



**KOLEJ UNIVERSITI TEKNOLOGI
TUN HUSSEIN ONN**

**PEPERIKSAAN AKHIR
SEMESTER I
SESI 2006/2007**

NAMA MATA PELAJARAN : MEDAN DAN GELOMBANG
ELEKTROMAGNET

KOD MATA PELAJARAN : BEE 2263

KURSUS : 2BET / 3BET / 3BER / 3BEM / 3BEP
/ 3BEI / 3BEK

TARIKH PEPERIKSAAN : NOVEMBER 2006

JANGKA MASA : 3 JAM

ARAHAN : JAWAB SEMUA SOALAN
BAHAGIAN A, DAN **TIGA (3)**
SOALAN DI BAHAGIAN B.

KERTAS SOALAN INI MENGANDUNGI 12 MUKA SURAT

SOALAN DALAM BAHASA MELAYU

BAHAGIAN A

S1 Satu gelombang satah merambat melalui medium dengan $\epsilon_r = 8$ dan $\mu_r = 2$ mempunyai $\vec{E} = 0.5e^{-z/3} \sin(10^8 t - \beta z) \hat{x}$ V/m. Tentukan:

- (a) Pemalar fasa, β (7 markah)
- (b) Tangen kehilangan (2 markah)
- (c) Galangan gelombang (3 markah)
- (d) Halaju gelombang (2 markah)
- (e) Medan magnet, \vec{H} (6 markah)

S2 Nisbah ketumpatan arus pengaliran kepada ketumpatan arus anjakan, J/J_d adalah penting dalam analisis frekuensi tinggi.

- (a) Kirakan nisbah tersebut pada frekuensi 1 GHz untuk:
- (i) Air biasa ($\mu = \mu_0$, $\epsilon = 81\epsilon_0$, $\sigma = 2 \times 10^{-3}$ S/m) (5 markah)
- (ii) Air laut ($\mu = \mu_0$, $\epsilon = 81\epsilon_0$, $\sigma = 25$ S/m) (5 markah)
- (b) Kirakan frekuensi pada ketumpatan arus pengaliran adalah 10 kali ganda ketumpatan arus anjakan untuk air biasa dan air laut. (10 markah)

BAHAGIAN B

- S3** Diberi beza upaya $V = \frac{10}{r^2} \sin \theta \cos \phi$:
- (a) Dapatkan keamatan medan elektrik, \bar{E} (5 markah)
- (b) Apakah daya, \bar{F} yang terhasil ke atas cas $10\mu\text{C}$ (3 markah)
- (c) Dapatkan ketumpatan fluk elektrik \bar{D} pada titik $(2, \pi/2, 0)$ (3 markah)
- (d) Kirakan kerja yang dilakukan untuk menggerakkan $10\mu\text{C}$ cas dari titik $A(1, 30^\circ, 120^\circ)$ ke $B(4, 90^\circ, 60^\circ)$ (9 markah)
- S4** Satu kepingan kaca selari ($\epsilon_r = 8.5$) yang diletakkan secara menegak untuk memisahkan minyak ($\epsilon_r = 3.0$) dan udara seperti yang ditunjukkan dalam Rajah S4. Medan elektrik seragam sekuaat 2000 V/m dipancarkan secara mendatar dari kawasan minyak. Kirakan arah dan magnitud medan elektrik di dalam kaca dan di dalam ruangan udara bila:
- (a) Medan tersebut normal dengan permukaan kaca, dan (10 markah)
- (b) Medan di dalam minyak membentuk sudut 75° dengan permukaan kaca. (10 markah)
- S5** (a) Dalam suatu kawasan tertentu bagi pengalir
- $$\bar{H} = \hat{x}(x^2 + y^2)yz + \hat{y}(zxy^2) - \hat{z}(4x^2y^2) \text{ A/m}$$
- (i) Tentukan ketumpatan arus, \bar{J} pada titik $(5, 2, -3)$ (7 markah)
- (ii) Dapatkan arus, I yang mengalir melalui $x = -1, 0 < y, z < 2$ (4 markah)
- (iii) Buktikan $\nabla \cdot \bar{B} = 0$ (3 markah)

- (b) Satu pengalir yang berongga mempunyai jejari dalaman, a dan jejari luaran, b serta mengalirkan arus, I sepanjang arah positif z . Dapatkan:
- (i) Medan magnet, \vec{H} pada $r < a$ (1 markah)
 - (ii) Medan magnet, \vec{H} pada $0 < r < b$ (3 markah)
 - (iii) Medan magnet, \vec{H} pada $b > r$ (2 markah)
- S6** (a) (i) Terangkan **TIGA (3)** perbezaan utama di antara daya elektrik dan daya magnet. (3 markah)
- (ii) Dengan bantuan gambarajah, jelaskan dengan terperinci perkaitan antara daya, \vec{F} , daya kilas, \vec{T} , arus, I dan ketumpatan fluk magnet, \vec{B} . (7 markah)
- (b) Dapatkan jumlah daya, \vec{F} yang dihasilkan oleh gelung segiempat tepat yang terletak pada satah $z=0$ seperti yang ditunjukkan pada Rajah S6 jika $\vec{B} = 6x\hat{x} - 9y\hat{y} + 3z\hat{z}$ (10 markah)
- S7** (a) Takrifkan hukum Coulomb untuk daya, \vec{F} dan keamatan medan elektrik, \vec{E} bagi cas titik. (4 markah)
- (b) Satu cas permukaan $0 \leq x \leq 1$ m, $0 \leq y \leq 1$ m terletak pada satah $z = 0$ mempunyai ketumpatan cas permukaan $xy(x^2 + y^2 + 36)^{3/2}$ nC/m².
- (i) Kirakan keamatan medan elektrik pada titik $P(x, y, z) = (0, 0, 6$ m). (9 markah)
 - (ii) Tentukan daya yang dirasakan oleh cas titik 4 nC yang berada pada (0, 0, 6 m). (3 markah)
- (c) Tuliskan persamaan-persamaan Maxwell yang berkaitan dengan medan elektrostatik. (4 markah)

SOALAN DALAM BAHASA INGGERIS

PART A

Q1 A plane wave propagating through a medium with $\epsilon_r = 8$ and $\mu_r = 2$ has $\vec{E} = 0.5e^{-z/3} \sin(10^8 t - \beta z) \hat{x}$ V/m. Determine:

- (a) Phase constant, β (7 marks)
- (b) The loss tangent (2 marks)
- (c) Wave impedance (3 marks)
- (d) Wave velocity (2 marks)
- (e) Magnetic field, \vec{H} (6 marks)

Q2 The ratio conduction current density to displacement current density J/J_d is very important at high frequencies analysis.

- (a) Calculate the ratio at 1 GHz for:
- (i) Water ($\mu = \mu_0$, $\epsilon = 81\epsilon_0$, $\sigma = 2 \times 10^{-3}$ S/m) (5 marks)
- (ii) Sea water ($\mu = \mu_0$, $\epsilon = 81\epsilon_0$, $\sigma = 25$ S/m) (5 marks)
- (b) Determine the frequency at which the conduction current density is 10 times the displacement current density in magnitude for both water and sea water. (10 marks)

PART B

- Q3** Given the potential $V = \frac{10}{r^2} \sin \theta \cos \phi$:
- (a) Find electric field intensity, \bar{E} (5 marks)
- (b) What is the force, \bar{F} on $10 \mu\text{C}$ charge (3 marks)
- (c) Find electric flux density, \bar{D} at point $(2, \pi/2, 0)$ (3 marks)
- (d) Calculate the work done in moving a $10 \mu\text{C}$ charge from point $A(1, 30^\circ, 120^\circ)$ to $B(4, 90^\circ, 60^\circ)$ (9 marks)
- Q4** A parallel sheet of glass ($\epsilon_r = 8.5$) mounted vertically to separate oil ($\epsilon_r = 3.0$) and air as shown in Figure Q4. A uniform electric field of strength 2000 V/m in the horizontal direction exists in the oil. Calculate the magnitude and direction of the electric field in the glass and in the air when:
- (a) The field is normal to the glass surfaces, and (10 marks)
- (b) The field in the oil makes an angle of 75° with a normal to the glass surfaces. (10 marks)
- Q5** (a) In a certain region of conducting
- $$\bar{H} = \hat{x}(x^2 + y^2)yz + \hat{y}(zxy^2) - \hat{z}(4x^2y^2) \text{ A/m}$$
- (i) Determine current density, \bar{J} at point $(5, 2, -3)$ (7 marks)
- (ii) Find the current, I passing through $x = -1, 0 < y, z < 2$ (4 marks)
- (iii) Proof $\nabla \cdot \bar{B} = 0$ (3 marks)

- (b) A hollow conductor has inner radius, a and outer radius and carries current, I along the positive z -direction. Find:
- (i) Magnetic field, \vec{H} at $r < a$ (1 marks)
 - (ii) Magnetic field, \vec{H} at $0 < r < b$ (3 marks)
 - (iii) Magnetic field, \vec{H} at $b > r$ (2 marks)
- Q6** (a) (i) Describe **THREE (3)** main differences between the electric force and magnetic force. (3 marks)
- (ii) With the aid of diagram, clarify the relationships between force, \vec{F} , torque, \vec{T} , current, I and magnetic flux density, \vec{B} . (7 marks)
- (b) Find the total force, \vec{F} , experienced by the rectangular loop located on plane $z=0$ as shown in Figure Q6 if $\vec{B} = 6x\hat{x} - 9y\hat{y} + 3z\hat{z}$. (10 marks)
- Q7** (a) Define Coulomb's law for force, \vec{F} and electric field intensity, \vec{E} of a point charge. (4 marks)
- (b) A surface charge $0 \leq x \leq 1$ m, $0 \leq y \leq 1$ m located at $z = 0$ plane has surface charge density $xy(x^2 + y^2 + 36)^{3/2}$ nC/m².
- (i) Calculate the electric field intensity at point $P(x, y, z) = (0, 0, 6)$ m. (9 marks)
 - (ii) Determine the force experienced by a 4 nC point charge located at $(0, 0, 6)$ m. (3 marks)
- (c) Write the Maxwell's equations related to electrostatic field. (4 marks)

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Rajah S4 / Figure Q4



Rajah S6 / Figure Q6

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Formula

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

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

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

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

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

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

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Gradient

$$\nabla f = \frac{\partial f}{\partial x} \hat{x} + \frac{\partial f}{\partial y} \hat{y} + \frac{\partial f}{\partial z} \hat{z}$$

$$\nabla f = \frac{\partial f}{\partial r} \hat{r} + \frac{1}{r} \frac{\partial f}{\partial \phi} \hat{\phi} + \frac{\partial f}{\partial z} \hat{z}$$

$$\nabla f = \frac{\partial f}{\partial R} \hat{R} + \frac{1}{R} \frac{\partial f}{\partial \theta} \hat{\theta} + \frac{1}{R \sin \theta} \frac{\partial f}{\partial \phi} \hat{\phi}$$

Divergence

$$\nabla \cdot \vec{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

$$\nabla \cdot \vec{A} = \frac{1}{r} \left[\frac{\partial (r A_r)}{\partial r} \right] + \frac{1}{r} \frac{\partial A_\phi}{\partial \phi} + \frac{\partial A_z}{\partial z}$$

$$\nabla \cdot \vec{A} = \frac{1}{R^2} \frac{\partial (R^2 A_R)}{\partial R} + \frac{1}{R \sin \theta} \left[\frac{\partial (A_\theta \sin \theta)}{\partial \theta} \right] + \frac{1}{R \sin \theta} \frac{\partial A_\phi}{\partial \phi}$$

Curl

$$\nabla \times \vec{A} = \left(\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z} \right) \hat{x} + \left(\frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x} \right) \hat{y} + \left(\frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y} \right) \hat{z}$$

$$\nabla \times \vec{A} = \left(\frac{1}{r} \frac{\partial A_z}{\partial \phi} - \frac{\partial A_\phi}{\partial z} \right) \hat{r} + \left(\frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r} \right) \hat{\phi} + \frac{1}{r} \left(\frac{\partial (r A_\phi)}{\partial r} - \frac{\partial A_r}{\partial \phi} \right) \hat{z}$$

$$\nabla \times \vec{A} = \frac{1}{R \sin \theta} \left[\frac{\partial (\sin \theta A_\phi)}{\partial \theta} - \frac{\partial A_\theta}{\partial \phi} \right] \hat{R} + \frac{1}{R} \left[\frac{1}{\sin \theta} \frac{\partial A_R}{\partial \phi} - \frac{\partial (R A_\phi)}{\partial R} \right] \hat{\theta} + \frac{1}{R} \left[\frac{\partial (R A_\theta)}{\partial R} - \frac{\partial A_R}{\partial \theta} \right] \hat{\phi}$$

Laplacian

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} + \frac{\partial^2 f}{\partial z^2}$$

$$\nabla^2 f = \frac{1}{r} \frac{\partial}{\partial r} \left(r \frac{\partial f}{\partial r} \right) + \frac{1}{r^2} \frac{\partial^2 f}{\partial \phi^2} + \frac{\partial^2 f}{\partial z^2}$$

$$\nabla^2 f = \frac{1}{R^2} \frac{\partial}{\partial R} \left(R^2 \frac{\partial f}{\partial R} \right) + \frac{1}{R^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial f}{\partial \theta} \right) + \frac{1}{R^2 \sin^2 \theta} \left(\frac{\partial^2 f}{\partial \phi^2} \right)$$

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

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