UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	ELECTROMAGNETIC FIELDS AND WAVES
COURSE CODE	:	BEJ 20303 / BEV 20303
PROGRAMME CODE	:	BEJ / BEV
EXAMINATION DATE	:	JULY/ AUGUST 2023
DURATION	:	3 HOURS

INSTRUCTION

1. ANSWER ALL QUESTIONS (**PART A & PART B**)
2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK**.
3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **FOURTEEN (14)** PAGES

PART A OBJECTIVES (40 marks)

Q1 The parallel metal plates of the capacitor is separated by _____.

(2 marks)

a. Insulator
b. Isolator
c. Both A and B
d. None of the above

Q2 The capacitance between two plates decreases with

(2 marks)

a. Shorter plate area and larger distance between them
b. Shorter plate area and higher applied voltage
c. Larger plate area and shorter distance between plates
d. Larger plate area, longer distance between plates and higher applied voltage

Q3 A 5 μF, 10 μF, 11 μF and 50 μF capacitor are arranged in parallel to each other. Determine the total capacitance of the capacitor.

(2 marks)

a. 2.43 μF
b. 0.41 μF
c. 76 μF
d. 152 μF

Q4 Consider the cross sections of two spherical capacitors as shown in **FIGURE Q4** with separation distance a = 2 mm, b = 4 mm, c = 3 mm, $\varepsilon_{r1} = 3.5$ and $\varepsilon_{r2} = 2.5$. Determine the capacitance of the capacitors.

(2 marks)

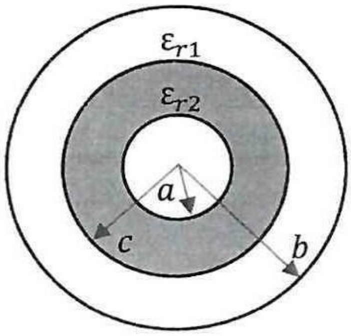

FIGURE Q4

a. 4.887 pF

b. 0.205 pF

c. 6.342 pF

d. 0.158 pF

Q5 Determine the capacitance of 5 m length of cylindrical capacitors as shown in **FIGURE Q5**. Take a = 1 mm, b = 2mm, $\varepsilon_{r1} = 3.5$ and $\varepsilon_{r2} = 2.5$.

(2 marks)

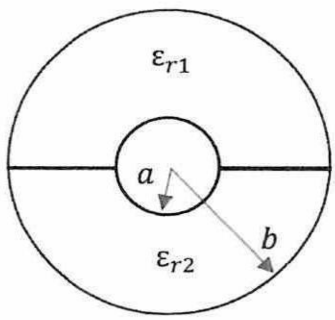

FIGURE Q5

a. 2.408 pF

b. 1.405 pF

c. 0.585 pF

d. 1.709 pF

Q6 **FIGURE Q6** shows a conducting triangular loop of 10A located in cartesian coordinate system. Determine magnetic field intensity at (0, 0, 5) due to side 1 of the loop.

(2 marks)

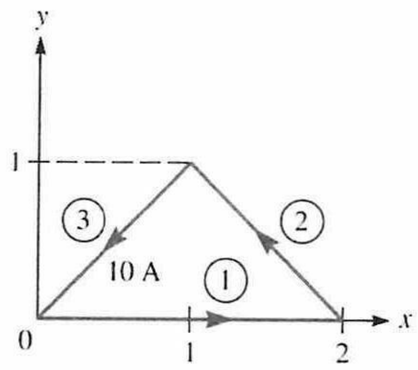

FIGURE Q6

a. $-55.1\hat{y}\ mA/m$
b. $45.7\hat{x}\ mA/m$
c. $-59.1\hat{y}\ mA/m$
d. $49.5\hat{x}\ mA/m$

Q7 Ampere's Circuital Law states that ____________________ over any closed path equals to ______________ enclosed by the path.

(2 marks)

a. the total charge distribution, the net electric flux density
b. the line integral of magnetic field intensity, the net current
c. the electromotive force (e.m.f.), the electric potential
d. the electric current density, total flux density

Q8 The point charge Q = 18 nC has a velocity of 5×10^6 m/s in the direction $\hat{a}_u = 0.6\hat{x} + 0.75\hat{y} + 0.3\hat{z}$. Calculate the magnitude of the force exerted on the charge by the field $\vec{B} = -3\hat{x} + 4\hat{y} + 6\hat{z}$ mT

(2 marks)

a. 625.5 μN
b. 535 μN
c. 525.3 μN
d. 653.7 μN

Q9 Calculate the value of $\oint_L \boldsymbol{H} \cdot \boldsymbol{dl}$ for the currents and closed paths in **FIGURE Q9.**

(2 marks)

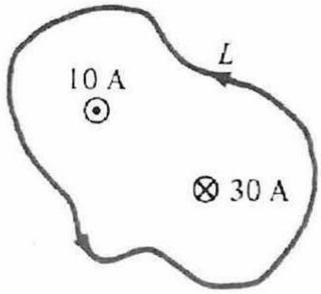

FIGURE Q9

a. 20 A
b. 30 A
c. 40 A
d. -20 A

Q10 Which of the following statements are **NOT TRUE** about electric force $\boldsymbol{F}_e$ and magnetic force $\boldsymbol{F}_m$ on a charged particle?

(2 marks)

(i) **E** and $\boldsymbol{F}_e$ are parallel to each other, whereas **B** and $\boldsymbol{F}_m$ are perpendicular to each other.
(ii) Both $\boldsymbol{F}_e$ and $\boldsymbol{F}_m$ depend on the velocity of the charged particle.
(iii) Both $\boldsymbol{F}_e$ and $\boldsymbol{F}_m$ can perform work.
(iv) $\boldsymbol{F}_m$ is generally small in magnitude in comparison to $\boldsymbol{F}_e$

(2 marks)

a. (i) and (ii)
b. (ii) and (iii)
c. (i) and (iv)
d. All of the above

Q11 State whether the following statement is true or false. Electromagnetic induction is a phenomenon of the production of electric current in a coil when the magnetic flux linked with the coil is changed.

(2 marks)

a. True
b. False

Q12 A bar magnet is moved at a steady speed of 0.5 m/s towards a coil of wire which is connected to a center zero galvanometer. The magnet is now withdrawn along the same path at 1.0 m/s. The deflection of the galvanometer is in the:

(2 marks)

a. the same direction as previously, with the magnitude of the deflection doubled.
b. opposite direction as previously, with the magnitude of the deflection halved.
c. same direction as previously, with the magnitude of the deflection halved.
d. opposite direction as previously, with the magnitude of the deflection doubled.

Q13 Faraday's law demonstrated that whenever a conducting loop connected to a galvanometer is placed in a varying magnetic field, an EMF is induced on the conductor. Consequently, a momentary deflection on the galvanometer's needle can be observed to exhibit the presence of current. Which of the following alternative methods cannot be used to induce a current on a conducting loop?

(2 marks)

a. By moving the conducting loop into or out of the magnetic field.
b. By increasing the number of turns of the conducting loop.
c. By changing the battery to AC source of the coil produces a magnetic field.
d. By changing the area of a conducting loop placed in the magnetic field.

Q14 Calculate the EMF when a coil of 100 turns is subjected to a flux of $3 \sin t + 5 \cos t$.

(2 marks)

a. $300 \sin t - 500 \cos t$
b. $3\,00 \sin t + 500 \cos t$
c. $500 \sin t - 300 \cos t$
d. $-500 \sin t + 300 \cos t$

Q15 Suppose that a straight conductor 0.1 m long moves in a uniform magnetic field 0.5 Tesla. The velocity of the conductor is 5 m/s and is directed perpendicular to the field. Calculate the induced EMF between the two ends of the conductor when the velocity of the conductor is doubled.

(2 marks)

a. 0.25 V
b. 0.5 V
c. 2.5 V
d. 5 V

Q16 If a magnetic field is given by $\boldsymbol{H} = 0.5\, e^{-0.1x} \sin\,(10^6 t - 2x)\hat{z}$. Which of these statements is incorrect?

(2 marks)

a. $\alpha = 0.1$ Np/m
b. $\beta = -2$ rad/m
c. $\omega = 10^6$ rad/s
d. the magnetic field travels along $\hat{x}$ direction.

Q17 The magnetic field in a certain medium is $\boldsymbol{H} = 5\,\sin\,(10^8 t - 0.33x)\hat{z}$. What type of medium is it?

a. Free space
b. Lossy dielectric
c. Lossless dielectric
d. Perfect conductor

Q18 Which of the following is the characteristic of lossy dielectric

(2 marks)

a. $\sigma = 0,\ \varepsilon = \varepsilon_r \varepsilon_0,\ \mu = \mu_r \mu_0$ or $\sigma << \omega\varepsilon$
b. $\sigma \neq 0,\ \varepsilon = \varepsilon_r \varepsilon_0,\ \mu = \mu_r \mu_0$
c. $\sigma = 0,\ \varepsilon = \varepsilon_0,\ \mu = \mu_0$
d. $\sigma \approx \infty,\ \varepsilon = \varepsilon_0,\ \mu = \mu_r \mu_0$ or $\sigma >> \omega\varepsilon$

Q19 A manufacturer produces a material with $\mu = 750\mu_o$, $\varepsilon = 5\varepsilon_o$ and $\sigma = 10^{-6}$ S/m at 10 MHz. This material should be classified as

(2 marks)

a. Good conductor

b. Semiconductor

c. Lossy dielectric

d. Lossless dielectric

Q20 In what condition that the attenuation constant is the same as the phase constant?

(2 marks)

a. When the medium is a conductor.

b. When the permeability is double of the permittivity value of the medium.

c. When the field is in near field (non plane wave).

d. When the conductivity of the medium is zero.

PART B SUBJECTIVES (60 marks)

Q1 A parallel-plate capacitor has an area of 200 cm^2 with a plate separation of 3 mm. The charge density is $1 \mu C/m^2$ and air is the dielectric.

(a) Determine the capacitance of the capacitor.

(3 marks)

(b) Calculate the voltage between the plates.

(5 marks)

(c) Sketch the force between the parallel plate.

(3 marks)

(d) Find the total force with which the plates attract each other.

(4 marks)

Q2 (a) Calculate the magnetic field, **H** at the origin due to the current filament AB as shown in **FIGURE Q2(a).**

(8 marks)

(b) Determine the total force experienced by the rectangular loop on xy plane as shown in **FIGURE Q2(b).** Given that the $\boldsymbol{B} = 6x\hat{x} - 9y\hat{y} + 3z\hat{z}$ Wb/m^2.

(7 marks)

Q3 An inductor is formed by winding, N turns of a thin conducting wire into a circular loop of a radius of 10 cm. The inductor loop is in the x-y plane with its center at the origin, and it is connected to a resistor $R = 1000\ \Omega$ as can be seen in **FIGURE Q3**. In the presence of a magnetic field of of $\vec{B} = 0.6sin10^3t\hat{z}$ Tesla, the current of $I = 190\cos 10^3t$ mA is induced in the circuit.

(a) Find the number of turns, N.

(11 marks)

(b) Suggest a method to obtain the induced current of $95\cos 10^3t$ mA. Justify your answer.

(4 marks)

Q4 A uniform plane wave is propagating in x-direction of free space. The electric field **E** (x, t) is polarized in the y-direction sinusoidally with maximum and minimum value of ± 1 V/m, occurring at x = 30m and x = 150 m respectively and **E** (0, 0) = 0. Calculate

(a) the wavelength, λ

(2 marks)

(b) the phase constant, β

(2 marks)

(c) angular frequency, ω

(2 marks)

(d) expression of electric field, **E**

(2 marks)

(e) the **E** when x = 120 m and t = 2μs

(2 marks)

(f) expression of the magnetic field, **H**

(3 marks)

(g) Justify whether the **E** field experiences amplitude reduction.

(2 marks)

-END OF QUESTIONS-

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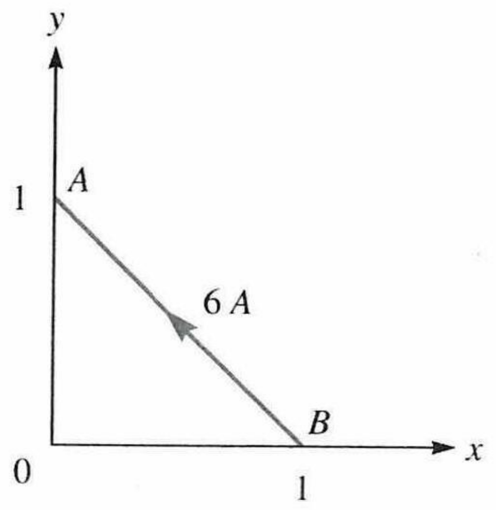

FIGURE Q2(a)

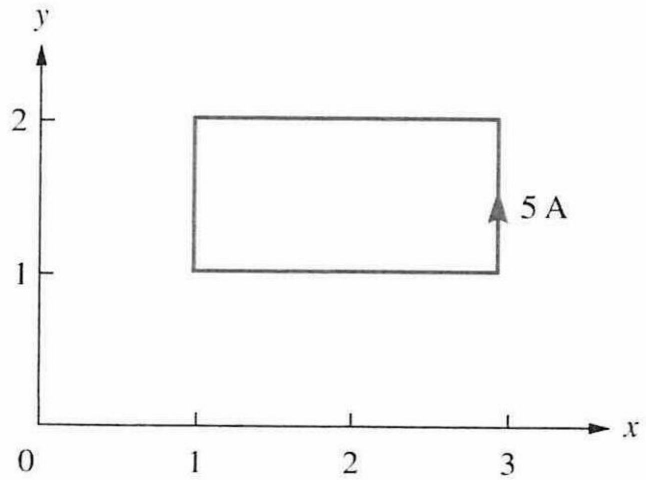

FIGURE Q2(b)

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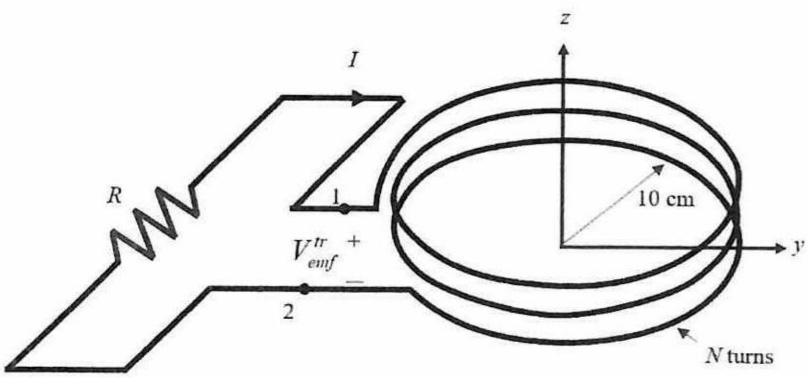

FIGURE Q3

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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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$$Q=\int \rho_\ell d\ell,$$
$$Q=\int \rho_s dS,$$
$$Q=\int \rho_v dv$$
$$\overline{F}_{12}=\frac{Q_1 Q_2}{4\pi\varepsilon_0 R^2}\hat{a}_{R_{12}}$$
$$\overline{E}=\frac{\overline{F}}{Q},$$
$$\overline{E}=\frac{Q}{4\pi\varepsilon_0 R^2}\hat{a}_R$$
$$\overline{E}=\int\frac{\rho_\ell d\ell}{4\pi\varepsilon_0 R^2}\hat{a}_R$$
$$\overline{E}=\int\frac{\rho_s dS}{4\pi\varepsilon_0 R^2}\hat{a}_R$$
$$\overline{E}=\int\frac{\rho_v dv}{4\pi\varepsilon_0 R^2}\hat{a}_R$$
$$\overline{D}=\varepsilon\overline{E}$$
$$\psi_e=\int\overline{D}\bullet d\overline{S}$$
$$Q_{enc}=\oint_S\overline{D}\bullet d\overline{S}$$
$$\rho_v=\nabla\bullet\overline{D}$$
$$V_{AB}=-\int_A^B\overline{E}\bullet d\overline{\ell}=\frac{W}{Q}$$
$$V=\frac{Q}{4\pi\varepsilon r}$$
$$V=\int\frac{\rho_\ell d\ell}{4\pi\varepsilon r}$$
$$\oint\overline{E}\bullet d\overline{\ell}=0$$
$$\nabla\times\overline{E}=0$$
$$\overline{E}=-\nabla V$$
$$\nabla^2 V=0$$
$$R=\frac{\ell}{\sigma S}$$
$$I=\int\overline{J}\bullet dS$$

$$d\overline{H}=\frac{Id\overline{\ell}\times\overline{R}}{4\pi R^3}$$
$$Id\overline{\ell}\equiv\overline{J}_s dS\equiv\overline{J}dv$$
$$\oint\overline{H}\bullet d\overline{\ell}=I_{enc}=\int\overline{J}_s dS$$
$$\nabla\times\overline{H}=\overline{J}$$
$$\psi_m=\int_s\overline{B}\bullet d\overline{S}$$
$$\psi_m=\oint\overline{B}\bullet d\overline{S}=0$$
$$\psi_m=\oint\overline{A}\bullet d\overline{\ell}$$
$$\nabla\bullet\overline{B}=0$$
$$\overline{B}=\mu\overline{H}$$
$$\overline{B}=\nabla\times\overline{A}$$
$$\overline{A}=\int\frac{\mu_0 Id\overline{\ell}}{4\pi R}$$
$$\nabla^2\overline{A}=-\mu_0\overline{J}$$
$$\overline{F}=Q\left(\overline{E}+\overline{u}\times\overline{B}\right)=m\frac{d\overline{u}}{dt}$$
$$d\overline{F}=Id\overline{\ell}\times\overline{B}$$
$$\overline{T}=\overline{r}\times\overline{F}=\overline{m}\times\overline{B}$$
$$\overline{m}=IS\hat{a}_n$$
$$V_{emf}=-\frac{\partial\psi}{\partial t}$$
$$V_{emf}=-\int\frac{\partial\overline{B}}{\partial t}\bullet d\overline{S}$$
$$V_{emf}=\int\left(\overline{u}\times\overline{B}\right)\bullet d\overline{\ell}$$
$$I_d=\int J_d.d\overline{S},J_d=\frac{\partial\overline{D}}{\partial t}$$
$$\gamma=\alpha+j\beta$$
$$\alpha=\omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left[\frac{\sigma}{\omega\varepsilon}\right]^2}-1\right]}$$
$$\beta=\omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left[\frac{\sigma}{\omega\varepsilon}\right]^2}+1\right]}$$

$$\overline{F}_1=\frac{\mu I_1 I_2}{4\pi}\oint_{L1}\oint_{L2}\frac{d\overline{\ell}_1\times\left(d\overline{\ell}_2\times\hat{a}_{R_{21}}\right)}{R_{21}{}^2}$$
$$|\eta|=\frac{\sqrt{\mu/\varepsilon}}{\left[1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2\right]^{\frac{1}{4}}}$$
$$tan\,2\theta_\eta=\frac{\sigma}{\omega\varepsilon}$$
$$tan\,\theta=\frac{\sigma}{\omega\varepsilon}=\frac{\overline{J}_s}{\overline{J}_{ds}}$$
$$\delta=\frac{1}{\alpha}$$
$$\varepsilon_0=8.854\times10^{-12}\ \text{Fm}^{-1}$$
$$\mu_0=4\pi\times10^{-7}\ \text{Hm}^{-1}$$

$$\int\frac{dx}{\left(x^2+c^2\right)^{3/2}}=\frac{x}{c^2\left(x^2+c^2\right)^{1/2}}$$
$$\int\frac{xdx}{\left(x^2+c^2\right)^{3/2}}=\frac{-1}{\left(x^2+c^2\right)^{1/2}}$$
$$\int\frac{dx}{\left(x^2\pm c^2\right)^{1/2}}=ln\left(x+\sqrt{x^2\pm c^2}\right)$$
$$\int\frac{dx}{\left(x^2+c^2\right)}=\frac{1}{c}tan^{-1}\left(\frac{x}{c}\right)$$
$$\int\frac{xdx}{\left(x^2+c^2\right)}=\frac{1}{2}ln\left(x^2+c^2\right)$$
$$\int\frac{xdx}{\left(x^2+c^2\right)^{1/2}}=\sqrt{x^2+c^2}$$