Physics 161
Makeup Exam
Friday, May 8, 2020

Directions:

The start time for this exam is 10:00 am. You must scan your answers with CamScanner and upload them as single pdf document to "Learn" by 11:59 am. For this I am giving you an extra hour beyond the normal class time. Your answers can be written down on a piece of notebook paper, but **please put your name on the it**. Just as with homework submissions to "Learn", you may upload your answers multiple times; the "Learn" software will only retain your last upload. This exam is closed-book/notes, except for the formulae I have provided below. You are not to consult with the computer, or with others. I will be grading your exams individually, so please indicate your answers clearly.

Show your work for every problem. For numerical questions, your answers will only be marked as being correct if **three** *things are satisfied simultaneously.* First, the work you do to arrive at your answer must be appropriate/correct. Second, your work must logically lead to the answer you record; you won't be given credit if your work leads to one answer but you record a different answer. Third, your answer must the correct one. Obviously some problems requre more work than others.

Each question is worth 5 points, and there are 18 questions for a maximum score of 90. There are two bonus problems, so it is possible to score 100/90.

$$R = 8.314\ \frac{\text{J}}{\text{mole}\cdot\text{K}} = 0.082\frac{\text{ltr-atm}}{\text{mole}\cdot\text{K}}$$
$$1\text{ atm} = 1.01\times10^5\text{ Pa}$$
$$k = 1.38\times10^{-23}\frac{\text{J}}{\text{K}}$$
$$C_p = C_V + nR$$

$$T(^\circ\text{C})+273.15=T(\text{K})$$
$$\Delta U = Q - W$$
$$dU = TdS - PdV$$
$$H = U + PV$$
$$dH = TdS + VdP$$
$$A = U - TS$$
$$G = H - TS$$
$$S = k\ln W;$$
$$W_{\text{monatomic gas}} = \left(T^{3/2}V\cdot\text{const.}\right)^N/N!$$
$$\frac{1}{2}m\left\langle v^2\right\rangle = \frac{3}{2}kT$$
$$\mu_0 = 4\pi\times10^{-7}\ \text{Ns}^2/\text{C}^2$$
$$\epsilon_0 = 8.84\times10^{-12}\ \text{C}^2/\text{Nm}^2$$
$$m_e = 9.1\times10^{-31}\text{ kg}$$
$$m_p = 1.67\times10^{-27}\text{ kg}$$
$$e = 1.6\times10^{-19}\text{C}$$
$$\vec{A}\times\vec{B} = \begin{vmatrix} \widehat{x} & \widehat{y} & \widehat{z} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

(1) Consider a *long* solenoid with length 20 cm and radius 0.5 cm. The number of windings is 1000. If the permeability of the core is $\mu_0 = 4\pi\times10^{-7}$ T·m/A, what is the magnetic field strength B within the solenoid (away from the ends) for a 1.0 A current?

(a) 4.5 mT
(b) 5.2 mT
(c) 6.3 mT
(d) 7.8 mT

$B = \mu_0 n I = 4\pi\times10^{-7}\times\frac{1000}{0.2}\times1\text{A} = \frac{4\pi}{2}\times10^{-7+4} = 2\pi\times10^{-3}\,T$

(2) Who is credited with the 1820 discovery that a magnetic field is generated by passing a current through a wire?

(a) Coulomb.

(b) Oersted.
(c) Gauss.
(d) Clausius.

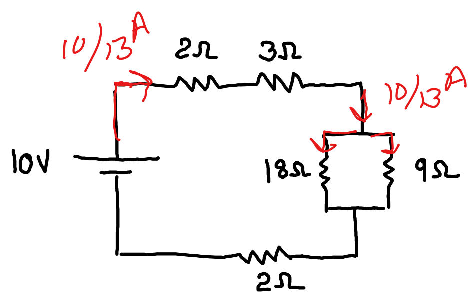
(3) A long straight wire carries a current of 1 Ampere. What is the strength of the magnetic field at a distance of 1 cm from the wire?
(a) 8×10^{-5}T
(b) 6×10^{-5}T
(c) 4×10^{-5}T
(d) 2×10^{-5}T

$\frac{\mu_0 I}{2\pi r} = \frac{4\pi\times10^{-7}\times 1}{2\pi(0.01)} = 2\times10^{-5}$ T

(4) The susceptibility of a diamagnetic material is typically
(a) 1×10^{-5}
(b) -1×10^{-5}
(c) 1×10^{-2}
(d) -1×10^{-2}

(5) Consider the circuit shown below, consisting of five resistors as marked, and a 10 V battery. What is the current in the18 Ω resistor? (Assume that the battery has no internal resistance.)
(a) 0.66 A
(b) 0.48 A
(c) 0.26 A
(d) 0.13 A

$2+3+2+\frac{1}{\left(\frac{1}{18}+\frac{1}{9}\right)} = 7+\frac{1}{3/18} = 13\Omega$



$\frac{10V}{13\Omega} = \frac{10}{13}A$

(current divider rule)

$\frac{10}{13}A \cdot \left(\frac{1/18}{1/18+1/9}\right) = \frac{10}{13}\times\frac{1}{3} = \frac{10}{39} \approx \frac{1}{4} A$

(6) Consider two capacitors connected in a closed-loop circuit as indicated in the figure. Initially the circuit is open, and the 1 F capacitor is uncharged, but there is a 1 volt drop across the 2 F capacitor, as measured by a volt meter. After the switch is closed and equilibrium is reestablished, what will be the reading on the volt meter?
(a) 0.33 V
(b) 0.67 V
(c) 1.0 V
(d) 1.5 V

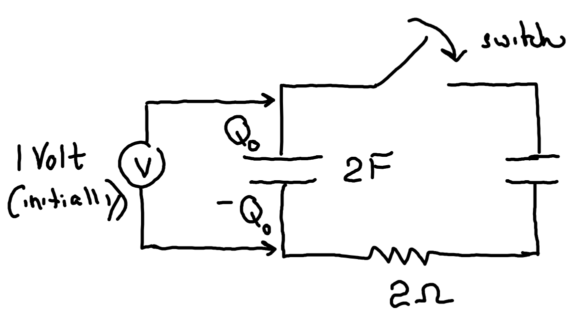
Charge will distribute so that both capacitors have the same voltage drop.

$\frac{Q_0}{2F} = 1$ Volt $\therefore Q_0 = 2F\times1V = 2C$

$\frac{Q_0 - q}{2} = \frac{q}{1}$

$\frac{Q_0}{2} = \frac{3}{2}q$

$q = Q_0/3$



$\therefore \Delta V = \frac{Q_0/3}{1F}$

$\Delta V_{final} = 2/3$ Volts

what is Q_0?

(7) What is the minimum work required to bring together two positive point-charges Q_1 and Q_2 from an initial separation of infinity to a final separation distance r?

$\frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$

(a) $Q_1Q_2/4\pi\epsilon_0 r$
(b) $Q_1Q_2/4\pi\epsilon_0 r^2$
(c) $Q_1Q_2/4\pi\epsilon_0 r^3$
(d) $Q_1Q_2/4\pi\epsilon_0 r^4$

(8) How much work is required to charge up a 2.5 F capacitor to a potential of 1.0 V?
(a) 2.25 J.
(b) 3.75 J.
(c) 4.25 J.
(d) 5.50 J.

(9) The charge density at a particular point on a conducting surface is 0.2 nC/m^2. What is the magnitude of the electric field just outside the conductor at this point?
(a) 23 N/C
(b) 11 N/C
(c) 6 N/C
(d) 3 N/C

(10) An electron moves in a uniform 2.0×10^{-9} Tesla magnetic field. If its speed perpendicular to the field is 300 m/s, what is the period of its circular orbit?
(a) 0.013 s
(b) 0.018 s
(c) 0.025 s
(d) 0.034 s

(11) A sphere with radius 1 m carries a uniform surface charge of 1.5 μC. What is the magnitude of the electric field at a point 1.5 m from the center of the sphere?
(a) 54 kV/m
(b) 27 kV/m
(c) 13 kV/m
(d) 6 kV/m

(12) An electron and a proton are separated from one another by a distance of 0.050 nm. What is the force of attraction between them?
(a) 62 nN
(b) 72 nN
(c) 82 nN
(d) 92 nN

(13) Consider a process in which a fluid expands spontaneously at a constant temperature $T = 300$ K. If $\Delta U = 200$ J, and $\Delta S = 2$ J/K, what is the maximum amount of work that could, in principle, be extracted during the expansion?
(a) 100 J
(b) 200 J
(c) 300 J
(d) 400 J

(14) An ideal gas initially at $P = 2$ atm and $V = 1$ liter expands isothermally and reversibly to a final pressure of 1 atm. How much work is performed on the surroundings in this expansion?
(a) 2.0 liter-atm
(b) $2.0 \times \ln(2.0)$ liter-atm
(c) 1.0 liter-atm
(d) 0.50 liter-atm

(15) Two identical glass bulbs are connected to one another by a stopcock. The first bulb is filled with n moles of ideal gas at 1 atm and 298 K, and the second bulb is evacuated. When the stopcock is opened, the gas expands to fill both bulbs. Assuming ideal gas behavior, what is $\Delta S_{\text{universe}}$ if the two bulbs are insulated from the surroundings?
(a) $nR\ln 2$

(b) $-nR\ln 2$
(c) $nR\ln 4$
(d) $-nR\ln 4$

(16) The second law of thermodynamics is a postulate that
(a) *entropy* is a state function, and the *energy* of the universe is constant.
(b) *entropy* is a state function, and the *entropy* of the universe always increases.
(c) *energy* is a state function, and the *energy* of the universe proceeds to a minimum.
(d) the *energy* of the universe remains constant.

(17) When the working fluid is an ideal gas, a (hypothetical) reversible heat engine operating between a hot reservoir at T_H and a cold reservoir at T_C has an efficiency $(T_H - T_C)/T_H$, where temperature is in Kelvin. When a non-ideal gas is substituted as the working fluid, which of the following will be true?
(a) The reversible heat engine will have an efficiency that *is lower* than $(T_H - T_C)/T_H$.
(b) The reversible heat engine will have an efficiency that *is higher* than $(T_H - T_C)/T_H$.
(c) The reversible heat engine will have an efficiency that *is the same* as its efficiency with an ideal gas.

(18) When a certain fluid with is heated at *constant pressure*, its temperature increases from 300 K to 400 K. If the heat capacity at constant pressure is a constant 20 J/K over this temperature range, which of the following *must* be true?
(a) $\Delta U = 2$ kJ
(b) $\Delta H = 2$ kJ
(c) $\Delta S = -5.8$ J/K
(d) $W = 2$ kJ

(19: Bonus 1) A monatomic ideal gas initially at 2.00 atm and 300 K expands adiabatically against a constant pressure of 1.00 atm, to a final pressure of 1.00 atm. What is the final temperature of the gas?
(a) 255 K
(b) 250 K
(c) 245 K
(d) 240 K

(20: Bonus 2) The globe of the Regener Hall van de Graff generator has a radius of 15 cm. In dry air, it can be charged until the maximum field reaches the breakdown threshold of 3×10^6 N/C. For this much charge, what is the *electric field energy density* $\frac{1}{2}\epsilon_0 E^2$ at a distance of 1 meter from the center of the globe? (Treat the globe is though an isolated metal sphere.)
(a) 0.01 J/m^3
(b) 0.02 J/m^3
(c) 0.03 J/m^3
(d) 0.04 J/m^3