Benha University
Benha Faculty of Engineering
Date: 22 / 1 / 2022
Semester: January 2022
Examiners: Physics Staff
Total marks: 90

Department: Basic Eng. Sciences
Program: All
Time: 3 hours
Subject: Physics A (B1031)
Grade: Preparatory year
No. of Pages: 2

Final Written Exam

CONSTANTS: $q = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg, $k_e = 9\times10^{9}$ N.m²/C², $m_p = 1.67\times 10^{-27}$ kg, $\varepsilon_o = 8.85 \times 10^{-12}\ \frac{C^2}{N.m^2}$, $\mu_o = 4\pi \times 10^{-7}\ \frac{T.m}{A}$, $G = 6.67 \times 10^{-11}\ \frac{m^3}{s^2.kg}$

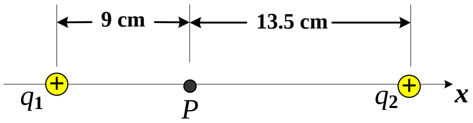
Answer all questions:

Question ① 《20 points》

a) [6 points, CLO: a1, b2**]** A particle of charge 5 µC and mass 0.2 g is in a region of uniform electric field E = 400 N/C in the x-direction. At time t = 0, the particle was at rest and was located at the origin. Determine the location and velocity of the particle at t = 5 ms (Neglect the effect of the weight on the motion).

b) [8 points CLO: a1, b2**]** A solid conducting sphere of radius 3 cm has a charge 2 nC. A conducting spherical shell of inner radius 5 cm and outer radius 8 cm is concentric with the solid sphere and has a charge –18 nC. **(i)** Find the electric field at r = 4 cm, **(ii)** Find the electric field at r = 6 cm, **(iii)** Find the surface charge density at the outer surface of the shell.

c) [6 points CLO: a1, b2**]** Two point-charges lie along a straight line as shown in the figure beside, where q_1 = 6 µC and q_2 = 1.5 µC. Find **(i)** the electric potential at point P, **(ii)** the potential energy of a third charge q_3 = –5 µC that is put on point P, **(iii)** the energy needed to assemble the three charges.

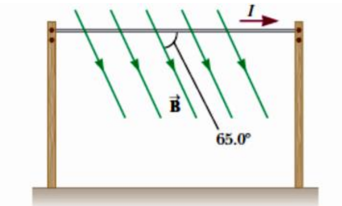


Question ② 《21 points》

a) [8 points CLO: a3, b2**]** A blood cell is seen as a spherical capacitor. It cosnsists of a positively charged conducting liquid sphere of radius a, separated by an insulating membrane from the surrounding negatively charged conducting fluid of radius b. A potential difference of 100 mV is measured across the membrane. Take the membrane's thickness as 100 nm and its dielectric constant as 5.00. Calculate the charge on the surfaces of the membrane. Assume that a typical red blood cell has an inner conducting liquid sphere of mass of 1.00×10^{-12} kg and density 1100 kg/m³.

b) [7 points CLO: a1, b2**]** One gram of gold is drawn into a wire 2.40 km long. The density of gold is 19.3×10^{3} kg/m³, and its resistivity is 2.44×10^{-8} Ω. m. What is the resistance of such a wire?

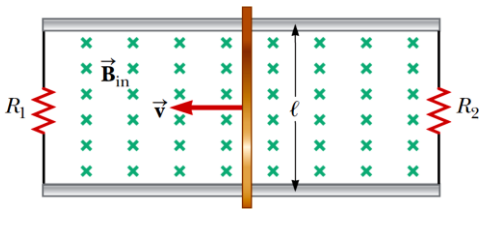
c) [6 points CLO: a1, b2**]** A horizontal power line of length 58.0 m carries a current of 2.20 kA northward as shown in figure. The Earth's magnetic field at this location has a magnitude of 5.00×10^{-5} T. The field at this location is directed toward the north at an angle 65.0° below the power line. Find (i) the magnitude and (ii) the direction of the magnetic force on the power line.



Question ③ 《22 points》

a) [6 points CLO: a1, b2**]** A long, cylindrical conductor of radius R carries a current I. The current density J is uniform over the cross section of the conductor. Find an expression for the magnetic field magnitude B (i) at a distance $r < R$ and (ii) at a distance $r > R$, measured from the center of the conductor.

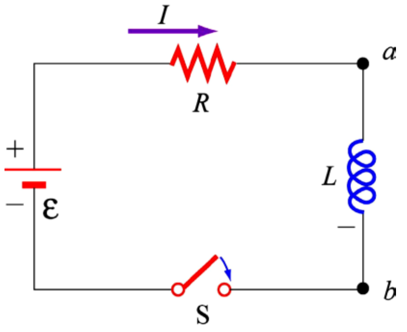
b) [8 points CLO: a3, b2**]** A conducting rod of length ℓ = 35.0 cm is free to slide on two parallel conducting bars as shown in figure. Two resistors R_1 = 2.00 Ω and R_2 = 5.00 Ω are connected across the ends of the bars to form a loop. A constant magnetic field B = 2.50 T is directed perpendicularly into the page. An external agent pulls the rod to the left with a constant speed of v = 8.00 m/s. Find (i) the currents in both resistors, (ii) the total power delivered to all the resistances of the circuit, and (iii) the magnitude of the applied force that is needed to move the rod with this constant velocity.



Continue with the remaining questions on the back

c) **[8 points** CLO: a1, b2**]** In the figure shown, the switch S is closed at $t = 0$, prove that the current change with time according to the relation:

$$I(t) = \frac{\varepsilon}{R}\left(1 - e^{\frac{-t}{\tau}}\right)$$



Question ④ 《27 points》

Choose the correct answer justifing your choice (answers without justification are ignored):

1. **[3 points** CLO: a1, b2**]** A negative charge is placed in an electric field **E** = (8 **i** – 6 **j**) N/C. The direction of the electric force on this charge is ....
(a) 8 **i** – 6 **j** (b) –8 **i** – 6 **j** (c) 8 **i** + 6 **j** (d) –4 **i** + 3 **j** (e) –3 **i** + 4 **j**

2. **[3 points** CLO: a1, b2**]** Two charges q_1 and q_2 are placed on the x axis at $x = 0$ and $x = 2$ m, respectively. The net flux through a spherical surface of radius 1 m centered at the origin is ..
(a) $(q_1+q_2)/\varepsilon_o$ (b) $(q_1-q_2)/\varepsilon_o$ (c) zero (d) q_2/ε_o (e) q_1/ε_o

3. **[3 points** CLO: a1, b2**]** Charge of uniform linear density 8.41 nC/m is distributed along a circular arc of radius 4 m and angle 50°. The electric potential (relative to zero at infinity) at the center of the arc is nearly V
(a) 20 (b) 16.5 (c) 66 (d) 4.7 (e) 3784.5

4. **[3 points** CLO: a3, b2**]** If both the plate area and the plate separation of a parallel-plate capacitor are doubled, the capacitance will be ....
(a) doubled (b) the same (c) hlaved (d) increase 4 times (e) decrease 4 times

5. **[3 points** CLO: a3, b2**]** A particle of charge 1 nC moves with a velocity of **v** = (4**j**+2**k**) ×10⁹ m/s in a region in which the magnetic field is **B** = 5**j** T. The magnetic force on this particle is .... N
(a) 10 **i** (b) –10 **k** (c) –10 **i** (d) 20 **j** + 2 **k** (e) 20 **k**

6. **[3 points** CLO: a1, b2**]** A rectangular coil in the xy-plane whose vertices are A(0 ,0), B(0, 5), C(5, 5) and D(5, 0) is affected by a magnetic field in the positive z-direction. If a current passes through the coil in the direction ABCD, the vector of the torque affecting the coil is ....
(a) in the x-direction (b) in the y-direction (c) in the z-direction
(d) zero (e) in the direction AC

7. **[3 points** CLO: a1, b2**]** An infinitely long thin wire is placed along the z-axis and carrying a current in the positive z-direction. The magnetic field of this wire at the point (0, 5, 12) is in the .... direction.
(a) positive x (b) positive y (c) positive z (d) negative x (e) negative z

8. **[3 points** CLO: a1, b2**]** The dimensions of the magnetic flux is ....
(a) $MLT^{-2}I^{-1}$ (b) $ML^2T^{-1}I^{-1}$ (c) $ML^2T^{-2}I$ (d) $ML^2T^{-2}I^{-1}$ (e) ML^2TI^{-1}

9. **[3 points** CLO: a1, b2**]** A coil has a stored magnetic energy 9 J when a current 3 A is passing through it for 5 seconds. The inductance of this coil is .... H
(a) 2 (b) 6 (c) 0.5 (d)1.5 (e) 5

End of the exam *Best wishes*

Benha University
Benha Faculty of Engineering
Date: 22 / 1 / 2021
Semester: January 2022
Examiners: Physics Staff
Total marks: 90

Department: Basic Eng. Sciences
Program: All
Time: 3 hours
Subject: Physics A (B1031)
Grade: Preparatory year
No. of Pages: 2

Final Written Exam

CONSTANTS: $q = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg, $k_e = 9\times10^{9}$ N.m^2/C^2, $m_p = 1.67\times 10^{-27}$ kg, $\varepsilon_o = 8.85 \times 10^{-12}\ \frac{C^2}{N.m^2}$, $\mu_o = 4\pi \times 10^{-7}\ \frac{T.m}{A}$, $G = 6.67 \times 10^{-11}\ \frac{m^3}{s^2.kg}$

Answers of Question ①:

(20 points)

-

a) [6 points, CLO: a1, b2**]** A particle of charge 5 µC and mass 0.2 g is in a region of uniform electric field E = 400 N/C in the x-direction. At time t = 0, the particle was at rest and was located at the origin. Determine the location and velocity of the particle at t = 5 ms (Neglect the effect of the weight on the motion).

Answer:

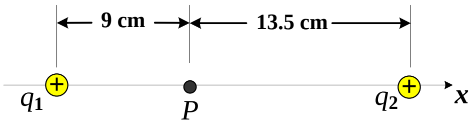
$a = q(1\times10^{-6})\ E/(m*1\times10^{-3}) = 10\ \text{m/s}^2$,
$v = v_o + at = 50\ \text{m/s} = 50\ \text{m/s}$,
$x = x_o + v_o t + (½)at^2 = 125\ \text{m}$

b) [8 points CLO: a1, b2**]** A solid conducting sphere of radius 3 cm has a charge 2 nC. A conducting spherical shell of inner radius 5 cm and outer radius 8 cm is concentric with the solid sphere and has a charge –18 nC. **(i)** Find the electric field at r = 4 cm, **(ii)** Find the electric field at r = 6 cm, **(iii)** Find the surface charge density at the outer surface of the shell.

Answer:

(i) E_1 = k*2×10^{-9}/ (0.04)^2 = 11250 N/C
(ii) E_2 = 0 (inside the conductor E = 0)
(iii) Q_{out} = –18 – (–2) = – 16 nC
(iv) σ_{out} = Q_{out}/(4*π*(0.08)^2) = -198.94 nC/m^2

c) [6 points CLO: a1, b2**]** Two point-charges lie along a straight line as shown in the figure beside, where q_1 = 6 µC and q_2 = 1.5 µC. Find **(i)** the electric potential at point P, **(ii)** the potential energy of a third charge q_3 = –5 µC that is put on point P, **(iii)** the energy needed to assemble the three charges.



Answer:

(i) $V = kq_1/d_1 + kq_2/d_2$ = 700 V
(ii) $U = q_3V$ = – 3.5 µJ
(iii) $W = k\ (q_1q_2/(d_1 + d_2) + q_1q_3/d_1 + q_2q_3/d_2)$ = –3.14 µJ

***Answers of* Question ②:**
(21 points)

a) [8 points CLO: a3, b2**]** A blood cell is seen as a spherical capacitor. It cosnsits of a positively charged conducting liquid sphere of radius *a*, separated by an insulating membrane from the surrounding negatively charged conducting fluid of radius *b*. A potential difference of 100 mV is measured across the membrane. Take the membrane's thickness as 100 nm and its dielectric constant as 5.00. Calculate the charge on the surfaces of the membrane. Assume that a typical red blood cell has an inner conducting liquid sphere of mass of 1.00×10^{-12} kg and density 1100 kg/m³.

Answer:

$$Volume = \frac{m}{\rho} = \frac{10^{-12}}{1100} = 9.09 \times 10^{-16}\ m^3$$
$$\because \frac{4}{3}\pi r^3 = 9.09 \times 10^{-16}\ m^3,$$
$$\therefore r = 6.0095 \times 10^{-6}\ m = a$$
$$b = a + t = 6.0095 \times 10^{-6} + 100 \times 10^{-9} = 6.109 \times 10^{-6}\ m$$
$$\because C = \kappa \frac{ab}{k(b-a)}$$
$$\therefore C \cong 2.04 \times 10^{-13}\ F$$
$$Q = C\Delta V \cong 2.04 \times 10^{-14}\ C$$

b) [7 points CLO: a1, b2**]** One gram of gold is drawn into a wire 2.40 km long. The density of gold is 19.3×10^3 kg/m³, and its resistivity is 2.44×10^{-8} Ω. m. What is the resistance of such a wire?

Answer:

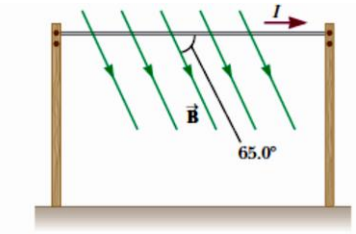
The volume of the gram of gold is given by $\rho = \frac{m}{V}$.

$$V = \frac{m}{\rho} = \frac{10^{-3}\ kg}{19.3 \times 10^3\ kg/m^3} = 5.18 \times 10^{-8}\ m^3 = A(2.40 \times 10^3\ m)$$

Then, $A = 2.16 \times 10^{-11}\ m^2$ and the resistance is

$$R = \frac{\rho \ell}{A} = \frac{(2.44 \times 10^{-8}\ \Omega \cdot m)(2.4 \times 10^3\ m)}{2.16 \times 10^{-11}\ m^2} = \boxed{2.71 \times 10^6\ \Omega}$$

c) [6 points CLO: a1, b2**]** A horizontal power line of length 58.0 m carries a current of 2.20 kA northward as shown in figure. The Earth's magnetic field at this location has a magnitude of 5.00×10^{-5} T. The field at this location is directed toward the north at an angle 65.0° below the power line. Find (i) the magnitude and (ii) the direction of the magnetic force on the power line.



Answer:

(a) The magnitude of the force is

$$F = ILB\sin\theta$$
$$= (2.20 \times 10^3\ A)(58.0\ m)(5.00 \times 10^{-5}\ N)\sin 65.0°$$
$$= \boxed{5.78\ N}$$

(b) By the right-hand rule, the direction of the magnetic force is $\boxed{\text{into the page}}$.

***Answers of* Question ③:**

(22 points)

a) **[6 points** CLO: a1, b2**]** A long, cylindrical conductor of radius R carries a current I. The current density J is uniform over the cross section of the conductor. Find an expression for the magnetic field magnitude B (i) at a distance $r < R$ and (ii) at a distance $r > R$, measured from the center of the conductor.

Answer:

(i) Using Ampere's law:

At r < R:

$$\oint_{closedpath} \boldsymbol{B}.\boldsymbol{ds} = B\oint ds = BL = \mu_0 I'$$

$$I' = J(\pi r^2) = \frac{I}{\pi R^2}(\pi r^2) = I\frac{r^2}{R^2}$$

$$B(2\pi r) = \mu_0 I_{enc} = \mu_0 I\frac{r^2}{R^2} \quad \rightarrow \quad B = \left(\frac{\mu_0 I}{2\pi R^2}\right) r$$

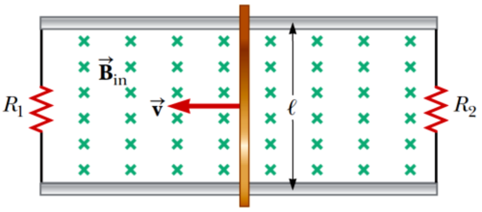
(ii) Using Ampere's law:

At r > R:

$$\oint_{closedpath} \boldsymbol{B}.\boldsymbol{ds} = B\oint ds = BL = \mu_0 I$$

$$B(2\pi r) = \mu_0 I \quad \rightarrow \quad B = \left(\frac{\mu_0 I}{2\pi r}\right)$$

b) **[8 points** CLO: a3, b2**]** A conducting rod of length ℓ = 35.0 cm is free to slide on two parallel conducting bars as shown in figure. Two resistors R_1 = 2.00 Ω and R_2 = 5.00 Ω are connected across the ends of the bars to form a loop. A constant magnetic field B = 2.50 T is directed perpendicularly into the page. An external agent pulls the rod to the left with a constant speed of v = 8.00 m/s. Find (i) the currents in both resistors, (ii) the total power delivered to all the resistances of the circuit, and (iii) the magnitude of the applied force that is needed to move the rod with this constant velocity.



Answer:

The emf induced between the ends of the moving bar is

$$\mathcal{E} = B\ell v = (2.50\text{ T})(0.350\text{ m})(8.00\text{ m/s}) = 7.00\text{ V}$$

The left-hand loop contains decreasing flux away from you, so the induced current in it will be clockwise, to produce its own field directed away from you. Let I_1 represent the current flowing upward through the 2.00-Ω resistor. The right-hand loop will carry counterclockwise current. Let I_3 be the upward current in the 5.00-Ω resistor.

(i) Kirchhoff's loop rule then gives:

$$+7.00\text{ V} - I_1(2.00\ \Omega) = 0 \quad \text{or} \quad I_1 = \boxed{3.50\text{ A}}$$

and $$+7.00\text{ V} - I_3(5.00\ \Omega) = 0 \quad \text{or} \quad I_3 = \boxed{1.40\text{ A}}$$

(ii) The total power converted in the resistors of the circuit is

$$P = \mathcal{E}I_1 + \mathcal{E}I_3 = \mathcal{E}(I_1 + I_3) = (7.00\text{ V})(3.50\text{ A} + 1.40\text{ A})$$

$$= \boxed{34.3\text{ W}}$$

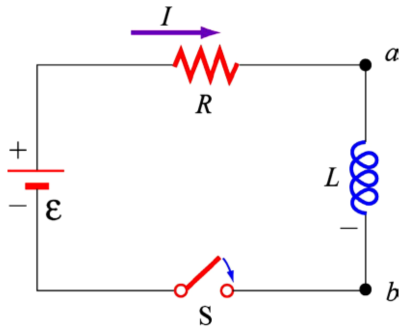
(iii) *Method 1*: The current in the sliding conductor is downward with value $I_2 = 3.50\text{ A} + 1.40\text{ A} = 4.90\text{ A}$. The magnetic field exerts a force of $F_m = I\ell B = (4.90\text{ A})(0.350\text{ m})(2.50\text{ T}) = 4.29\text{ N}$ directed toward the right on this conductor. An outside agent must then exert a force of $\boxed{4.29\text{ N}}$ to the left to keep the bar moving.

Method 2: The agent moving the bar must supply the power according to $P = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}} = Fv\cos 0°$. The force required is then:

$$F = \frac{P}{v} = \frac{34.3\text{ W}}{8.00\text{ m/s}} = \boxed{4.29\text{ N}}$$

c) **[8 points** CLO: a1, b2**]** In the figure shown, the switch S is closed at $t = 0$, prove that the current change with time according to the relation:

$$I(t) = \frac{\varepsilon}{R}\left(1 - e^{\frac{-t}{\tau}}\right)$$



Answer:

We can apply Kirchhoff's loop equation to this circuit:

$$\varepsilon - iR - L\frac{di}{dt} = 0$$

To obtain a mathematical solution of above Equation represents the current in the circuit as a function of time. To find the solution, we change variables for convenience, taking

$$x = \frac{\varepsilon}{R} - i$$

so that $dx = -di$. With these substitutions, the above equation can be written as:

$$x + \frac{L}{R}\frac{dx}{dt} = 0$$

Rearranging and integrating this expression gives:

$$\int_{Xo}^{X} \frac{dx}{x} = -\frac{R}{L}\int_0^t dt$$

$$\ln\frac{X}{X_o} = -\frac{R}{L}t$$

where x_o is the value of x at time t = 0. Taking the antilogarithm of this result gives:

$$x = x_o\, e^{\frac{-Rt}{L}}$$

Since at t = 0, I = 0, we note that $x_o = \varepsilon / R$. Hence, this last expression is equivalent to

$$\frac{\varepsilon}{R} - i = \frac{\varepsilon}{R}\, e^{\frac{-Rt}{L}}$$

$$i = \frac{\varepsilon}{R}\left(1 - e^{\frac{-Rt}{L}}\right)$$

This above expression shows how the inductor affects the current. The current does not increase instantly to its final equilibrium value when the switch is closed, but instead increases according to an exponential function.

We can also write this expression as:

$$\text{where } \tau = \frac{L}{R} \qquad\qquad I_{(t)} = \frac{\varepsilon}{R}\left(1 - e^{-t/\tau}\right)$$

***Answers of* Question ④:** **(27 points)**

1. **[3 points** CLO: a1, b2**]** A negative charge is placed in an electric field $\mathbf{E} = (8\ \mathbf{i} - 6\ \mathbf{j})$ N/C. The direction of the electric force on this charge is ....

(a) $8\ \mathbf{i} - 6\ \mathbf{j}$ (b) $-8\ \mathbf{i} - 6\ \mathbf{j}$ (c) $8\ \mathbf{i} + 6\ \mathbf{j}$ **(d) $-4\ \mathbf{i} + 3\ \mathbf{j}$** (e) $-3\ \mathbf{i} + 4\ \mathbf{j}$

Justification: $\mathbf{F} = q\mathbf{E} = -q(8\ \mathbf{i} - 6\ \mathbf{j})$ ➔ The direction is $-(8\ \mathbf{i} - 6\ \mathbf{j}) = -4\ \mathbf{i} + 3\ \mathbf{j}$

2. **[3 points** CLO: a1, b2**]** Two charges q_1 and q_2 are placed on the x axis at $x = 0$ and $x = 2$ m, respectively. The net flux through a spherical surface of radius 1 m centered at the origin is ..

(a) $(q_1+q_2)/\varepsilon_o$ (b) $(q_1-q_2)/\varepsilon_o$ (c) zero (d) q_2/ε_o **(e) q_1/ε_o**

Justification: The charge q_1 is the only charge inside the surface ➔ $\Phi_E = q_1/\varepsilon_o$

3. **[3 points** CLO: a1, b2**]** Charge of uniform linear density 8.41 nC/m is distributed along a circular arc of radius 4 m and angle 50°. The electric potential (relative to zero at infinity) at the center of the arc is nearly V

(a) 20 (b) 16.5 **(c) 66** (d) 4.7 (e) 3784.5

Justification: $V = kQ/r = (9\times10^9)(8.41\times10^{-9})(4)(50*\pi/180)/4 = 66\ V$

4. **[3 points** CLO: a3, b2**]** If both the plate area and the plate separation of a parallel-plate capacitor are doubled, the capacitance will be ....

(a) doubled **(b) the same** (c) hlaved (d) increase 4 times (e) decrease 4 times

Justification: $C = \varepsilon A/d$ ➔ $C' = \varepsilon(2A)/(2d) = \varepsilon A/d = C$

5. **[3 points** CLO: a3, b2**]** A particle of charge 1 nC moves with a velocity of $\mathbf{v} = (4\mathbf{j}+2\mathbf{k})\times10^9$ m/s in a region in which the magnetic field is $\mathbf{B} = 5\mathbf{j}$ T. The magnetic force on this particle is .... N

(a) $10\ \mathbf{i}$ (b) $-10\ \mathbf{k}$ **(c) $-10\ \mathbf{i}$** (d) $20\ \mathbf{j} + 2\ \mathbf{k}$ (e) $20\ \mathbf{k}$

Justification: $\mathbf{F} = q\mathbf{v}\times\mathbf{B}$ ➔ $\mathbf{F} = (1\times10^{-9})(2\times10^9)(5)\ (-\mathbf{i}) = -10\ \mathbf{i}$

6. **[3 points** CLO: a1, b2**]** A rectangular coil in the xy-plane whose vertices are A(0 ,0), B(0, 5), C(5, 5) and D(5, 0) is affected by a magnetic field in the positive z-direction. If a current passes through the coil in the direction ABCD, the vector of the torque affecting the coil is ....

(a) in the x-direction (b) in the y-direction (c) in the z-direction **(d) zero** (e) in the direction AC

Justification: $\boldsymbol{\tau} = \boldsymbol{\mu}\times\mathbf{B}$

Since $\boldsymbol{\mu} = NI\mathbf{A}$ is in the z-direction and $\mathbf{B}$ is also in the z-direction ➔ $\boldsymbol{\tau} = 0$

7. **[3 points** CLO: a1, b2**]** An infinitely long thin wire is placed along the z-axis and carrying a current in the positive z-direction. The magnetic field of this wire at the point (0, 5, 12) is in the .... direction.

(a) positive x (b) positive y (c) positive z **(d) negative x** (e) negative z

Justification: $\mathbf{B}$ is along= $I\mathbf{L}\times\mathbf{r}$ $\mathbf{L} = L\ \mathbf{k}$, $\mathbf{r} = r\ \mathbf{j}$ ➔ $\mathbf{B}$ is in $-\mathbf{i}$

8. [**[3 points** CLO: a1, b2**]** The dimensions of the magnetic flux is ....

(a) $MLT^{-2}I^{-1}$ (b) $ML^2T^{-1}I^{-1}$ (c) $ML^2T^{-2}I$ **(d) $ML^2T^{-2}I^{-1}$** (e) ML^2TI^{-1}

Justification: Φ_B = V.T = UT/Q = FLT/(IT) = $MLT^{-2}LT/(IT)$ = $M\ L^2T^{-2}I^{-1}$

9. **[3 points** CLO: a1, b2**]** A coil has a stored magnetic energy 9 J when a current 3 A is passing through it for 5 seconds. The inductance of this coil is .... H

(a) 2 (b) 6 (c) 0.5 (d)1.5 (e) 5

Justification: $U_B = \frac{1}{2} LI^2$ ➔ $9 = \frac{1}{2} L\ (9)$ ➔ L = 2 H

End of the exam