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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(TAKE HOME)
SEMESTER II
SESSION 2019/2020

COURSE NAME	:	ELECTROMAGNETIC FIELDS AND WAVES
COURSE CODE	:	BEJ 20303
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY 2020
DURATION	:	5 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS **OPEN BOOK EXAMINATION**

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

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Q1 (a) Two concentric conducting sphere with radius a and b where $b > a$ are centred at the origin as shown in the **Figure Q1(a)**. The figure shows the cross-section of the spherical shell. Noted that, the inner conductor carries a total electric charge, +Q and the outer conductor carries a total electric charge, -Q. The space between the shells is filled with material with the dielectric constant of ε_{r1} and free space, ε_o

(i) Based on **Figure Q1(a)**, draw the free charge density by using plus sign, + (positive charge density, $+\rho_s$) and negative sign, - (negative charge density, $-\rho_s$) and **sketch** the vector electric field intensity, **E**.

(2 marks)

(ii) Based on **Figure Q1(a)**, indicate the polarization charge density, (**P**) that may exist by marking it as ⊕ (positive in circle) and ⊖ (negative in circle) for positive and negative charge density, respectively and **sketch** the **P**.

(3 marks)

(iii) State the vector of electric flux density, **D, E** and **P** between two conducting planes

(5 marks)

(iv) Calculate the surface bound density, ρ_{sb} at radius a and b, and the volume bound density, ρ_{vb} in the medium of a dielectric.

(3 marks)

(b) Given the radius of inner conductor in **Figure Q1(a)** is $a = 4mm$, and the radius for an outer layer is $b = 10mm$, if the space in the shell between $\emptyset = 120° \ to \ \emptyset = 240°$ is equipped with the dielectric constant of ε_{r1}.

(i) Determine the electric potential between two conductors

(3 marks)

(ii) Calculate the capacitance between two conductors

(3 marks)

(iii) Now, another dielectric material with the dielectric constant of ε_{r2} is loaded to the shells to replace the free space, determine the total capacitance and polarization charge density , $\mathbf{P_2}$

(6 marks)

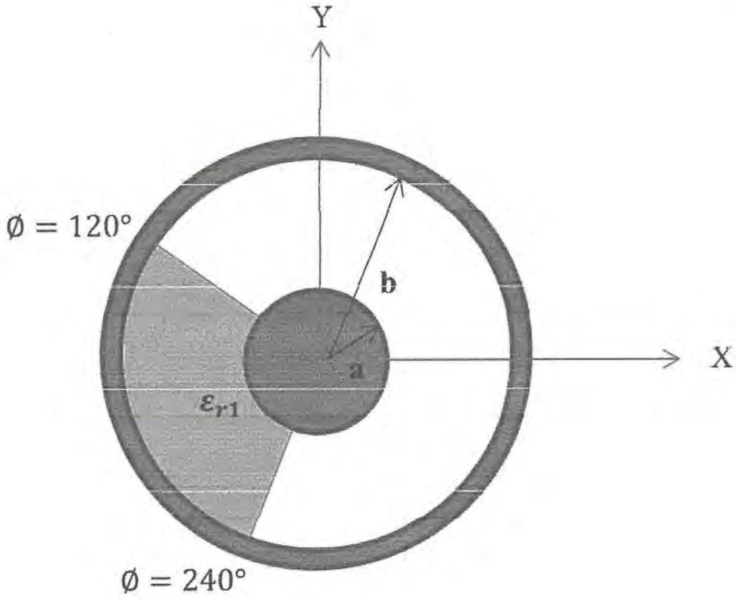

Figure Q1(a): Cross-section of a spherical shell

Q2 (a) Calculate the magnetic field, **B** at point a, b and c as given in **Figure Q2(a)**.

(15 marks)

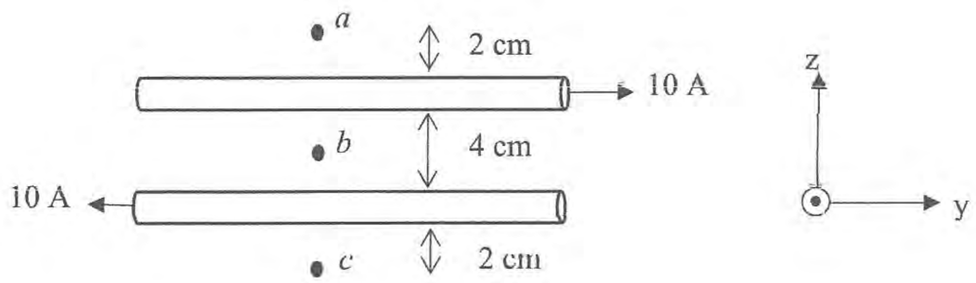

Figure Q2(a): Two infinitely long conducting wires

(b) In your own words, conclude your findings based on your answer in **Q2(a)**.

(3 marks)

(c) A long cylindrical conductor as shown in **Figure Q2(c)** is located at the origin has a radius, a and carries current characterized by current density, $\vec{J} = J_0 e^{-r}\hat{z}$, where J_0 is a constant and r is the radial distance from the cylinder's axis. Obtain an expression for the magnetic field, $\vec{H}$ for

(i) $0 \leq r \leq a$

(5 marks)

(ii) $r \geq a$

(2 marks)

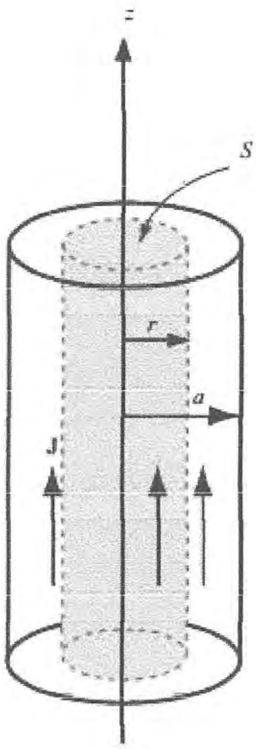

Figure Q2(c): An infinitely long cylindrical conductor

Q3 (a) Briefly -define Faraday's Law.

(4 marks)

(b) A conducting bar can slide freely over two conducting rails as shown in **Figure Q3(b)**. Calculate the induced voltage in the bar

(i) If the bar is stationed at y= 8 cm and $\mathbf{B} = 4 \cos 10^6 t\ \mathbf{a}_z$ mWb/m^2

(8 marks)

(ii) If the bar slides at a velocity $u = 20\ \mathbf{a}_y$ m/s and $\mathbf{B} = 4\mathbf{a}_z$ mWb/m^2

(8 marks)

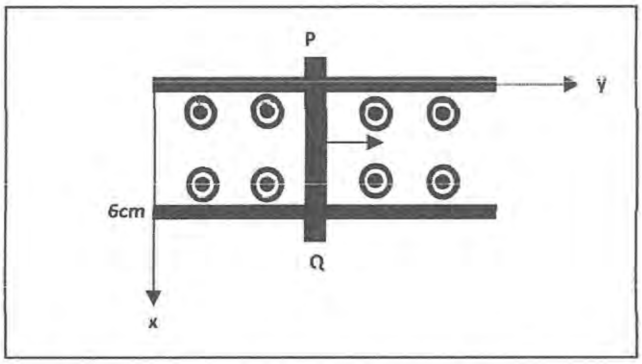

Figure Q3(b): A conducting bar

(c) A 50 Hz High Voltage (HV) power transmission line (Alternate Current, AC) can produce a strong magnetic field varies with time which will induce dangerous voltage on the adjacent cable (victim) as shown in **Figure Q3(c)(i).** The victim's cable is laid parallel with the transmission line at distance, L = 2 km and the distance between victim cable and its ground is 10 cm as shown in **Figure Q3(c)(ii)** and can be represented as a complete equivalent circuit as shown in **Figure Q3(c)(iii).** Determine the total induce voltage (V_{emf}) on the victim's cable if the magnetic field (H-field) produce at the intended location is B = 0.99 μT using a Faraday's law.

(5 marks)

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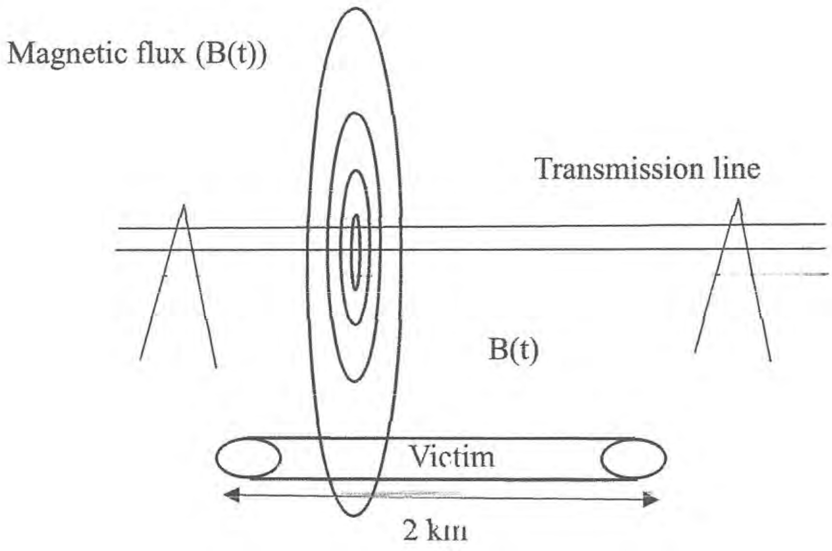

Figure Q3(c)(i): Power Transmission line produce strong magnetic field (H(t)) and induced V_{emf} to the adjacent cable.

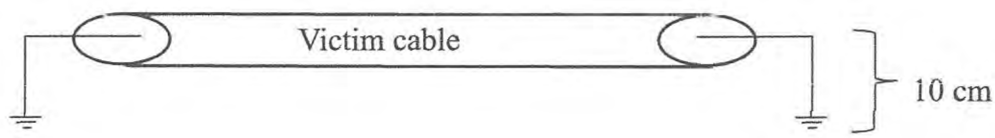

Figure Q3(c)(ii): Victim Cable parameters.

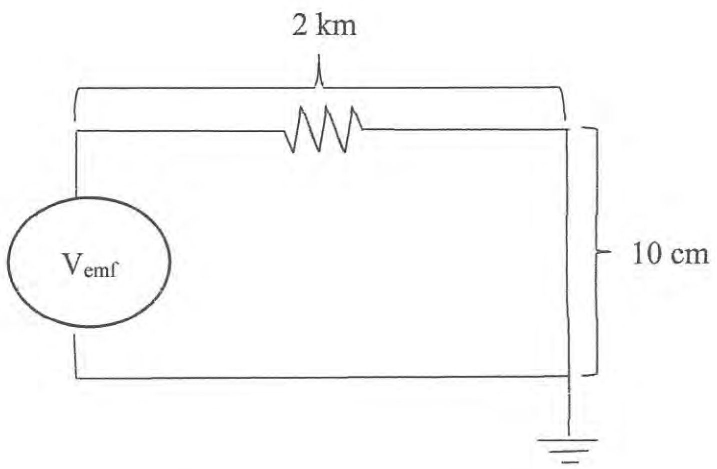

Figure Q3(c)(iii): Equivalent circuit for a victim cable

Q4 (a) A uniform plane wave is a particular solution of Maxwell's Equations with **E** assuming the same direction, same magnitude and same phase in infinite planes perpendicular to the direction of propagation. This is also applied to the **H** field. By using the formulas obtained for the plane waves in lossy media, determine the permeability (μ), phase constant (β), conductivity (σ), attenuation constant (α), permittivity (ε), and phase velocity, v of other three mediums.

(6 marks)

(b) The electric field intensity of a linearly polarized uniform plane wave propagating in the +z direction in seawater is $\mathbf{E} = \mathbf{a}_x\, 50\cos(2\text{x}10^7\pi t)$ (V/m) at $z = 0$. The constitutive parameters of seawater are $\varepsilon_r = 72$, $\mu_r = 1$ and $\sigma = 4$ (S/m). Determine:

(i) The type of the medium

(3 marks)

(ii) The phase constant, β and attenuation constant, α

(2 marks)

(iii) The phase velocity, v and intrinsic impedance, η

(4 marks)

(iv) The skin depth, δ and wave length, λ

(3 marks)

(v) The distance at which the amplitude of **E** is 2% of its value at $z = 0$

(2 marks)

(vi) Write the expressions for $\mathbf{E}(z,t)$ and $\mathbf{H}(z,t)$ at $z = 1$m as function of t

(5 marks)

- END OF QUESTIONS-

FINAL EXAMINATION

SEMESTER/SESSION : II/ 2019/2020
COURSE NAME : ELECTROMAGNETIC FIELDS AND WAVES
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Formula

	Cartesian	Cylindrical	Spherical
Coordinate parameters	x, y, z	r, ϕ, z	R, θ, ϕ
Vector $\vec{A}$	$A_x\hat{\mathbf{x}}+A_y\hat{\mathbf{y}}+A_z\hat{\mathbf{z}}$	$A_r\hat{\mathbf{r}}+A_\phi\hat{\boldsymbol{\varphi}}+A_z\hat{\mathbf{z}}$	$A_R\hat{\mathbf{R}}+A_\theta\hat{\boldsymbol{\theta}}+A_\phi\hat{\boldsymbol{\varphi}}$
Magnitude $\vec{A}$	$\sqrt{A_x^{\,2}+A_y^{\,2}+A_z^{\,2}}$	$\sqrt{A_r^{\,2}+A_\phi^{\,2}+A_z^{\,2}}$	$\sqrt{A_R^{\,2}+A_\theta^{\,2}+A_\phi^{\,2}}$
Position vector, $\overrightarrow{OP}$	$x_1\hat{\mathbf{x}}+y_1\hat{\mathbf{y}}+z_1\hat{\mathbf{z}}$ for point $P(x_1, y_1, z_1)$	$r_1\hat{\mathbf{r}}+z_1\hat{\mathbf{z}}$ for point $P(r_1, \phi_1, z_1)$	$R_1\hat{\mathbf{R}}$ for point $P(R_1, \theta_1, \phi_1)$
Unit vector product	$\hat{\mathbf{x}}\bullet\hat{\mathbf{x}}=\hat{\mathbf{y}}\bullet\hat{\mathbf{y}}=\hat{\mathbf{z}}\bullet\hat{\mathbf{z}}=1$ $\hat{\mathbf{x}}\bullet\hat{\mathbf{y}}=\hat{\mathbf{y}}\bullet\hat{\mathbf{z}}=\hat{\mathbf{z}}\bullet\hat{\mathbf{x}}=0$ $\hat{\mathbf{x}}\times\hat{\mathbf{y}}=\hat{\mathbf{z}}$ $\hat{\mathbf{y}}\times\hat{\mathbf{z}}=\hat{\mathbf{x}}$ $\hat{\mathbf{z}}\times\hat{\mathbf{x}}=\hat{\mathbf{y}}$	$\hat{\mathbf{r}}\bullet\hat{\mathbf{r}}=\hat{\boldsymbol{\varphi}}\bullet\hat{\boldsymbol{\varphi}}=\hat{\mathbf{z}}\bullet\hat{\mathbf{z}}=1$ $\hat{\mathbf{r}}\bullet\hat{\boldsymbol{\varphi}}=\hat{\boldsymbol{\varphi}}\bullet\hat{\mathbf{z}}=\hat{\mathbf{z}}\bullet\hat{\mathbf{r}}=0$ $\hat{\mathbf{r}}\times\hat{\boldsymbol{\varphi}}=\hat{\mathbf{z}}$ $\hat{\boldsymbol{\varphi}}\times\hat{\mathbf{z}}=\hat{\mathbf{r}}$ $\hat{\mathbf{z}}\times\hat{\mathbf{r}}=\hat{\boldsymbol{\varphi}}$	$\hat{\mathbf{R}}\bullet\hat{\mathbf{R}}=\hat{\boldsymbol{\theta}}\bullet\hat{\boldsymbol{\theta}}=\hat{\boldsymbol{\varphi}}\bullet\hat{\boldsymbol{\varphi}}=1$ $\hat{\mathbf{R}}\bullet\hat{\boldsymbol{\theta}}=\hat{\boldsymbol{\theta}}\bullet\hat{\boldsymbol{\varphi}}=\hat{\boldsymbol{\varphi}}\bullet\hat{\mathbf{R}}=0$ $\hat{\mathbf{R}}\times\hat{\boldsymbol{\theta}}=\hat{\boldsymbol{\varphi}}$ $\hat{\boldsymbol{\theta}}\times\hat{\boldsymbol{\varphi}}=\hat{\mathbf{R}}$ $\hat{\boldsymbol{\varphi}}\times\hat{\mathbf{R}}=\hat{\boldsymbol{\theta}}$
Dot product $\vec{A}\bullet\vec{B}$	$A_xB_x+A_yB_y+A_zB_z$	$A_rB_r+A_\phi B_\phi+A_zB_z$	$A_RB_R+A_\theta B_\theta+A_\phi B_\phi$
Cross product $\vec{A}\times\vec{B}$	$\begin{vmatrix}\hat{\mathbf{x}} & \hat{\mathbf{y}} & \hat{\mathbf{z}}\\ A_x & A_y & A_z\\ B_x & B_y & B_z\end{vmatrix}$	$\begin{vmatrix}\hat{\mathbf{r}} & \hat{\boldsymbol{\varphi}} & \hat{\mathbf{z}}\\ A_r & A_\phi & A_z\\ B_r & B_\phi & B_z\end{vmatrix}$	$\begin{vmatrix}\hat{\mathbf{R}} & \hat{\boldsymbol{\theta}} & \hat{\boldsymbol{\varphi}}\\ A_R & A_\theta & A_\phi\\ B_R & B_\theta & B_\phi\end{vmatrix}$
Differential length, $\overrightarrow{d\ell}$	$dx\,\hat{\mathbf{x}}+dy\,\hat{\mathbf{y}}+dz\,\hat{\mathbf{z}}$	$dr\,\hat{\mathbf{r}}+rd\phi\,\hat{\boldsymbol{\varphi}}+dz\,\hat{\mathbf{z}}$	$dR\,\hat{\mathbf{R}}+Rd\theta\,\hat{\boldsymbol{\theta}}+R\sin\theta\,d\phi\hat{\boldsymbol{\varphi}}$
Differential surface, $\overrightarrow{ds}$	$\overrightarrow{ds}_x=dy\,dz\,\hat{\mathbf{x}}$ $\overrightarrow{ds}_y=dx\,dz\,\hat{\mathbf{y}}$ $\overrightarrow{ds}_z=dx\,dy\,\hat{\mathbf{z}}$	$\overrightarrow{ds}_r=rd\phi\,dz\,\hat{\mathbf{r}}$ $\overrightarrow{ds}_\phi=dr\,dz\,\hat{\boldsymbol{\varphi}}$ $\overrightarrow{ds}_z=rdr\,d\phi\,\hat{\mathbf{z}}$	$\overrightarrow{ds}_R=R^2\sin\theta\,d\theta\,d\phi\,\hat{\mathbf{R}}$ $\overrightarrow{ds}_\theta=R\sin\theta\,dR\,d\phi\,\hat{\boldsymbol{\theta}}$ $\overrightarrow{ds}_\phi=R\,dR\,d\theta\,\hat{\boldsymbol{\varphi}}$
Differential volume, $\overrightarrow{dv}$	$dx\,dy\,dz$	$r\,dr\,d\phi\,dz$	$R^2\sin\theta\,dR\,d\theta\,d\phi$

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$Q = \int \rho_\ell d\ell,$

$Q = \int \rho_s dS,$

$Q = \int \rho_v dv$

$\overline{F}_{12} = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 R^2}\hat{a}_{R_{12}}$

$\overline{E} = \dfrac{\overline{F}}{Q},$

$\overline{E} = \dfrac{Q}{4\pi\varepsilon_0 R^2}\hat{a}_R$

$\overline{E} = \int \dfrac{\rho_\ell d\ell}{4\pi\varepsilon_0 R^2}\hat{a}_R$

$\overline{E} = \int \dfrac{\rho_s dS}{4\pi\varepsilon_0 R^2}\hat{a}_R$

$\overline{E} = \int \dfrac{\rho_v dv}{4\pi\varepsilon_0 R^2}\hat{a}_R$

$\overline{D} = \varepsilon\overline{E}$

$\psi_e = \int \overline{D} \bullet d\overline{S}$

$Q_{enc} = \oint_S \overline{D} \bullet d\overline{S}$

$\rho_v = \nabla \bullet \overline{D}$

$V_{AB} = -\int_A^B \overline{E} \bullet d\overline{\ell} = \dfrac{W}{Q}$

$V = \dfrac{Q}{4\pi\varepsilon r}$

$V = \int \dfrac{\rho_\ell d\ell}{4\pi\varepsilon r}$

$\oint \overline{E} \bullet d\overline{\ell} = 0$

$\nabla \times \overline{E} = 0$

$\overline{E} = -\nabla V$

$\nabla^2 V = 0$

$R = \dfrac{\ell}{\sigma S}$

$I = \int \overline{J} \bullet dS$

$d\overline{H} = \dfrac{Id\overline{\ell} \times \overline{R}}{4\pi R^3}$

$Id\overline{\ell} \equiv \overline{J}_s dS \equiv \overline{J}dv$

$\oint \overline{H} \bullet d\overline{\ell} = I_{enc} = \int \overline{J}_s dS$

$\nabla \times \overline{H} = \overline{J}$

$\psi_m = \int_s \overline{B} \bullet d\overline{S}$

$\psi_m = \oint \overline{B} \bullet d\overline{S} = 0$

$\psi_m = \oint \overline{A} \bullet d\overline{\ell}$

$\nabla \bullet \overline{B} = 0$

$\overline{B} = \mu\overline{H}$

$\overline{B} = \nabla \times \overline{A}$

$\overline{A} = \int \dfrac{\mu_0 Id\overline{\ell}}{4\pi R}$

$\nabla^2 \overline{A} = -\mu_0 \overline{J}$

$\overline{F} = Q(\overline{E} + \overline{u} \times \overline{B}) = m\dfrac{d\overline{u}}{dt}$

$d\overline{F} = Id\overline{\ell} \times \overline{B}$

$\overline{T} = \overline{r} \times \overline{F} = \overline{m} \times \overline{B}$

$\overline{m} = IS\hat{a}_n$

$V_{emf} = -\dfrac{\partial\psi}{\partial t}$

$V_{emf} = -\int \dfrac{\partial\overline{B}}{\partial t} \bullet d\overline{S}$

$V_{emf} = \int (\overline{u} \times \overline{B}) \bullet d\overline{\ell}$

$I_d = \int J_d . d\overline{S}, J_d = \dfrac{\partial\overline{D}}{\partial t}$

$\gamma = \alpha + j\beta$

$\alpha = \omega\sqrt{\dfrac{\mu\varepsilon}{2}\left[\sqrt{1 + \left[\dfrac{\sigma}{\omega\varepsilon}\right]^2} - 1\right]}$

$\beta = \omega\sqrt{\dfrac{\mu\varepsilon}{2}\left[\sqrt{1 + \left[\dfrac{\sigma}{\omega\varepsilon}\right]^2} + 1\right]}$

$\overline{\overline{F}}_1 = \dfrac{\mu I_1 I_2}{4\pi}\oint_{L1}\oint_{L2}\dfrac{d\overline{\ell}_1 \times (d\overline{\ell}_2 \times \hat{a}_{R_{21}})}{R_{21}^2}$

$|\eta| = \dfrac{\sqrt{\mu/\varepsilon}}{\left[1 + \left(\dfrac{\sigma}{\omega\varepsilon}\right)^2\right]^{\frac{1}{4}}}$

$\tan 2\theta_\eta = \dfrac{\sigma}{\omega\varepsilon}$

$\tan\theta = \dfrac{\sigma}{\omega\varepsilon} = \dfrac{\overline{J}_s}{\overline{J}_{ds}}$

$\delta = \dfrac{1}{\alpha}$

$\varepsilon_0 = 8.854 \times 10^{-12}\ \text{Fm}^{-1}$

$\mu_0 = 4\pi \times 10^{-7}\ \text{Hm}^{-1}$

$\int \dfrac{dx}{(x^2 + c^2)^{3/2}} = \dfrac{x}{c^2(x^2 + c^2)^{1/2}}$

$\int \dfrac{xdx}{(x^2 + c^2)^{3/2}} = \dfrac{-1}{(x^2 + c^2)^{1/2}}$

$\int \dfrac{dx}{(x^2 \pm c^2)^{1/2}} = ln\left(x + \sqrt{x^2 \pm c^2}\right)$

$\int \dfrac{dx}{(x^2 + c^2)} = \dfrac{1}{c}tan^{-1}\left(\dfrac{x}{c}\right)$

$\int \dfrac{xdx}{(x^2 + c^2)} = \dfrac{1}{2}ln(x^2 + c^2)$

$\int \dfrac{xdx}{(x^2 + c^2)^{1/2}} = \sqrt{x^2 + c^2}$