \mu_0 \int \left(\vec{J} + \epsilon_0 \frac{\partial}{\partial t} \vec{E}\right) \cdot d\vec{A}$

Which is Ampere's law (as modified by Maxwell)?

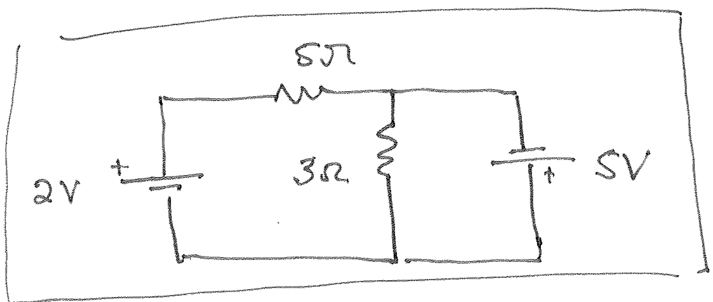
(12) What is the minimum amount of work required to charge a 5 μF capacitor to 10 μC?
(a) 1×10^{-5} J.
(b) 3×10^{-5} J.
(c) 4×10^{-5} J.
(d) 6×10^{-5} J.

$$\frac{Q^2}{2C} = \frac{(10 \times 10^{-6} C)^2}{2(5 \times 10^{-6} F)} = \frac{100}{10} \times 10^{-6} = \underline{10^{-5} J}$$

(13) Consider the circuit shown below, consisting of a 5 Ω resistor, a 3 Ω resistor, a 2 V battery and a 5 V battery. What is the current through the 3 Ω resistor?
(a) ~~34/15 A~~ 5/3 A
(b)38/15 A
(c)46/15 A
(d)52/15 A

Mistake

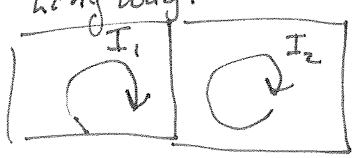
Closest answer.



5 Volts across 3Ω

Short Way: $\boxed{I = V/R = 5/3\ A}$

Long way:



$\therefore\ 2 - I_1 \cdot 5 - (I_1 - I_2)3 = 0$

$5 - (I_2 - I_1)3 = 0$

$\therefore\ (I_2 - I_1) = \frac{5}{3}A =$ current through 3Ω.

Note: $2 - 5I_1 + \frac{5}{3} \cdot 3 = 0 \quad I_1 = 7/5\ A$

$I_2 = \frac{5}{3} + \frac{7}{5} = \frac{25+21}{15} = \underline{\underline{\frac{46}{15}\ A}}$

(14) The surface charge density on a uniformly charged spherical soap bubble is 9.7×10^{-11} C/m^2. What is the electric field just inside the soap bubble?

(a) 11 N/C.
(b) 5 N/C.
(c) 2 N/C.
(d) 0 N/C.

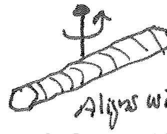
E=0 inside uniformly charged sphere.
(can prove using Gauss's law!)

(15) A solenoid of length 10 cm and diameter 0.5 cm has 1000 turns. It carries a current of 1A, and is suspended from the ceiling on frictionless bearings so that it is completely free to rotate. When a horizontal external magnetic field of strength 0.20 T is applied, the solenoid stops rotating and comes to an equilibrium position in the field. What is the total magnetic field strength inside the solenoid in equilibrium?

(a) 0.33 T
(b) 0.07 T
(c) 0.24 T
(d) 0.11 T

closest

$\xrightarrow[B]{0.20T}$



Aligns with $\vec{B}$.

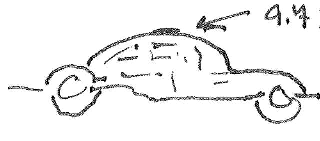
$B_{solenoid} = \frac{\mu_0 N I}{L} = \frac{4\pi\times10^{-7}\cdot10^3\cdot1}{(0.1)} = 4\pi\times10^{-3} \approx 0.013\,T$

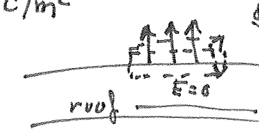
$B_{Total} = 0.20T + 0.013T = 0.21\,T$

(16) The surface charge density on the metal roof of a 1974 VW bug is 9.7×10^{-11} C/m^2. What is the electric field just above the surface?

(a) 11 N/C.
(b) 5 N/C.
(c) 2 N/C.
(d) 0 N/C.

$\leftarrow 9.7\times10^{-11}$ C/m^2





$\oint \vec{E}\cdot d\vec{A} = EA = \frac{Q}{\varepsilon_0}$

$E = \frac{Q}{A\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{9.7\times10^{-11}}{\varepsilon_0} = 11\frac{N}{C}$

(17) An electron and a proton are separated from one another by a distance of 0.05 nm in the hydrogen atom. What is the magnitude of the force between them?

Mistake (Free Credit)

(a) 1.5 pN
(b) 6.3 pN
(c) 8.4 pN
(d) 9.2 ~~pN~~ $\times10^{-8}$ N

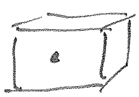
+e −e
|← .05 nm →|

$|F| = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}^2} = \frac{(1.6\times10^{-19})^2\, 9\times10^9\, Nm^2/C^2}{(5\times10^{-11}m)^2}$

$= 9.2\times10^{-8}\,N$

(18) A point charge of 1.0 μC is placed in the geometric center of a 10 cm $\times$10 cm $\times$10 cm plastic cube. If the cube is uncharged, what is the total electrical flux through the 6 faces of the cube?

(a) 9.1×10^5 Nm^2/C
(b) 3.5×10^5 Nm^2/C
(c) 2.2×10^5 Nm^2/C
(d) 1.1×10^5 Nm^2/C



$\underbrace{\oint}_{\text{closed surface}} \vec{E}\cdot d\vec{A} = \frac{q_{enclosed}}{\varepsilon_0} = (1.0\times10^{-6}C)\cdot4\pi\cdot9\times10^9\,Nm^2/C^2$

$= \underbrace{(4\pi\cdot9)}_{108}\times10^3\,Nm^2/C = 1.08\times10^5\,Nm^2/C$

(19) 200 grams of hot water initially at 100 degrees C cools to the ambient temperature of 25 degrees C. What is the change in the entropy of the water? The specific heat (at constant pressure) for water is 4.186 J/(g C), and is nearly constant over this range of temperature.

(a) 210 J/K
(b) −188 J/K
(c) 59 J/K
(d) −43 J/K

$dH = C_p dT = T ds + V \overset{\to 0}{dp}$

$ds = C_p \frac{dT}{T} \quad \Delta S = C_p \ln\left(\frac{T_2}{T_1}\right) = 200g\cdot4.186\frac{J}{gC}\ln\left(\frac{298}{373}\right)$

$= -188\,J/K$

(20) A heat engine operates between a reservoir at 100 C and the surroundings at 35 C. What is the minimum amount of heat absorbed from the hot reservoir for every Joule of work performed?

(a) 2.3 J
(b) 4.3 J
(c) 5.7 J
(d) 6.1 J.

$\frac{W}{Q_H} = \varepsilon = \frac{T_H - T_C}{T_H} = \frac{65}{373} \qquad Q_H = 1J\cdot373/65 = 5.7J$

(21) One mole of ideal gas initially at a pressure of 100 atm and temperature 300 K expands isothermally and reversibly to a pressure of 1 atm. How much heat is absorbed from the surroundings?

(a) 11.4 kJ
(b) 18 kJ
(c) 12 kJ
(d) 10 kJ

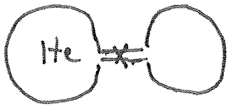
$\Delta U = 0$ for const. T, ideal gas.
$\Delta U = Q - W$, so $Q = W$

$W = \int p\,dV = nRT\int\frac{dV}{V} = nRT\ln\left(\frac{V_2}{V_1}\right)$

$= 1\cdot(8.314)(300)\ln\left(\frac{P_1}{P_2}\right) = 11.5\,kJ$

(22) Two glass bulbs having the same volume are connected to one another by a stopcock. Initially, one bulb is filled with 1 mole of helium gas, and the other bulb is evacuated. The bulbs are in thermal contact with the surroundings at 298 K. When the stopcock is opened, the gas expands to fill both bulbs. Assuming ideal gas behavior, what is the change in entropy of the universe (system plus surroundings)?

(a) $\Delta S_{\text{universe}} = 5.76$ J/K
(b) $\Delta S_{\text{universe}} = -5.76$ J/K
(c) $\Delta S_{\text{universe}} = -3.18$ J/K
(d) $\Delta S_{\text{universe}} = 0$ J/K



298 K.

$\Delta S = k\ln W_2 - k\ln W_1$
$= k\ln\left(\frac{W_2}{W_1}\right) = Nk\ln\left(\frac{V_2}{V_1}\right) = Nk\ln(2)$

$Nk = nR = 8.314\,\frac{J}{K}$

$(8.314)\ln(2)$
$\Delta S = 5.76$ J/K
and $\Delta S_{surr} = 0$

(23) When a process takes place spontaneously in a closed (no heat or work) system, it follows that

(a) the energy is constant and the entropy increases.
(b) the energy is constant and the entropy decreases.
(c) the energy is constant and the entropy of the surroundings increases.
(d) the energy decreases.

(24) One mole of ideal gas expands from 100 atm and 300 K to 1 atm and 200 K. What is the change in the volume of the gas?

(a) 25 liters
(b) 16 liters
(c) 35 liters
(d) 45 liters

$V_1 = \frac{nRT_1}{P_1} = 1\cdot\frac{(0.082)(300\,K)}{100\,atm} = 0.246\,l$

$V_2 = \frac{nRT_2}{P_2} = 1\cdot\frac{(0.082)(200\,K)}{1\,atm} = 16.4\,l$

$V_2 - V_1 \cong 16\,l$

(25) One mole of ideal gas, initially at a pressure of 10 atm and temperature 300 K, expands isothermally against a constant external pressure of 1 atm, coming to equilibrium at 1 atm. How much work is performed on the surroundings?

(a) 2.2 kJ
(b) 2.7 kJ
(c) 3.8 kJ
(d) 4.1 kJ

$W = \int P_{ext}\,dV = P_{ext}(V_2 - V_1)$

$= 1\,atm\left(\frac{nRT}{1\,atm} - \frac{nRT}{10\,atm}\right)$

$= nRT\left(1 - \frac{1}{10}\right) = (0.9)(1)(8.314)(300)$

$= 2.24\,kJ$