Dear respected student,

To get the most benefit from this old exam, I suggest the following,

1. Solve it without seeing the answers.
2. Time yourself. A question should not take more than 6 minutes.
3. Compare your answers with the answers provided at the end of this exam.
4. If your answer is wrong, study why you did not get it right. If you cannot know your mistake, ask your friends or come to me.

The formula sheet, figures and answers are provided at the end of the exam.

INSTRUCTIONS:

1. PRINT YOUR STUDENT NUMBER, NAME, AND SECTION NUMBER ON THE EXAM.
2. PRINT YOUR STUDENT NUMBER, SECTION NUMBER, AND YOUR NAME ON THE EXAM ANSWER FORM. PRINT THE TEST CODE NUMBER, OR CHECK IT IF IT HAS ALREADY BEEN PRINTED ON YOUR ANSWER FORM.
3. CODE YOUR STUDENT NUMBER AND SECTION NUMBER ON THE EXAM ANSWER FORM. CODE THE TEST CODE NUMBER, OR CHECK IT IF IT IS ALREADY CODED.
4. CODE YOUR ANSWERS ON THE EXAM ANSWER FORM. YOU MUST NOT GIVE MORE THAN ONE ANSWER PER QUESTION.
5. RETURN THE EXAM AND ANSWER FORM TO THE INSTRUCTOR WHEN YOU HAVE FINISHED.

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**QUESTION NO: 1**

The capacitor in figure (1) is initially charged to 50 V and then the switch is closed. What charge flows out of the capacitor during the first minute after the switch was closed?

A. 1.4 mC.
B. 3.6 mC.
C. 4.8 mC.
D. 0.3 mC.
E. 1.7 mC.

**QUESTION NO: 2**

Electrons are accelerated from rest through a potential difference of 500 V. They are then deflected by a magnetic field of 0.2 T that is perpendicular to their velocity. The radius of the electrons trajectory is:

A. 2.4 milli-m.
B. 0.38 milli-m.
C. 1.6 milli-m.
D. 0.54 milli-m.
E. 0.15 milli-m.

**QUESTION NO: 3**

A parallel combination of two capacitors, C1 and C2 where C2=2*C1, is connected to a battery. If the charge accumulated on C1 is 2.0*10**(-6) C and the total energy stored in the combination is 12.0*10**(-9) Joule, then the capacitance of C2 is:

A. 1.5*10**(-3) F.
B. 2.5*10**(-6) F.
C. 1.5*10**(-6) F.
D. 3.0*10**(-6) F.
E. 1.0*10**(-3) F.
QUESTION NO: 4

Consider a circular loop of wire within which the magnetic flux, \( \Phi \), is given as a function of time, \( t \), as

\[ \Phi = at^2 + b, \]

where \( a \) and \( b \) are constants. If the induced emf is measured as 48 V at \( t=3 \) s, what is the value of \( a \)?

A. \(-4.0 \) V/s
B. \(-6.0 \) V/s
C. \(-2.1 \) V/s
D. \(-3.2 \) V/s
E. \(-8.0 \) V/s

QUESTION NO: 5

In figure (4), a loop of wire carrying a current, \( I \), of 2.0 A is in the shape of a right triangle with two equal sides, each 15 cm long. A 0.7 T uniform magnetic field is in the plane of the triangle and is perpendicular to the hypotenuse. The resultant magnetic force on the two equal sides is:

A. 0.30 N, out of the page.
B. 0.41 N, into the page.
C. 0.41 N, out of the page.
D. Zero.
E. 0.30 N, into the page.

QUESTION NO: 6

Suppose that the identical currents \( I \) in figure (7) are all out of the page. The magnitude of the force per unit length on the wire at the origin is:

\[ \text{[take } I = 10.0 \text{ A, and } a = 1.0 \times 10^{-4} \text{ m.]} \]

A. 0.18 N/m
B. 0.17 N/m
C. 0.28 N/m
D. 0.30 N/m
E. 0.55 N/m
If the electric potential in a certain region is given by:
\[ V(x,y,z) = -4x^2y - 5xyz + 3z^2 \text{ Volts}, \]
where \( x, y \) and \( z \) are in meters. What is the magnitude of the electric field at the point \((+2,-1,-3)\)?

A. 125 V/m.
B. 25 V/m.
C. 29 V/m.
D. 35 V/m.
E. 10 V/m.

Find the values of the currents in figure (3).

A. \( I_1 = 2 \text{ A}, I_2 = 2 \text{ A}, I_3 = 4 \text{ A}. \)
B. \( I_1 = 2 \text{ A}, I_2 = 2 \text{ A}, I_3 = -4 \text{ A}. \)
C. \( I_1 = -2 \text{ A}, I_2 = -2 \text{ A}, I_3 = -4 \text{ A}. \)
D. \( I_1 = 2 \text{ A}, I_2 = -2 \text{ A}, I_3 = \text{ zero}. \)
E. \( I_1 = -2 \text{ A}, I_2 = 2 \text{ A}, I_3 = \text{ zero}. \)

An electric device, which heats water by immersing a resistance wire in the water, generates 153 J of heat per second when an electric potential difference of 12 V is placed across its ends. What is the resistance of the heater wire?

A. 0.58 Ohms
B. 2.10 Ohms
C. 0.94 Ohms
D. 0.81 Ohms
E. 0.48 Ohms
A magnet is taken towards a metallic ring in such a way that a constant current of $10^{-2}$ A is induced in it. The total resistance of the ring is 0.25 Ohm. In 10 seconds, the flux of the magnetic field through the ring changes by:

A. $2.5 \times 10^{-3}$ Wb.
B. $2.5 \times 10^{-6}$ Wb.
C. $2.5 \times 10^{-2}$ Wb.
D. $2.5 \times 10^{-9}$ Wb.
E. $2.5 \times 10^{-1}$ Wb.

Faraday's law states that an induced emf is proportional to:

A. the rate of change of magnetic flux.
B. the rate of change of magnetic field.
C. the rate of change of electric flux.
D. the rate of change of gravitational field.
E. the rate of change of electric field.

The linear density of a vibrating string is 1 g/m. A transverse wave is propagating on the string and is given by the equation:

$$y(x,t) = 2.0 \sin(x - 40t),$$

where $x$ and $y$ are in meters and $t$ is in seconds. What is the tension in the string?

A. 5.2 N.
B. 0.9 N.
C. 2.1 N.
D. 1.9 N.
E. 1.6 N.
A solenoid is 3.0 m long and has a circumference of 9.4*10**(-2) m. It carries a current of 12.0 A. The magnetic field inside the solenoid is 25.0*10**(-3) T. The length of the wire forming the solenoid is:

A. 410 m.
B. 900 m.
C. 233 m.
D. 467 m.
E. 245 m.

3.00-kg of water at 100 degrees Celsius is converted to steam at 100 degrees Celsius by boiling at one atmospheric pressure. For one kg of water, the volume changes from an initial value of 1.0*10**(-3) m**3 as a liquid to 1.671 m**3 as steam. The work done by the water in this process is:

A. 3.01*10**5 J.
B. 1.69*10**5 J.
C. 5.07*10**5 J.
D. 2.45*10**5 J.
E. 1.23*10**5 J.

A stationary source emits a sound wave of frequency f. If a man travels toward this stationary source with a speed twice the speed of sound, he would observe the emitted sound to have a frequency of:

A. 3*f.
B. f.
C. indefinite frequency.
D. 2*f.
E. f/2.
QUESTION NO: 16

The mass of a hydrogen molecule is $3.3 \times 10^{-27}$ kg. If 1.0 $\times 10^{23}$ hydrogen molecules per second strike 2.0 cm$^2$ of wall at an angle of 55 degrees with the normal when moving with a speed of 1.0 $\times 10^3$ m/s, what pressure do they exert on the wall?

A. $2.8 \times 10^3$ Pa.
B. $5.7 \times 10^3$ Pa.
C. $1.9 \times 10^3$ Pa.
D. $8.6 \times 10^3$ Pa.
E. $0.9 \times 10^3$ Pa.

QUESTION NO: 17

In figure (8), a hollow sphere, of radius $r$ and carries a negative charge $-q$, is put inside another hollow sphere, of radius $R$ and carries a positive charge $Q$. At a distance $x$ from the common center, such that $r < x < R$, the potential is:

A. $k[(Q/R)-(q/r)]$
B. $k[(Q/R)+(q/x)]$
C. $k[(Q/x)-(q/R)]$
D. $k[(Q/R)+(q/r)]$
E. $k[(Q/R)-(q/x)]$

QUESTION NO: 18

In figure (2), if $V_C-V_D=6.0$ Volts, what is the emf of the battery?

A. 9.61 Volts.
B. 18.2 Volts.
C. 13.9 Volts.
D. 10.8 Volts.
E. 11.7 Volts.
A ball of charge \(-50\, \text{e}\) lies at the center of a hollow spherical metal shell that has a net charge of \(-100\, \text{e}\). What is the charge on the outer surface of the shell?

A. \(100\, \text{e}\).
B. \(-50\, \text{e}\).
C. \(150\, \text{e}\).
D. \(-100\, \text{e}\).
E. \(-150\, \text{e}\).

A conductor consists of a circular loop of radius \(R = 0.10\, \text{m}\) and two straight, long sections, as in Figure (6). The wire lies in the plane of the paper (xy-plane) and carries a current of \(I = 5.3\, \text{A}\). Determine the magnetic field, in Tesla, at the center of the loop. (\(k\) is a unit vector in +z-direction)

A. \(-5.8\times10^{-5}\, \text{k}\).
B. \(5.8\times10^{-5}\, \text{k}\).
C. \(-4.4\times10^{-5}\, \text{k}\).
D. \(1.8\times10^{-5}\, \text{k}\).
E. \(4.4\times10^{-5}\, \text{k}\).

Two positive charges, \(q1\) and \(q2\), lie on the x-axis. The first charge, \(q1 = 12.0\times10^{-6}\, \text{C}\), is at the origin, and the second charge, \(q2 = 3.0\times10^{-6}\, \text{C}\), is at 3.0 m. Where must a negative charge, \(q3\), be placed on the x-axis such that the resultant force on it is zero?

A. 3.0 m.
B. –1.0 m.
C. 2.0 m.
D. –1.5 m.
E. 1.0 m.
QUESTION NO: 22

The current loop in figure (5) consists of one loop with two semicircles of different radii. If the current in the circuit is 19 A, $a = 3.0$ cm and $b = 5.0$ cm, then the magnetic dipole moment of the current loop is:

A. $1.15 \ A*m**2$, into the page.
B. $0.02 \ A*m**2$, into the page.
C. $0.02 \ A*m**2$, out of the page.
D. $0.10 \ A*m**2$, out of the page.
E. $0.10 \ A*m**2$, into the page.

QUESTION NO: 23

A magnetic field CANNOT:

A. accelerate a charge.
B. exert a force on a charge.
C. change the momentum of a charge.
D. exert a torque on a charged particle.
E. change the kinetic energy of a charge.

QUESTION NO: 24

Which of the following statements are CORRECT:

1. Waves carry energy and momentum.
2. Mechanical waves need a medium to propagate.
3. Sound waves are transverse waves.
4. A wave on a stretched string is a longitudinal wave.
5. For a tube closed at one end, only odd harmonics are present.

A. 2 and 4.
B. 1, 2 and 3.
C. 1 and 4.
D. 3 and 5.
E. 1, 2, and 5.
Which of the following statements are WRONG:

1. In order to achieve the lowest resistance from several resistors, they should be connected in parallel.
2. In order to achieve the lowest capacitance from several capacitors, they should be connected in parallel.
3. The resistance of a conductor does not depend on temperature.
4. A dielectric increases the capacitance of a capacitor.
5. The electric flux through a closed surface is always zero.

A. 1 and 4.
B. 1 and 3.
C. 2 and 4.
D. 1, 2 and 3.
E. 2, 3 and 5.

An electric dipole, of electric charge $9.3 \times 10^{-12}$ C and distance $1.0 \times 10^{-3}$ m, is in an electric field of strength $1100$ N/C. What is the difference in potential energy corresponding to dipole orientations parallel and anti-parallel to the field?

A. $1.03 \times 10^{-11}$ J.
B. $6.15 \times 10^{-15}$ J.
C. $4.08 \times 10^{-13}$ J.
D. $3.87 \times 10^{-11}$ J.
E. $2.05 \times 10^{-11}$ J.
An electron is projected into a uniform magnetic field 
B = (0.8 k) T. Find the magnitude of the magnetic force, 
on the electron when the velocity is:
\[ v = (5.0 \times 10^5 i + 3.0 \times 10^5 j) \text{ m/sec.} \]
(i, j and k are the unit vectors in the x, y and z directions, 
respectively).

A. \(0.0\) N.
B. \(1.2 \times 10^{13}\) N.
C. \(5.2 \times 10^{15}\) N.
D. \(7.5 \times 10^{14}\) N.
E. \(7.8 \times 10^{18}\) N.

Which of the following statements are CORRECT:

1. Two objects are in thermal equilibrium if they have the same 
temperature.
2. In an isothermal process, the work done by an ideal gas is 
equal to the heat energy.
3. In an adiabatic process, no heat enters or leaves the system.
4. The thermal efficiency of an ideal engine can be = 1.0.
5. For any process the change in entropy of a closed system < 0.

A. 4 and 5.
B. 1, 2 and 5.
C. 1, 2, and 3.
D. 1 and 4.
E. 3 and 5.

The sum of the currents entering a junction equals the sum 
of the currents leaving that junction is a consequence of:

A. Ampere's law
B. conservation of charge
C. Coulomb's law
D. conservation of energy
E. Newton's second law
A long solid cylindrical conductor of radius $R = 4.0$ mm carries a current $I$ parallel to its axis. The current density in the wire is $2 \times 10^{-4}$ A/m$^2$. Determine the magnitude of the magnetic field at a point that is 5.0 mm from the axis of the conductor.

A. 55 micro-T.
B. 12 micro-T.
C. 40 micro-T.
D. 17 micro-T.
E. 30 micro-T.
Physics 102  
Formula sheet for Final Exam  
Fall Session 2000-2001 (Term 002)

\[ v = \sqrt{\frac{F}{\mu}} \quad v = \lambda f \]

\[ v = \sqrt{\frac{Y}{\rho}} \quad v = \sqrt{\frac{B}{\rho}} \]

\[ S = S_m \cos(kx - \omega t) \]

\[ I = \frac{\text{Power}}{\text{Area}} \]

\[ y = y_m \sin(kx - \omega t - \phi) \]

\[ P = \frac{1}{2} \mu \omega^2 A^2 v \]

\[ \Delta P = \Delta P_m \sin(kx - \omega t) \]

\[ \Delta P_m = p \nu \omega S_m \]

\[ I = \left( \frac{1}{2} \rho (\omega S_m)^2 \right) \]

\[ \beta = 10 \log \frac{I}{I_0}, \quad I_0 = 10^{-12} \text{W/m}^2 \]

\[ f' = f \left( \frac{v + v_p}{v + v_s} \right) \]

\[ y = \left( 2y_m \cos \frac{\phi}{2} \right) \sin \left( kx - \omega t - \frac{\phi}{2} \right) \]

\[ \Delta L = \alpha L \Delta T \quad \Delta L = \frac{\lambda}{2 \pi} \phi \]

\[ \Delta L = n \frac{\lambda}{2} \quad n = 0, 2, 4, \ldots \]

\[ \Delta L = n \frac{\lambda}{2} \quad n = 1, 3, 5, \ldots \]

\[ \Delta L = m \lambda \quad \Delta L = \left( m + \frac{1}{2} \right) \lambda \]

\[ f_n = \frac{n}{2L} \sqrt{\frac{T}{\mu}}, \quad n = 1, 2, 3, \ldots \]

\[ f_n = \frac{n \nu}{2L}, \quad n = 1, 2, 3, \ldots \]

\[ f_n = \frac{n \nu}{4L}, \quad n = 1, 3, 5, \ldots \]

\[ y = 2y_m \sin kx \cos \omega t \]

\[ \alpha = \frac{\Delta L}{L} \frac{1}{\Delta T}, \quad F = \left( \frac{\Delta L}{L} \right) EA \]

\[ n = 1, 2, 3, \ldots \]

\[ PV = nRT = NkT \]

\[ \beta = \frac{1}{V} \frac{\Delta V}{\Delta T}, \quad n = \frac{m}{M} = \frac{N}{N_A} \]

\[ Q = mL \quad \Delta U = Q - W \]

\[ W = \int p \, dV \]

\[ P = \frac{2}{3} N \left( \frac{1}{2} m v^2 \right) \quad v_{ms} = \sqrt{\frac{3RT}{M}} \]

\[ \frac{1}{2} m v^2 = \frac{3}{2} k_B T, \quad \Delta U = n c_v \Delta T \]

\[ Q = m c_p \Delta T, \quad Q = n c_v \Delta T \]

\[ \Delta E_{\text{int}} = Q - W, \quad \Delta E_{\text{int}} = n c_v \Delta T \]

\[ C_p - C_v = R \]

\[ H = \frac{Q}{t} = \kappa A \frac{T_h - T_c}{T} \]

\[ Q = n c_p \Delta T, \quad Q = n c_v \Delta T \]

\[ P V^* = \text{constant}, \quad T V^{*^{-1}} = \text{constant} \]

\[ F = \frac{C}{5} - 32, \quad K = C + 273 \]

\[ W = Q_h - Q_c, \quad \varepsilon = \frac{W}{Q_h} = 1 - \frac{Q_c}{Q_h} \]

\[ \frac{Q_e}{Q_h} = \frac{T_e}{T_h}, \quad (K)_{\text{Ref}} = \frac{Q_e}{W} \]

\[ (K)_{\text{Heat-Pump}} = \frac{Q_h}{W}, \quad \Delta S = \int \frac{dQ_e}{T} \]

\[ F = \frac{k q_1 q_2}{r^2}, \quad F = q_0 E \]

\[ \varphi = \int E \cdot d\bar{A}, \quad E = \frac{k q}{r^2} \]

\[ E = \frac{k Q}{R^3 r}, \quad E = \frac{2kQ}{r} \]

\[ U = -P \cdot \bar{E}, \quad \varphi_e = \int E \cdot d\bar{A} = \frac{q_m}{e_0} \]

\[ E = \frac{\sigma}{2e_0}, \quad E = \frac{\sigma}{e_0} \]

\[ \tau = \bar{P} \times \bar{E}, \quad V = \frac{kQ}{r} \]

\[ W = \Delta K = -\Delta U \]

\[ \Delta V = V_B - V_A = \frac{b}{A} \int E \cdot dS = \frac{\Delta U}{q_o} \]

\[ E_x = -\frac{\partial V}{\partial x}, \quad E_y = -\frac{\partial V}{\partial y}, \quad E_z = -\frac{\partial V}{\partial z} \]

\[ U = \frac{k q_1 q_2}{r_{12}}, \quad C = \frac{Q}{V}, \quad C = \frac{e_0 A}{d} \]

\[ U = \frac{1}{2} C V^2, \quad C = \kappa C_0, \quad E = \frac{E_0}{\kappa}, \quad \theta = \frac{\Delta Q}{Q} \]

\[ V = \frac{V_0}{\kappa}, \quad I = \frac{dQ}{dt}, \quad I = \frac{\Delta Q}{\Delta t}, \quad I = J A \]

\[ R = \frac{V}{I} = \frac{\rho L}{A}, \quad J = \sigma E \]

\[ \rho = \rho_0 [1 + \alpha (T - T_0)], \quad P = IV \]

\[ q(t) = C e^{[1 - e^{-\nu RC}]}, \quad q(t) = q_0 e^{-\nu RC} \]

\[ d\bar{F} = I d\bar{s} \times \bar{B}, \quad r = \frac{m v}{q B} \]

\[ \tau = \mu \times \bar{B}, \quad \mu = I A \]

\[ d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\bar{s} \times \bar{r}}{r^3}, \quad \int d\vec{B} \cdot \bar{B} = \mu_0 i_{\text{enc}} \]

\[ B = \mu_0 \frac{I}{4\pi R} \varphi, \quad B = \frac{\mu_0}{2\pi} n I \]

\[ B_s = \frac{\mu_0}{L} I = \mu_0 n I \]

\[ \varphi_B = \int \bar{B} \cdot d\bar{A} \]

\[ \varepsilon = \frac{d\varphi_B}{dt}, \quad \varepsilon = B L V \]

\[ v = v_0 + at \]

\[ x - x_o = v_o t + \frac{1}{2} at^2 \]

\[ v^2 = v_o^2 + 2a(x - x_o) \]

\[ e_0 = 8.85 \times 10^{-12} \text{C}^2/\text{N.m}^2 \]

\[ k = 9.0 \times 10^9 \text{N.m}^2/\text{C}^2 \]

\[ q_e = -1.6 \times 10^{-19} \text{C} \]

\[ m_e = 9.11 \times 10^{-31} \text{kg} \]

\[ m_p = 1.67 \times 10^{-27} \text{kg} \]

\[ 1 \text{eV} = 1.6 \times 10^{-19} \text{J} \]

\[ 1 \text{cal} = 4.186 \text{J} \]

\[ \text{micro} = 10^{-6}, \quad \text{nano} = 10^{-9}, \quad \text{pico} = 10^{-12} \]

\[ \mu_0 = 4\pi \times 10^{-7} \text{Wb.A/m} \]

\[ k = 1.38 \times 10^{-23} \text{J/K} \]

\[ N_A = 6.02 \times 10^{23} \text{molecules/mole} \]

\[ 1 \text{atm} = 1.013 \times 10^5 \text{N/m}^2 \]

\[ R = 8.31 \text{J/mol.K} \]

\[ \rho(\text{water}) = 1 \text{g/cm}^3 \]

\[ g = 9.8 \text{m/s}^2 \]

\[ 1 \text{cal} = 4.186 \text{Joule} \]
Q1

\[ q = q_0 e^{-t/RC} \]

Differentiate:
\[ dq = \frac{-q_0}{RC} e^{-t/RC} dt \]

Total charge flows during the first minute = \( \int_{t_0}^{t_1} dq \)
\[ = \int_{t_0}^{t_1} (-\frac{q_0}{RC}) e^{-t/RC} dt = -\frac{q_0}{R} (-Rc) \left[ e^{-t_1/RC} - e^{-t_0/RC} \right] \]
\[ = v_0 e \left[ e^{-t_1/RC} - e^{-t_0/RC} \right] \]
\[ = \left( 50 \right) \left( 100 \times 10^{-6} \right) \left[ e^{-2 \times 10^{-3}} - e^{-1 \times 10^{-3}} \right] = 4.8 \mu C \]

Q2

\[ T = \frac{m v}{q B} \]

Velocity of an electron before it enters the magnetic field region

\[ \Delta K + \Delta U = 0 \]
\[ K_f - K_i + q (\Delta V) = 0 \]
\[ \frac{1}{2} m_e v^2 = 0 - e \Delta V = 0 \]
\[ v = \sqrt{\frac{2e \Delta V}{m_e}} \]

\[ T = \frac{m_e}{eB} \sqrt{\frac{2e \Delta V}{m_e}} = \frac{1}{B} \sqrt{\frac{2m_e \Delta V}{e}} \]
\[ = \frac{1}{0.2} \sqrt{\frac{2 \left( 9.1 \times 10^{-31} \right) \left( 500 \right)}{1.6 \times 10^{-19}}} = 0.38 \text{ mm} \]

Q3

\[ V = \frac{Q_0}{C_1} \]

\[ C_2 = 2C_1 \]

\[ U = \frac{1}{2} Q_0^2 C_1 \]

\[ \Rightarrow C_2 = 2C_1 = 3 \frac{Q_0^2}{U} = 3 \frac{\left( \frac{2 \times 10^{-6}}{12 \times 10^{-9}} \right)^2}{1.0 \times 10^{-3}} = 1.0 \times 10^{-3} \text{ F} \]
Q4 \[ q = -\frac{d\phi}{dt} = -2\alpha t \Rightarrow a = -\frac{E}{2t} = -\frac{48}{2(3)} = -8.0 \text{m/s}^2 \]

Q5  

**Force on side 1**  
\[ F = i\vec{t} \times \vec{B} \]  
\[ F = i\vec{B}\sin\theta_1 \]  
\[ F = 2(0.15)(0.7)\sin 45^\circ = 0.148 \text{ N into the plane} \]  

**Force on side 2**  
\[ F_2 = i\vec{B}\sin 135^\circ \]  
\[ F_2 = 2(0.15)(0.7)\sin 135^\circ \]  
\[ F_2 = 0.148 \text{ N into the plane} \]  

Total force on side 1 and 2 = \(2(0.148) = 0.30 \text{ N into the plane} \]

Q6  
\[ F_1 = F_2 = i\vec{B}\sin\theta \]  
\[ = i\left(\frac{\mu_0 i^2}{2\pi}\right) \sin 90^\circ \]  
\[ = \frac{\mu_0 i^2}{2\pi} \]  

Total force \( F = \sqrt{F_1^2 + F_2^2} = \sqrt{2} F_1 \)

Total force per unit length \( \frac{F}{\ell} = \sqrt{2} \frac{F_1}{\ell} \)
\[ = \sqrt{2} \frac{\mu_0 \ell^2}{2\pi} = \sqrt{2} \frac{4\pi \times 10^{-7} \ell^2}{2\pi} \text{ N/m} \]
\[ = 0.28 \text{ N/m} \]

Q7  
\[ E_x = -\frac{\partial V}{\partial x} = -4(-3) = 12 \text{ V/m} \]
\[ E_y = -\frac{\partial V}{\partial y} = -5 \text{ V/m} \]
\[ E_z = -\frac{\partial V}{\partial z} = -4x + 6z = -4(2) + 6(-3) = -26 \]
\[ E = \sqrt{E_x^2 + E_y^2 + E_z^2} = \sqrt{(12)^2 + (-5)^2 + (-26)^2} = 29 \text{ V/m} \]
**Q8**

\[\text{loop 1} \quad 10 + 4 - 7i_1 = 0 \Rightarrow i_1 = 2 \text{ A}\]

\[\text{loop 2} \quad -6 + 5i_2 - 4 = 0 \Rightarrow i_2 = 2 \text{ A}\]

\[\text{Junction} \quad i_1 + i_2 + i_3 = 0 \Rightarrow i_3 = i_1 - i_3 = -4 \text{ A}\]

**Q9**

\[P = IV = \frac{V}{R} \Rightarrow R = \frac{V^2}{P} = \frac{12^2}{153} = 0.94 \Omega\]

**Q10**

\[\ell = -\frac{\Delta \phi}{\Delta t} \Rightarrow \Delta \phi = -iR \Delta t\]

\[= (10^{-3})(0.25)(10) = 2.5 \times 10^{-2} \text{ Wb}\]

**Q11**

The rate of change of magnetic flux

**Q12**

\[y = 2 \sin (1x - 4\pi t)\]

\[v = \sqrt{\frac{I}{\mu}} \quad \text{and} \quad v = \frac{\omega}{k} \Rightarrow \sqrt{\frac{I}{\mu}} = \frac{\omega}{k}\]

\[T = \mu \left(\frac{\omega}{k}\right)^2 = (10^{-3})(\frac{40}{3})^2 = 1.6 \text{ N}\]

**Q13**

\[B = \mu_0 i = \frac{\mu_0 i \ell}{N} \quad \left\text{length of the solenoid}\right\]

Length of the wire = \(N \text{ (circumference)}\)

\[= \frac{Bl}{\mu_0 i} \text{ (circumference)} = \frac{(25 \times 10^{-3})(3)}{4\pi \times 10^{-7}(12)}(9.4 \times 10^{-2})\]

\[= 467 \text{ m}\]
Q14 \[ \text{d}w = p \text{d}V \Rightarrow W = \int p \text{d}V = p \int \text{d}V = p \Delta V \]

\[
= 1 \text{ atm} \left( \frac{1.013 \times 10^5 \text{Pa}}{1 \text{ atm}} \right) (1.67 - 1 \times 10^{-3})^3 \]

\[
= 1.69 \times 10^5 \text{ J} \]

Q15 \[ f' = f \left( \frac{\frac{v}{2} + \frac{u}{2}}{\frac{v}{2} - \frac{u}{2}} \right) \Rightarrow f' = f \left( \frac{v + 2u}{v} \right) = 3f \]

Choose + to make \( f' \) larger since the detector is approaching the source.

Q16 \[ P = \frac{F}{A} \]

\[ \text{linear momentum} \]

\[ \text{number of molecules} \]

\[ \text{change in velocity} \]

\[ \Delta v = v_x - (-v_x) = 2v_x \]

\[ = 2v \cos \theta \]

\[ N \frac{m(2v \cos \theta)}{A} \]

\[ = (1 \times 10^{23}) (3.3 \times 10^{-7}) (2 \times 10^3) (2 \times 10^{-5}) \]

\[ \frac{A}{1 \text{ cm}^2} \]

\[ = 1.9 \times 10^3 \text{ Pa} \]

Q17 inside a conducting sphere, the potential is constant \( V = k \frac{Q_0}{R_0} \)

outside a conducting sphere, the potential is decreasing with the distance from \( x \) the sphere \( V = k \frac{Q_0}{x} \)

\[ \begin{cases} \text{if } x \text{ is inside the outer sphere} \Rightarrow \text{the potential due to the outer sphere } V = k \frac{Q_0}{x} \cr \text{if } x \text{ is outside the inner sphere} \Rightarrow \text{the potential due to the inner sphere } V = -k \frac{Q}{x} \cr \text{total potential } V = V_Q + V = k \left( \frac{Q}{R} - \frac{Q_0}{x} \right) \end{cases} \]
Q18

\[ i_1 = \frac{v_c - v_d}{5\, \Omega} = \frac{6}{5} \, A \]

\[ \varepsilon - i_1(4) - i_1(5) = 0 \]

\[ \varepsilon = i_1(9) = \frac{6}{5} \times 9 = 10.8 \, V \]

Q19

For electrostatic case, the electric field inside conductor
= 0 \implies\text{ flux through a Gaussian surface inside the conductor } = 0 \implies \text{ charge inside this Gaussian surface } = 0.

the net charge on the shell = -100e
= charge on the outer surface of the shell + charge on the inner surface of the shell.

\implies \text{ charge on the outer surface}

\[ = -100e - \text{ charge on the inner surface} \]

\[ = -100e - (-50e) = -150e. \]

Q20

\[ \vec{B} = \frac{\mu_0}{4\pi} \frac{i}{R} \hat{k} + \frac{\mu_0 i}{2\pi R} \hat{k} \]

\[ = \frac{\mu_0 i}{2\pi R} \left(1 + \frac{1}{\pi}\right) \hat{k} \]

\[ = \frac{(4\pi \times 10^7) (5.3) (1 + \frac{1}{\pi})}{2(0.1)} \hat{k} \]

\[ = -4.4 \times 10^6 \, \hat{k} \]

Using the right-hand rule:
\[ F_{32} = F_{31} \]
\[ \sqrt{\frac{q_2 q_3}{(3-x_3)^2}} = \sqrt{\frac{q_1 q_3}{x_3^2}} \Rightarrow \frac{q_1}{q_2} = \left( \frac{x_3}{3-x_3} \right)^2 \]
\[ \Rightarrow \sqrt{\frac{q_1}{q_2}} = \frac{x_3}{3-x_3} \Rightarrow \frac{12}{3} = \frac{x_3}{3-x_3} \]
\[ \Rightarrow 2 = \frac{x_3}{3-x_3} \Rightarrow 6 - 2x_3 = x_3 \Rightarrow x_3 = 2 \]

**Q22**
\[
\mu = iA = i \left( \frac{\pi a^2}{2} + \frac{\pi b^2}{2} \right) = \frac{i \pi}{2} (a^2 + b^2)
\]
\[
= 10 \frac{\pi}{2} (3 \times 1^2)^2 + (5 \times 1^2)^2 = 60.10 \text{ A.m.}
\]

**Right-hand rule:**

- Put your four straight fingers of your right hand along the direction of the current.
- The inner side of your hand should face the loop.
- Your thumb points along \( \mu \).
- \( \mu \) points into the page.

**Q23**
A magnetic field cannot change the kinetic energy of a charge.

**Q24**
1, 2 and 5

**Q25**
2, 3 and 5
Q26 \[ U = - \mathbf{p} \cdot \mathbf{E} \]

\[ \Delta U = (-pE\cos(80) - (-pE\cos(0)) \]

\[ = 2pE = 2g \quad dE = 2(9.3\times 10^2)(1.1\times 10^{-3}) \]

\[ = 2.05 \times 10^{-1} J \]

Q27 \[ F = q \times \mathbf{u} \times \mathbf{B} \]

\[ = -1.6 \times 10^{-19} \left( (5 \times 10^5 \mathbf{\hat{c}} + 3 \times 10^5 \mathbf{\hat{j}}) \times (0.8 \mathbf{\hat{k}}) \right) \]

\[ = -1.6 \times 10^{-19} \left( (5 \times 10^5)(0.8)(\mathbf{\hat{c}} \times \mathbf{\hat{k}}) + (3 \times 10^5)(0.8)(\mathbf{\hat{j}} \times \mathbf{\hat{k}}) \right) \]

\[ = -6.4 \times 10^{-14} \mathbf{\hat{c}} \times \mathbf{\hat{k}} - 3.84 \times 10^{-14} \mathbf{\hat{j}} \times \mathbf{\hat{k}} \]

\[ = 6.4 \times 10^{-14} \mathbf{\hat{c}} - 3.84 \times 10^{-14} \mathbf{\hat{j}} \]

\[ F = \sqrt{F_x^2 + F_y^2} \]

\[ = \sqrt{(6.34 \times 10^{-14})^2 + (6.4 \times 10^{-14})^2} \]

\[ = 7.46 \times 10^{-14} \text{ N} \]

Q28 1, 2 and 3

Q29 Conservation of charge

Q30 \[ B = \frac{\mu_0 \mathbf{J}}{2\pi R} = \frac{\mu_0}{2\pi R} \]

\[ = \frac{4\pi \times 10^{-7}}{2\pi} \frac{2 \times 10^4 \pi (4 \times 10^3)^2}{5 \times 10^3} \]

\[ = 4 \times 10^{-6} \text{T} = 40 \mu T \]

\[ R = 4 \text{ mm} \]

\[ R = 5 \text{ mm} \]