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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2017/2018

COURSE NAME	:	ELECTROMAGNETIC FIELDS AND WAVES
COURSE CODE	:	BEB 20303
PROGRAMME	:	BEV / BEJ
EXAMINATION DATE	:	JUNE / JULY 2018
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER ALL QUESTIONS

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

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Q1 (a) Define the meaning of the following terms

(i) Capacitance

(ii) Absolute permittivity

(4 marks)

(b) Calculate the charge stored by a parallel plate capacitor whose 0.01 m^2 plates are 0.1 mm apart if the capacitor voltage is 12 V and $\varepsilon_r = 3$.

(9 marks)

(c) A capacitor is made with seven metal plates and separated by sheets of mica having a thickness of 0.3 mm and a relative permittivity, ε_r of 6. The area of one side of each plate is 500 cm^2. A potential difference of 400 V is maintained across the terminals of the capacitor. Calculate:

(i) The capacitance, C

(ii) The charge, Q

(iii) The electric field strength, E

(iv) The electric flux density in the dielectric, D

(12 marks)

Q2 (a) A wire of length 50 cm and mass 10 g is suspended in a horizontal plane by a pair of flexible leads as shown **Figure Q2 (a)**. The wire is then subjected to a constant magnetic field of magnitude, 0.50 T, which is directed as shown. Determine the magnitude of the current in the wire needed in order to remove the tension in the supporting leads.

(4 marks)

(b) A current sheet with $\boldsymbol{K} = 10\ \hat{x}\ A/m$ lies in free space in $z = 2\ m$ plane. A filamentary conductor on the x-axis carries a current of 2.5 A in the positive x- direction. Determine the force per unit length on the conductor.

(11 marks)

(c) A long coaxial cable consists of a hollow cylindrical conductor has an inner radius, a of 2 m and an outer radius, b of 4 m and carries current, I of 10 A along the positive z-direction.

(i) Find **H** everywhere.

(ii) Sketch the magnitude of **II**.

(10 marks)

Q3 (a) Faraday's Law governs the condition where a generator converts mechanical motion to an electrical potential in the presence of electromagnetic field. As illustrated in **Figure Q3 (a)**, a conductive loop is turned in the presence of the magnetic field from a permanent magnet. The loop rotates with an angular velocity ω radians per second.

(i) Explain mathematically why side a, and c are not contributing to the total V_{emf}, thus can be ignored.

(5 marks)

(ii) With an appropriate diagram, discuss the waveform generated by this particular generator whether it is producing AC or DC electrical potential.

(4 marks)

(iii) Based on Q3 (a)(ii), state which part of the generator in **Figure Q3 (a)** that determine this.

(1 mark)

(iv) Calculate the total V_{emf} generated when the loop is turning.

(5 marks)

(b) The left-hand side of the Maxwell equation below is similar, but not on the right-hand side.

$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$$

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

Justify your answer by the aid of diagrams.

(10 marks)

Q4 (a) Skin depth is a measure of the depth at which an EM wave can penetrate any medium or conductor. As shown in **Figure Q4 (a)**, it refers to the distance, δ in which the wave amplitude decreases by a factor e^{-1} or 0.368 (about 37%). According to the skin depths information of several types of materials at various frequencies as tabulated in **Table Q4 (a)**, state your observations, and then, conclude your findings.

(5 marks)

(b) A manufacturer produces a ferrite material with $\mu = 750\ \mu_o$, $\varepsilon = 5\varepsilon_o$ and $\sigma = 10^{-6}$ S/m at 10 MHz. Identify the type of material based on the characteristic given, lossless, lossy or conducting?

(4 marks)

(c) A plane wave propagating through a medium with $\varepsilon_r = 8$, $\mu_r = 2$ has $\boldsymbol{E} = 0.5e^{-z/3}\sin(10^8 t - \beta z)\hat{x}$ V/m. Determine,

(i) Phase constant, β

(2 marks)

(ii) The loss tangent, $\dfrac{\sigma}{\omega\varepsilon}$

(5 marks)

(iii) Intrinsic impedance, η

(4 marks)

(iii) Wave velocity, u

(2 marks)

(iv) Magnetic field, $\boldsymbol{H}$

(3 marks)

– END OF QUESTIONS –

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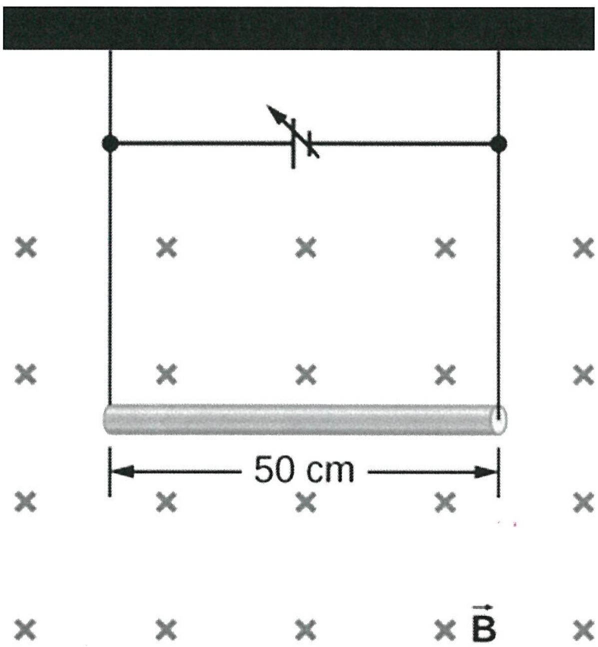

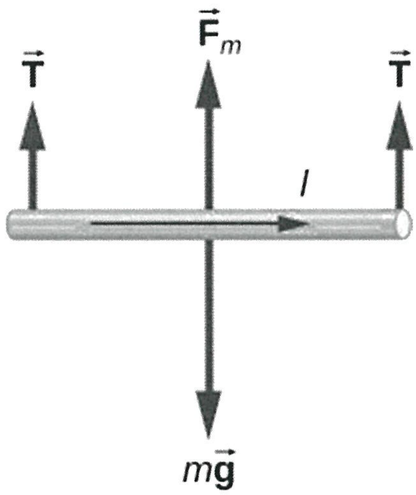

(i) (ii)

Figure Q2 (a): (i) A wire suspended in a magnetic field. (ii) The free-body diagram for the wire.

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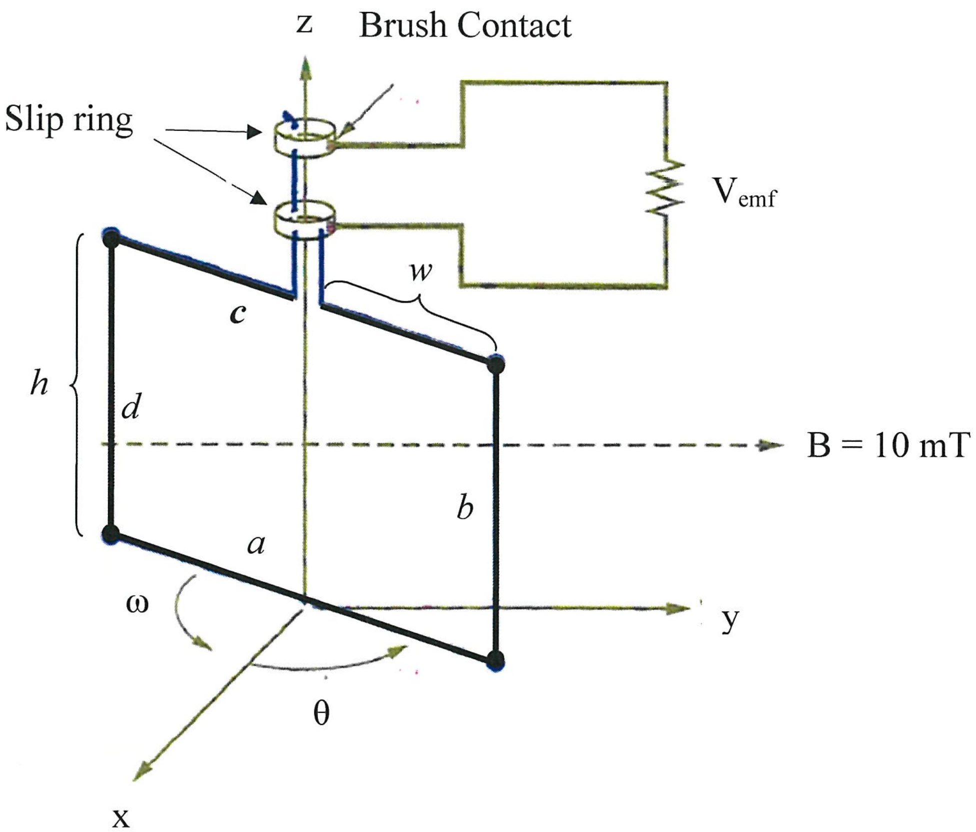

$h = 10$ cm

$w = 10$ cm

FIGURE Q3 (a)

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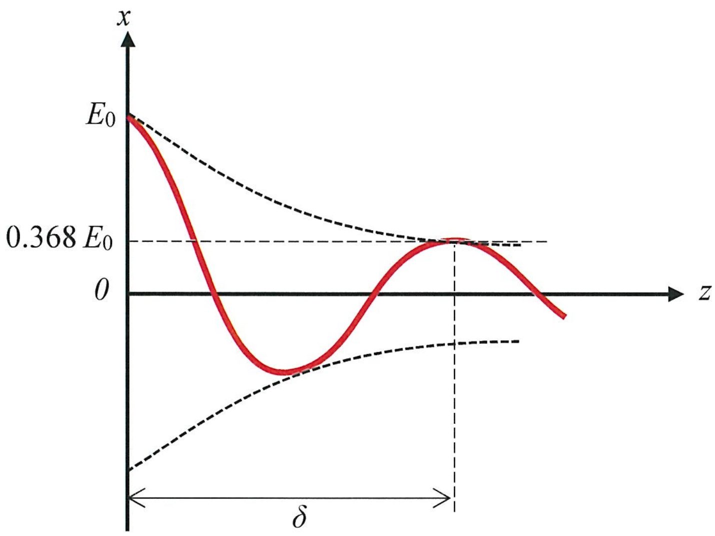

Figure Q4 (a) Illustration of skin depth

Table Q4 (a) Skin depths, δ in (mm) of various materials

Material	σ (S/m)	Frequency		
		60 Hz	1 MHz	1 GHz
Silver	6.17×10^7	8.27 mm	0.064 mm	0.0020 mm
Copper	5.80×10^7	8.53 mm	0.066 mm	0.0021 mm
Gold	4.10×10^7	10.14 mm	0.079 mm	0.0025 mm
Aluminum	3.54×10^7	10.92 mm	0.084 mm	0.0027 mm

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FORMULA

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

$Q = \int \rho_s dS,$

$Q = \int \rho_v dv$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\nabla^2 V = 0$

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

$I = \int J \bullet dS$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\gamma = \alpha + j\beta$

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

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

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

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

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

$\tan\theta = \dfrac{\sigma}{\omega\varepsilon} = \dfrac{J_s}{J_{ds}}$

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

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

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

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

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

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

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

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

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

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FORMULA

Transformation	Coordinate Variables	Unit Vectors	Vector Components
Cartesian to Cylindrical	$r=\sqrt{x^2+y^2}$ $\phi=\tan^{-1}(y/x)$ $z-z$	$\hat{\mathbf{r}}=\hat{\mathbf{x}}\cos\phi+\hat{\mathbf{y}}\sin\phi$ $\hat{\boldsymbol{\varphi}}=-\hat{\mathbf{x}}\sin\phi+\hat{\mathbf{y}}\cos\phi$ $\hat{\mathbf{z}}=\hat{\mathbf{z}}$	$A_r=A_x\cos\phi+A_y\sin\phi$ $A_\phi=-A_x\sin\phi+A_y\cos\phi$ $A_z=A_z$
Cylindrical to Cartesian	$x=r\cos\phi$ $y=r\sin\phi$ $z=z$	$\hat{\mathbf{x}}=\hat{\mathbf{r}}\cos\phi-\hat{\boldsymbol{\varphi}}\sin\phi$ $\hat{\mathbf{y}}=\hat{\mathbf{r}}\sin\phi+\hat{\boldsymbol{\varphi}}\cos\phi$ $\hat{\mathbf{z}}=\hat{\mathbf{z}}$	$A_x=A_r\cos\phi-A_\phi\sin\phi$ $A_y=A_r\sin\phi+A_\phi\cos\phi$ $A_z=A_z$
Cartesian to Spherical	$R-\sqrt{x^2+y^2+z^2}$ $\theta=\tan^{-1}(\sqrt{x^2+y^2}/z)$ $\phi=\tan^{-1}(y/x)$	$\hat{\mathbf{R}}=\hat{\mathbf{x}}\sin\theta\cos\phi$ $+\hat{\mathbf{y}}\sin\theta\sin\phi+\hat{\mathbf{z}}\cos\theta$ $\hat{\boldsymbol{\theta}}=\hat{\mathbf{x}}\cos\theta\cos\phi$ $+\hat{\mathbf{y}}\cos\theta\sin\phi-\hat{\mathbf{z}}\sin\theta$ $\hat{\boldsymbol{\varphi}}=-\hat{\mathbf{x}}\sin\phi+\hat{\mathbf{y}}\cos\phi$	$A_R=A_x\sin\theta\cos\phi$ $+A_y\sin\theta\sin\phi+A_z\cos$ $A_\theta=A_x\cos\theta\cos\phi$ $+A_y\cos\theta\sin\phi-A_z\sin$ $A_\phi=-A_x\sin\phi+A_y\cos\phi$
Spherical to Cartesian	$x=R\sin\theta\cos\phi$ $y=R\sin\theta\sin\phi$ $z=R\cos\theta$	$\hat{\mathbf{x}}=\hat{\mathbf{R}}\sin\theta\cos\phi+$ $\hat{\boldsymbol{\theta}}\cos\theta\cos\phi-\hat{\boldsymbol{\varphi}}\sin\phi$ $\hat{\mathbf{y}}=\hat{\mathbf{R}}\sin\theta\sin\phi+$ $\hat{\boldsymbol{\theta}}\cos\theta\sin\phi+\hat{\boldsymbol{\varphi}}\cos\phi$ $\hat{\mathbf{z}}=\hat{\mathbf{R}}\cos\theta-\hat{\boldsymbol{\theta}}\sin\theta$	$A_x=A_R\sin\theta\cos\phi$ $+A_\theta\cos\theta\cos\phi-A_\phi\sin$ $A_y=A_R\sin\theta\sin\phi$ $+A_\theta\cos\theta\sin\phi+A_\phi\cos$ $A_z=A_R\cos\theta-A_\theta\sin\theta$
Cylindrical to Spherical	$R=\sqrt{r^2+z^2}$ $\theta=\tan^{-1}(r/z)$ $\phi=\phi$	$\hat{\mathbf{R}}=\hat{\mathbf{r}}\sin\theta+\hat{\mathbf{z}}\cos\theta$ $\hat{\boldsymbol{\theta}}=\hat{\mathbf{r}}\cos\theta-\hat{\mathbf{z}}\sin\theta$ $\hat{\boldsymbol{\varphi}}=\hat{\boldsymbol{\varphi}}$	$A_R=A_r\sin\theta+A_z\cos\theta$ $A_\theta=A_r\cos\theta-A_z\sin\theta$ $A_\phi=A_\phi$
Spherical to Cylindrical	$r=R\sin\theta$ $\phi=\phi$ $z=R\cos\theta$	$\hat{\mathbf{r}}=\hat{\mathbf{R}}\sin\theta+\hat{\boldsymbol{\theta}}\cos\theta$ $\hat{\boldsymbol{\varphi}}=\hat{\boldsymbol{\varphi}}$ $\hat{\mathbf{z}}=\hat{\mathbf{R}}\cos\theta-\hat{\boldsymbol{\theta}}\sin\theta$	$A_r=A_R\sin\theta+A_\theta\cos\theta$ $A_\phi=A_\phi$ $A_z=A_R\cos\theta-A_\theta\sin\theta$