UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	ELECTROMAGNETIC FIELDS AND WAVES
COURSE CODE	:	BEB 20303
PROGRAMME	:	BEV / BEJ
EXAMINATION DATE	:	DECEMBER 2018 / JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER ALL QUESTIONS

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 (a) State the Faraday's Law.

(3 marks)

(b) An inductor is formed by winding, N = 10 turns of a thin conducting wire into a square loop centered at the origin. It has 20 cm sides oriented parallel to the x and y axes and are shown in **Figure Q1 (b)**. The winding is connected to a resistor R. In the presence of a magnetic field given by $\vec{B} = B_o x^2 \cos 10^3 t\, \hat{z}$ and $B_0 = 100$ T, find the current in the circuit.

(10 marks)

(c) Determine the voltages V_1 and V_2 across the 2 Ω and 4 Ω resistors as shown in **Figure Q1(c)**. The loop is located in the x – y plane, its area is 4 m^2, the magnetic flux density is $\boldsymbol{B} = -0.3t\hat{z}$ (T), and the internal resistance of the wire may be ignored.

(12 marks)

Q2 (a) A spherical shell centered at the origin extends between $R = 2\ cm$ and $R = 3\ cm$. If the volume charge density is given by $\rho_v = 6R \times 10^{-4} (C/m^3)$, find the total charge contained in the shell.

(5 marks)

(b) Determine the capacitance for the following configuration shown in **Figure Q2(b)**.

(10 marks)

(c) A coaxial capacitor consists of two concentric, conducting, cylindrical surfaces. One of the radius is a and another radius is b, as shown in the **Figure Q2(c)**. The insulating layer separating the two conducting surfaces is divided equally into two semi-cylindrical sections, one filled with dielectric ε_1 and the other filled with dielectric ε_2.

(i) Develop an expression for capacitance, C in terms of the length and the given quantities.

(ii) Evaluate the value of capacitance, C for a = 2 mm, b = 6 mm, $\varepsilon_{r1} = 2$, $\varepsilon_{r2} = 4$ and l = 4 cm.

(10 marks)

Q3 (a) States the difference between Ampere's law and Biot Savart's law.

(5 marks)

(b) A communication engineer decided to use a coaxial cable as the transmission line for a mission critical communication link. The coaxial cable has an inner radius a and an outer conductor has inner radius b with thickness t. If we assume that the current $+I$ is travelling along the positive z-direction and is uniformly distributed in both conductors,

(i) provide **ONE (1)** reason why a coaxial cable is chosen,

(3 marks)

(ii) calculate **H** everywhere,

(10 marks)

(iii) sketch a graph depicting the relationship between the magnitude of **H** and the radial distance from the center or the coaxial cable, and

(5 marks)

(iv) if a conductor carrying a current is brought near to the coaxial cable, explain what will happen to the conductor and explain why.

(2 marks)

Q4 Currently, airline passengers will be able to use certain electronic devices throughout their entire flight. Consequently, some parts of an aircraft require some lossy material to absorb some electromagnetic fields generated by certain electronic devices.

(a) Explain the term lossy material in terms of its conductivity, permittivity and permeability.

(5 marks)

(b) A certain mobile phone produces a plane wave propagating through the lossy material, at a particular radian frequency ω with the **H** component of

$$5e^{-\alpha x}\cos\left(\omega t - \tfrac{1}{4}x\right) a_y \ (A/m),$$

(i) Solve **E** if the lossy dielectric of his choice has an intrinsic impedance of $100\, e^{j\pi/6}$ at that particular radian frequency.

(6 marks)

(ii) Explain the term 'skin depth of a material'. Calculate α and then the minimum depth of this material for it to be effective.

(5 marks)

(iii) Define and calculate the lost tangent of the material.

(5 marks)

(iv) Based on the calculated skin depth and loss tangent in Q4 b (ii) and Q4 b (iii) respectively, analyse if the material can be used in an airplane realistically.

(4 marks)

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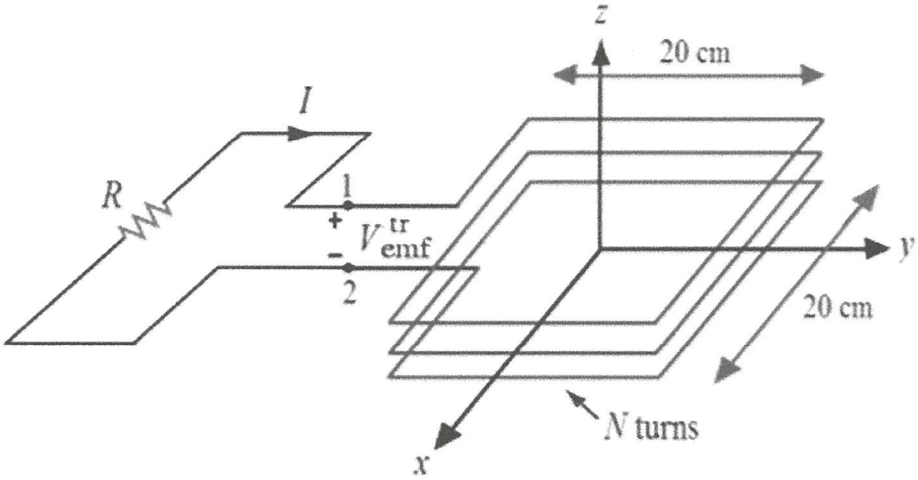

FIGURE Q1 (b)

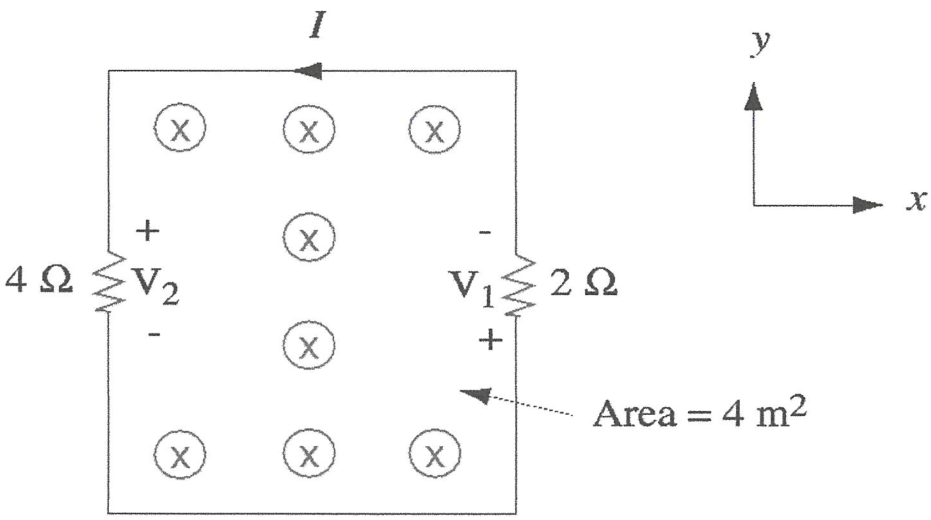

FIGURE Q1(c)

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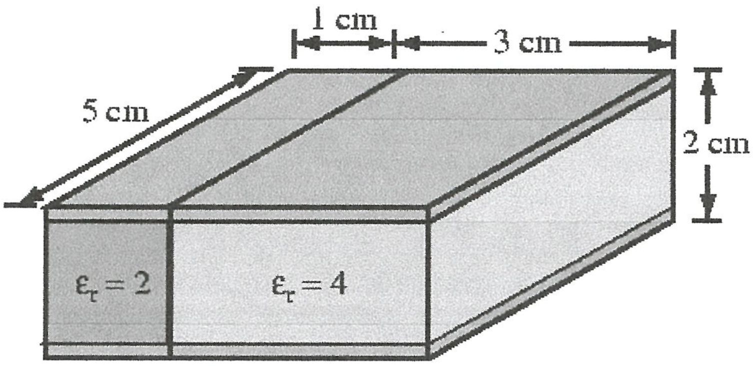

FIGURE Q2 (b)

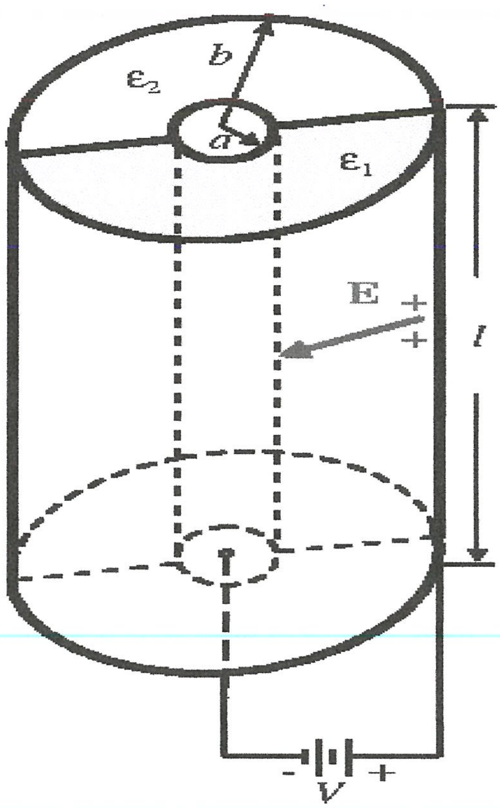

FIGURE Q2 (c)

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FORMULA

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

$Q = \int \rho_s dS,$

$Q = \int \rho_v dv$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\nabla^2 V = 0$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\gamma = \alpha + j\beta$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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FORMULA

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