Solutions

Physics 161
Makeup Exam

Directions: The exam consists of 25 multiple choice questions. Each question carries equal weight.

(1-4pts) A circular wire loop lies in the plane of the page, as shown in the figure. A uniform magnetic field B is directed into the page. What happens as the loop is gradually squashed into the shape of an ellipse?

(a) A current is induced in the loop in the counter clockwise direction.
(b) A current is induced in the loop in the clockwise direction.
(c) A current is not induced.

(2-4pts) The following equations describing all of the laws of electricity and magnetism are known as "Maxwell's equations":

(a)

$$\oint \vec{E}\cdot d\vec{A} = 0$$
$$\oint \vec{E}\cdot d\vec{s} = -\frac{d}{dt}\int \vec{B}\cdot d\vec{A}$$
$$\boxed{\oint \vec{B}\cdot d\vec{A} = \frac{Q}{\epsilon_0}}$$
$$\oint \vec{B}\cdot d\vec{s} = \mu_0 I + \mu_0\epsilon_0\frac{d}{dt}\int \vec{E}\cdot d\vec{A}$$

(b)

$$\oint \vec{E}\cdot d\vec{A} = \frac{Q}{\epsilon_0}$$
$$\boxed{\oint \vec{E}\cdot d\vec{s} = 0}$$
$$\oint \vec{B}\cdot d\vec{A} = 0$$
$$\boxed{\oint \vec{B}\cdot d\vec{s} = \mu_0 I}$$

(c)

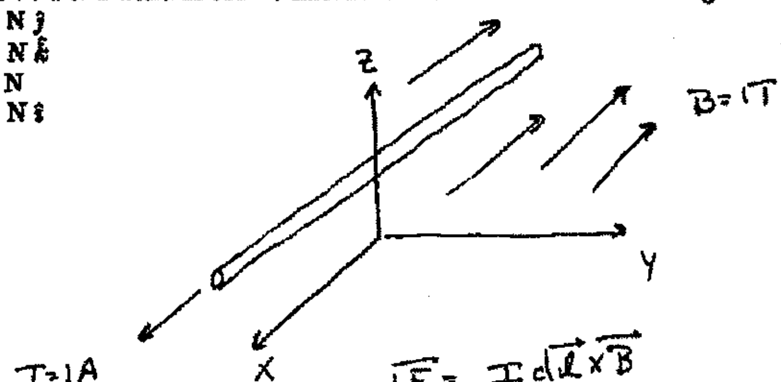
$$\oint \vec{E}\cdot d\vec{A} = \frac{Q}{\epsilon_0}$$
$$\oint \vec{E}\cdot d\vec{s} = -\frac{d}{dt}\int \vec{B}\cdot d\vec{A}$$
$$\boxed{\oint \vec{B}\cdot d\vec{A} = \mu_0 I}$$
$$\boxed{\oint \vec{B}\cdot d\vec{s} = \mu_0\epsilon_0\frac{d}{dt}\int \vec{E}\cdot d\vec{A}}$$

(d)

$$\oint \vec{E}\cdot d\vec{A} = \frac{Q}{\epsilon_0}$$
$$\oint \vec{E}\cdot d\vec{s} = -\frac{d}{dt}\int \vec{B}\cdot d\vec{A}$$
$$\oint \vec{B}\cdot d\vec{A} = 0$$
$$\oint \vec{B}\cdot d\vec{s} = \mu_0 I + \mu_0\epsilon_0\frac{d}{dt}\int \vec{E}\cdot d\vec{A}$$

(3-4pts) A straight segment of wire carrying current of 1 Ampere in the $\hat{i}$ direction is placed in a uniform magnetic field of 1 Tesla in the $-\hat{i}$ direction. What is the force on the segment if it has a length of 1 meter?

(a) 1 N $\hat{j}$
(b) 1 N $\hat{k}$
(c) 0 N
(d) 1 N $\hat{i}$

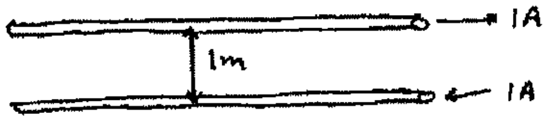


$d\vec{F} = I\, d\vec{l} \times \vec{B}$

$d\vec{l} \parallel \vec{B}$

(4-4pts) Two infinitely long straight wires each carry a steady current. One wire carries a current of 1 Ampere in the $\hat{\imath}$ direction, and the other wire carries a current of 1 Ampere in the $-\hat{\imath}$ direction. If the distance between the two wires is 1 meter, the magnetic force (per meter) between them is

(a) 2×10^{-7} N/m (attractive).
(b) 1.4×10^{-7} (attractive).
(c) 2×10^{-7} N/m (repulsive).
(d) 0 N



(5-4pts) Consider the circuit shown below, consisting of three 1 Ω resistors and a 2 V battery. At what rate is work done by the battery? (Assume that the battery has no internal resistance.)

(a) 3 W
(b) 4 W
(c) 5 W
(d) 6 W

$R_{eq} = \frac{1}{\frac{1}{1\Omega}+\frac{1}{2\Omega}} = \frac{2}{3}\Omega$ $\quad I = \frac{2V}{2/3\,\Omega} = 3A$

$P = VI = 2V \times 3A = 6W$

(6-4pts) A long solenoid has a diameter of 2 cm and a winding density of 5000 turns per cm. If the magnetic field strength inside the solenoid is 1.5 mT, what is the current in the solenoid?

(a) 21 μA.
(b) 24 mA.
(c) 5.2 A.
(d) 0.13 A.

$B = \mu_0 n I$

$I = \frac{1.5\times10^{-3}T}{4\pi\times10^{-7}(5000/0.01\,m)} = \frac{1.5}{5(4\pi)}\times10^{-3-3+7-2} \approx \frac{1.5}{20\pi}\times10^{-1} \approx \frac{1}{40}\times10^{-1} = 0.024\times1$

decimal pt. missing

(7-4pts) An 0.5 μF capacitor consists of two metal spheres which are held separate from one another by an insulator. When a charge of 1 μC is removed from one of the spheres and place on the other sphere, the potential between them is

(a) 0.5 V
(b) 1 V
(c) 2 V
(d) 0.1 V

$V = \frac{Q}{C} = \frac{1\mu C}{0.5\mu F} = 2V$

(8-4pts) A parallel plate capacitor consists of two metal plates, each having an area of 1 m^2. The plates are separated from one another in a vacuum by 0.5 cm. If an insulator having dielectric constant of 4 is inserted between the plates, the capacitance

(a) Decreases by a factor of 8
(b) Increases by a factor of 8
(c) Decreases by a factor of 4
(d) Increases by a factor of 4

$C = \frac{\varepsilon A}{d}$ $\quad \varepsilon = 4\varepsilon_0$

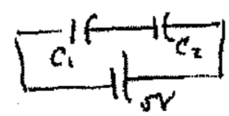
(9-4pts) How much work must be performed to charge an 0.5 μF capacitor to a voltage of 5V?

(a) 6.3 μJ
(b) 12.4 μJ
(c) 15.6 μJ
(d) 2.5 μJ

$\frac{1}{2}CV^2 = \frac{1}{2}\,0.5\times10^{-6}\times(25) = \frac{25}{4}\times10^{-6} = 6.25\times10^{-6}\,J$

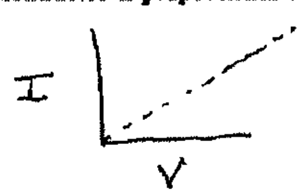
(10-4pts) A 5 V battery is connected to two different capacitors in series in a closed loop circuit. How is the voltage divided between the two?

(a) The voltage across each capacitor is 5 V.
(b) The largest voltage drop is across the largest capacitor.
(c) The largest voltage drop is across the smallest capacitor.
(d) Half the voltage is dropped across one capacitor and half the voltage is dropped across the other.



(11-4pts) Which is a statement of Ohm's law?

(a) The voltage across a battery is always slightly smaller than the ideal voltage.
(b) The current in a conductor is proportional to the voltage across the conductor.
(c) The current in a conductor decreases exponentially with time due to resistance.
(d) The current in a conductor is proportional to the square of the voltage.



(12-4pts) A 5 V battery drives a 1 mA current through a circuit. At what rate is work done by the battery?

(a) 0.2 mW

(b) 25 mW

(c) 5 mW

(d) Cannot be determined unless the resistance, inductance, and capacitance are specified.

$P = 5V \times 1mA = 5 mW$

(13-4pts) How long does it take for charge build up on an initially uncharged 1 μF capacitor which is placed in a series circuit with a 10 kΩ resistor and a 5 V battery?

(a) 5 ms

(b) 10 ms

(c) 50 ms

(d) 2 ms

$RC = 10 k\Omega \times 1 \mu F = 10 \times 10^{3} \times 10^{-6}$

$= 1 \times 10^{-2} = 10 ms$

(14-4pts) What is the most general trajectory of a charged particle in a uniform magnetic field?

(a) a straight line

(b) an ellipse

(c) a circle

(d) a helix

(15-4pts) The cyclotron is a device which

(a) determines the sign of the charges which move in a conductor by measuring the transverse voltage which develops across a conductor in a magnetic field.

(b) accelerates charged particles to high energies with an ac electric field by taking advantage of the fact that the orbital period of a particle in a uniform magnetic field remains constant as its energy increases.

(c) measures the strength of a magnetic field by looking at the deflection of a galvanometer caused by changes in magnetic flux in a coil.

(d) allows one to determine the chemical composition of a substance by sorting ions by their charge to mass ratio.

(16-4pts) The discovery that a current-carrying wire is a source of magnetic field is attributed to

(a) Ampere.

(b) Biot and Savart.

(c) Oersted.

(d) Faraday.

(17-4pts) Two electrons are at rest. Assuming that they are initially far from one another, what is the minimum amount of work which must be performed to bring the electrons together to a separation of 1 nm? (1 eV = 1.6×10^{-19} J)

(a) 1.4 eV

(b) 1.8 eV

(c) 2.1 eV

(d) 0.8 eV

$\frac{e^2}{4\pi\epsilon_0}\left(\frac{1}{1nm} - \frac{1}{\infty}\right) = \frac{1.6 \times 10^{-19} \cdot e \cdot 9 \times 10^{9}}{1 \times 10^{-9}}$

$= e\left(9(1.6)\right) \times 10^{-1} = 1.44 eV$

(18-4pts) At a particular point just above the surface of a conductor, the electric field is found to be directed towards the surface, having a magnitude of 57 N/C. What is the charge density on the conducting surface at this point?

(a) -0.3 nC/m^2

(b) -0.4 nC/m^2

(c) -0.5 nC/m^2

(d) 0.2 nC/m^2

$EA = \frac{q}{\epsilon_0} = \frac{\sigma A}{\epsilon_0}$

$E_{surface} = \sigma/\epsilon_0$ & $\sigma = \epsilon_0 E = \frac{4\pi\epsilon_0 E}{4\pi} = \frac{57 N/C}{4\pi \cdot 9 \times 10^{9}}$

$= \frac{57}{36\pi} \times 10^{-9} C/m^2$

(19-4pts) A uniform electric field has a strength $\vec{E}$ = 2 N/C $\hat{\imath}$+1 N/C $\hat{\jmath}$. Consider a square surface with area vector $\vec{A}$ = 3 m^2 $\hat{\imath}$ - 2 m^2 $\hat{\jmath}$. What is magnitude of the electric flux through this surface?

(a) 1 Nm^2/C

(b) 4 Nm^2/C

(c) 5 Nm^2/C

(d) 0 Nm^2/C

$\vec{E} \cdot \vec{A} = 2 \times 3 - 1 \times 2 = 4 Nm^2/C$

(20-4pts) The electric flux through a spherical Gaussian surface having a 5 m radius is -100 Nm^2/C. Which of the following *must* be true?

(a) The charge enclosed by the Gaussian surface is located at the center of the sphere.

(b) The magnitude of the electric field at the Gaussian surface is -0.3 N/C

(c) The charge enclosed by the Gaussian surface is -0.9 nC

(d) The total charge enclosed by the Gaussian surface is zero.

$\Phi = Q/\epsilon_0$

$Q = \frac{4\pi\epsilon_0 \cdot (-100\,Nm^2/C)}{4\pi} = -0.9\times10^{-9}\,C$

(21-4pts) An ideal gas is expanded isothermally, from $P = 2$ atm and $V = 1$ liter, to $P = 1$ atm and $V = 2$ liters. The expansion may or may not have been carried out reversibly. Circle the statement which *might* be true:

(a) $\Delta S_{surroundings} > 0$.

(b) the work performed on the surroundings is smaller than 2 ln 2 liter-atm.

(c) the heat added to the gas from the surroundings is greater than 2 ln 2 liter-atm.

(d) $\Delta U < 0$.

$W_{reversible} = \int p\,dV = nRT\int \frac{dV}{V} = nRT \ln \frac{V_2}{V_1}$

$= nRT \ln 2$

$nRT = PV = 2$ atm-liter

$W \le W_{reversible}$ for expansion.

(22-4pts) The working fluid in a heat engine undergoes a cyclic process, repeatedly returning to its initial state. This means that over each cycle, the change

(a) $\Delta S > 0$.

(b) $\Delta H < 0$.

(c) $\Delta P > 0$

(d) $\Delta U = 0$.

$\Delta U = 0 \therefore Q = W$

so $Q \le Q_{reversible}$ for exp.

(23-4pts) If 600 kJ of heat is transferred to a system which is in contact with the surroundings at 300 K, the change in entropy of the surroundings is

(a) −18 kJ/K

(b) 18 kJ/K

(c) −2 kJ/K

(d) 2 kJ/K

$\Delta S_{surr} = \frac{Q_{surr}}{T} = -\frac{Q}{T} = \frac{-600\,kJ}{300K} = -2\,kJ/K$

(24-4pts) Two glass bulbs having the same volume are connected to one another by a stopcock. Initially, one bulb is filled with helium gas at 1 atm, and the other bulb is filled with xenon gas at 1 atm. The bulbs are in thermal contact with the surroundings at 298 K. When the stopcock is opened, the gases mix. Assuming ideal gas behavior, which of the following statements is true?

(a) $\Delta S_{surroundings} > 0$

(b) $\Delta S_{universe} > 0$

(c) $Q > 0$

(d) $\Delta U < 0$

$\Delta S_{surr} = 0$

$\Delta U = 0$

$Q = 0$

(25-4pts) When combined with Boltzmann's postulate, the second law of thermodynamics implies that

(a) an increase in entropy may always be associated with a transfer of heat. (Certainly Not)

(b) entropy increases with the logarithm of a system's weight.

(c) an increase in entropy represents an increase in disorganization. ?

(d) the energy of the universe remains constant. First law