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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	ELECTROMAGNETIC FIELDS & WAVES
COURSE CODE	:	BEB20303
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	DECEMBER 2019/JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS

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

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Q1 (a) **Figure Q1 (a)** shows a dielectric spherical shell with inner radius, $a = 2$ m and outer radius $b = 4$ m carries the volume charge density $\rho_v = 2$ nC/m^3. The centre of the dielectric spherical shell is located at $(2, 4, -6)$. In addition, a point charge with $Q_1 = 10\mu$C is located at the center of the spherical shell and an infinite long wire is located along the z-axis with line charge density $\rho_l = 12$ nC/m.

(i) Derive the electric field, ***E*** formula for infinitely long wire using a Gauss's Law

(6 marks)

(ii) Derive the ***E*** Field formula for spherical shell with a point charge at the center of the shell as shown in **Figure Q1(c)** for R > b using a Gauss's Law

(8 marks)

(iii) Calculate the total electric field, ***E*** at coordinate (0, -6, 4).

(5 marks)

(b) Given two dielectrics with relative permittivity (ε_{r1}) for $k_1 = 2.5$ and relative permittivity (ε_{r2}) for $k_2 = 1.7$ each fill half the space between the plates of a parallel-plate capacitor as shown in **Figure Q1 (b)**. Each plate has an area, $A = 0.04$ m^2 and the plates are separated by a distance, $d = 0.01$m. Calculate the capacitance of the system.

(6 marks)

Q2 (a) Consider an infinite sheet located at z = 0 with current density of ***K*** A/m as shown in **Figure Q2 (a).**

(i) Identify the magnitude and direction of the current density, ***K***.

(3 mark)

(ii) Explain the generation of magnetic field intensity, ***H*** above and below the infinite sheet with an aid of diagram.

(7 marks)

(b) Consider an infinitely long transmission line consisting of two concentric cylinders having their axes along the x-axis. The inner conductor has radius $a = 3$ cm and carries current $I = 2$ A while the outer conductor has inner radius $b = 5$ cm with thickness $t = 0.4$ cm and carries return current $I = -2$ A.

(i) Determine $\vec{H}$ in the inner conductor.

(5 marks)

(ii) Determine $\vec{H}$ between the conductors.

(7 marks)

(iii) Determine $\vec{H}$ outside the transmission line.

(3 marks)

Q3 (a) Briefly explain 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

(7 marks)

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

(9 marks)

(a) A 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) near the transmission line as shown in **Figure Q3(a)(i).** The victim 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(a)(ii)** and can be represented as a complete equivalent circuit as shown in **Figure Q3(a)(iii).**

(i) Determine the total induce voltage (V_{emf}) on the victim cable if the magnetic field (H-field) produce at the intended location is 0.99 μT using a Faraday's law.

(5 marks)

Q4 (a) Distinguish the propagation of electromagnetic wave in a lossless medium, low loss medium and free space.

(5 marks)

(b) Determine the average power density of an electric field incident on a copper slab such that the field in the slab is given by;

$$\vec{E}(z,t) = 1.0e^{-\alpha z} \cos(2\pi \times 10^7 t - \beta z)\hat{x} \ \text{V/m}$$

(10 marks)

(c) A uniform plane wave propagates in a perfect dielectric (dielectric medium without losses) at $+z$ direction. Electric field is given as;

$$\vec{E}(z,t) = 377\cos\left[\omega t - \left(\frac{4\pi}{3}\right)z + \frac{\pi}{6}\right]\hat{x}\ \text{V/m}$$

If, the average power density is $377\ \text{W/m}^2$.

(i) Determine the dielectric constant (ε_r) value for the medium if $\mu = \mu_o$.

(ii) Determine wave frequency, β

(iii) Determine equation magnetic field intensity, ***H(z, =t).***

(10 marks)

-END OF QUESTIONS –

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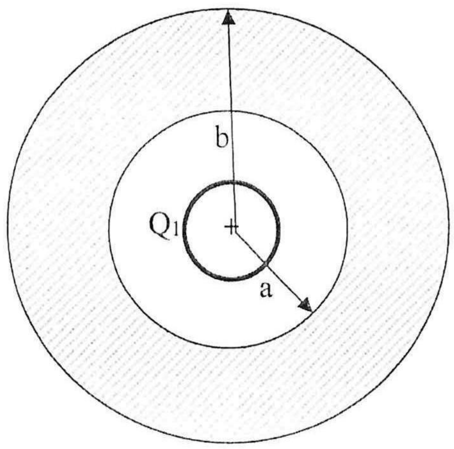

Figure Q1 (a): Spherical shell with inner radius a and outer radius b and Q_1 at the center of the shell

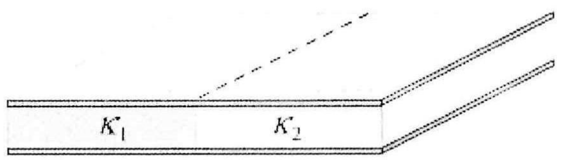

Figure Q1 (b): Capacitor filled with two different dielectrics.

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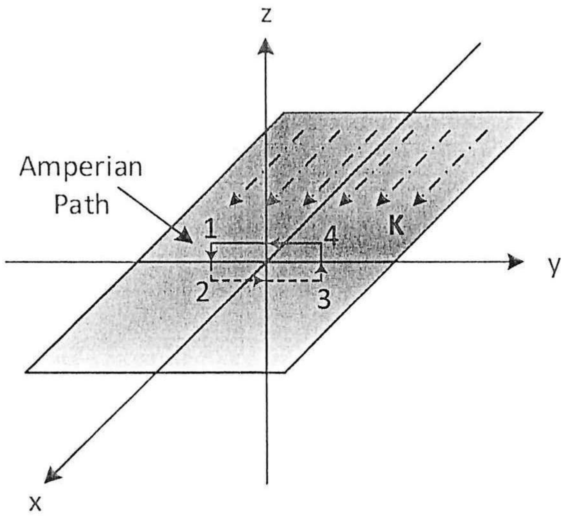

Figure Q2 (a): Infinite Sheet of current

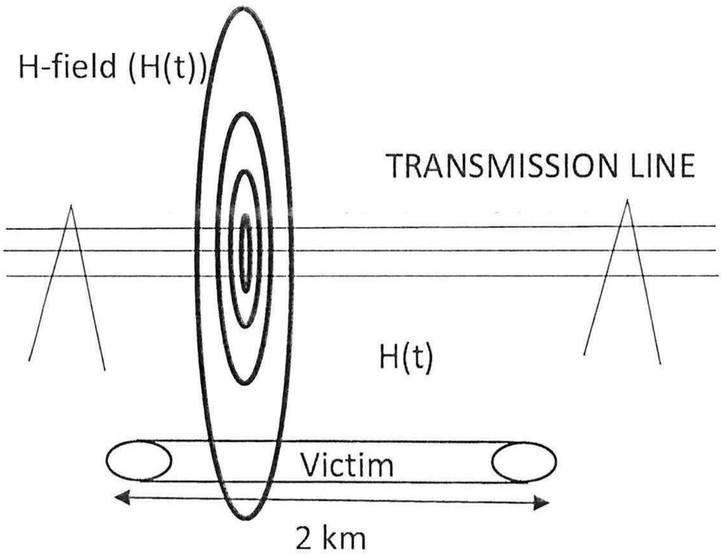

Figure Q3(a)(i): Power Transmission line produce strong magnetic field (H(t)) and induced V_{emf} to the adjacent cable.

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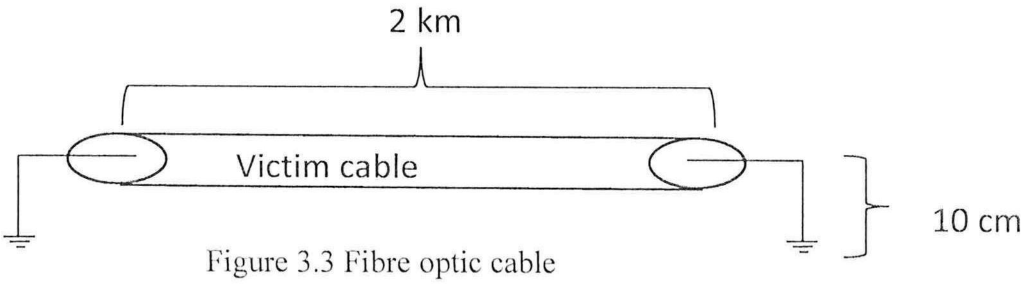

Figure Q3(a)(ii): Victim Cable parameters.

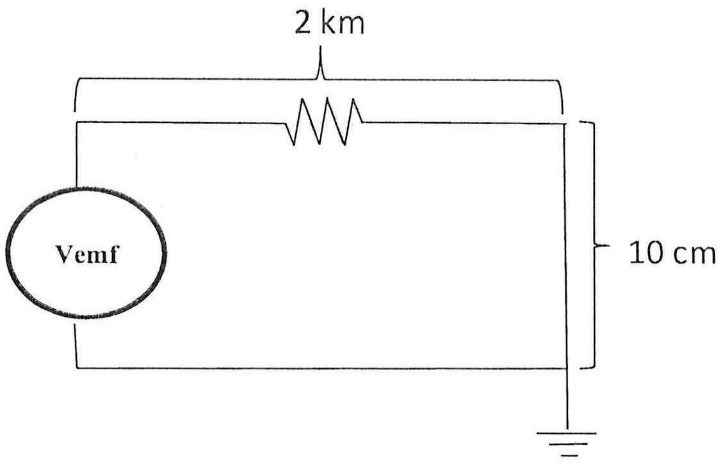

Figure Q3(a)(iii): Equivalent circuit for a victim cable

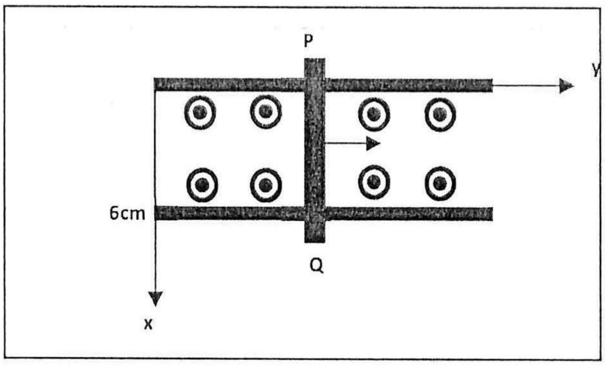

Figure Q3(b): A conducting bar

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

$Q = \int \rho_s dS,$

$Q = \int \rho_v dv$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\nabla^2 V = 0$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\gamma = \alpha + j\beta$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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