KOLEJ UNIVERSITI TEKNOLOGI TUN HUSSEIN ONN

PEPERIKSAAN AKHIR SEMESTER I SESI 2006/2007

NAMA MATA PELAJARAN	:	MEDAN DAN GELOMBANG ELEKTROMAGNET
KOD MATA PELAJARAN	:	BKE 3163
KURSUS	:	4BKL
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 $\varepsilon_r = 8$ dan $\mu_r = 2$ mempunyai $\overline{E} = 0.5e^{-z/3}\sin\left(10^8 t - \beta z\right)\hat{\mathbf{x}}$ 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, $\overline{H}$

(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 ($\mu = \mu_o$, $\varepsilon = 81\varepsilon_o$, $\sigma = 2\text{x } 10^{-3}$ S/m)

(5 markah)

(ii) Air laut ($\mu = \mu_o$, $\varepsilon = 81\varepsilon_o$, $\sigma = 25$ 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, $\overline{E}$

(5 markah)

(b) Apakah daya, $\overline{F}$ yang terhasil ke atas cas 10μC

(3 markah)

(c) Dapatkan ketumpatan fluk elektrik $\overline{D}$ pada titik (2, π/2, 0)

(3 markah)

(d) Kirakan kerja yang dilakukan untuk menggerakkan 10μC cas dari titik $A(1, 30^o, 120^o)$ ke $B(4, 90^o, 60^o)$

(9 markah)

S4 Satu kepingan kaca selari (ε_r = 8.5) yang diletakkan secara menegak untuk memisahkan minyak (ε_r = 3.0) dan udara seperti yang ditunjukkan dalam Rajah S4. Medan elektrik seragam sekuat 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^o dengan permukaan kaca.

(10 markah)

S5 (a) Dalam suatu kawasan tertentu bagi pengalir

$$\overline{H} = \hat{\mathbf{x}}(x^2+y^2)yz + \hat{\mathbf{y}}(zxy^2) - \hat{\mathbf{z}}(4x^2y^2)A/m$$

(i) Tentukan ketumpatan arus, $\overline{J}$ pada titik (5, 2, -3)

(7 markah)

(ii) Dapatkan arus, I yang mengalir melalui $x = -1,\ 0 < y, z < 2$

(4 markah)

(iii) Buktikan $\nabla \bullet \overline{B} = 0$

(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, $\overline{H}$ pada $r < a$

(1 markah)

(ii) Medan magnet, $\overline{H}$ pada $0 < r < b$

(3 markah)

(iii) Medan magnet, $\overline{H}$ 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, $\overline{F}$, daya kilas, $\overline{T}$, arus, I dan ketumpatan fluk magnet, $\overline{B}$.

(7 markah)

(b) Dapatkan jumlah daya, $\overline{F}$ yang dihasilkan oleh gelung segiempat tepat yang terletak pada satah $z = 0$ seperti yang ditunjukkan pada Rajah S6 jika $\overline{B} = 6x\hat{\mathbf{x}} - 9y\hat{\mathbf{y}} + 3z\hat{\mathbf{z}}$

(10 markah)

S7 (a) Takrifkan hukum Coulomb untuk daya, $\overline{F}$ dan keamatan medan elektrik, $\overline{E}$ 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/m^2.

(i) Kirakan keamatan medan elektrik pada titik $P(x, y, z) =$ (0, 0, 6 m).

(9 markah)

(ii) Tentukan daya yang dirasai 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 $\varepsilon_r = 8$ and $\mu_r = 2$ has $\overline{E} = 0.5e^{-z/3}\sin(10^8 t - \beta z)\hat{\mathbf{x}}$ 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, $\overline{H}$

(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 ($\mu = \mu_o$, $\varepsilon = 81\varepsilon_o$, $\sigma = 2\text{x } 10^{-3}$ S/m)

(5 marks)

(ii) Sea water ($\mu = \mu_o$, $\varepsilon = 81\varepsilon_o$, $\sigma = 25$ 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, $\overline{E}$

(5 marks)

(b) What is the force, $\overline{F}$ on 10 μC charge

(3 marks)

(c) Find electric flux density, $\overline{D}$ at point (2, π/2 , 0)

(3 marks)

(d) Calculate the work done in moving a 10 μC charge from point A(1, 30°, 120°) to B(4, 90°, 60°)

(9 marks)

Q4 A parallel sheet of glass (ε_r = 8.5) mounted vertically to separate oil (ε_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

$$\overline{H} = \hat{\mathbf{x}}(x^2 + y^2)yz + \hat{\mathbf{y}}(zxy^2) - \hat{\mathbf{z}}(4x^2y^2)A/m$$

(i) Determine current density, $\overline{J}$ at point (5, 2, -3)

(7 marks)

(ii) Find the current, I passing through $x = -1$, $0 < y, z < 2$

(4 marks)

(iii) Proof $\nabla \bullet \overline{B} = 0$

(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, $\overline{H}$ at $r<a$

(1 marks)

(ii) Magnetic field, $\overline{H}$ at $0<r<b$

(3 marks)

(iii) Magnetic field, $\overline{H}$ 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, $\overline{F}$, torque, $\overline{T}$, current, I and magnetic flux density, $\overline{B}$.

(7 marks)

(b) Fine the total force, $\overline{F}$, experienced by the rectangular loop located on plane $z=0$ as shown in Figure Q6 if $\overline{B}=6x\hat{\mathbf{x}}-9y\hat{\mathbf{y}}+3z\hat{\mathbf{z}}$.

(10 marks)

Q7 (a) Define Coulomb's law for force, $\overline{F}$ and electric field intensity, $\overline{E}$ 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/m^2.

(i) Calculate the electric field intensity at point $P(x, y, z)$ = (0, 0, 6 m).

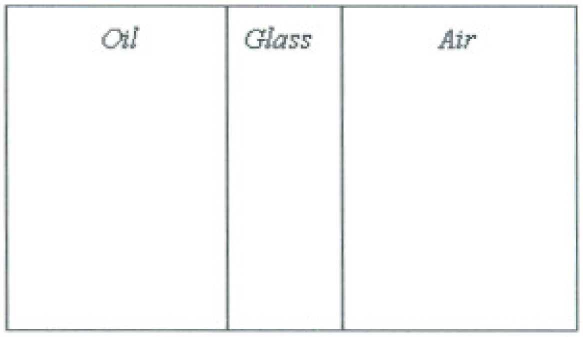
(9 marks)

(ii) Determine the force experienced by a 4 nC point charge located at (0, 0, 6 m).

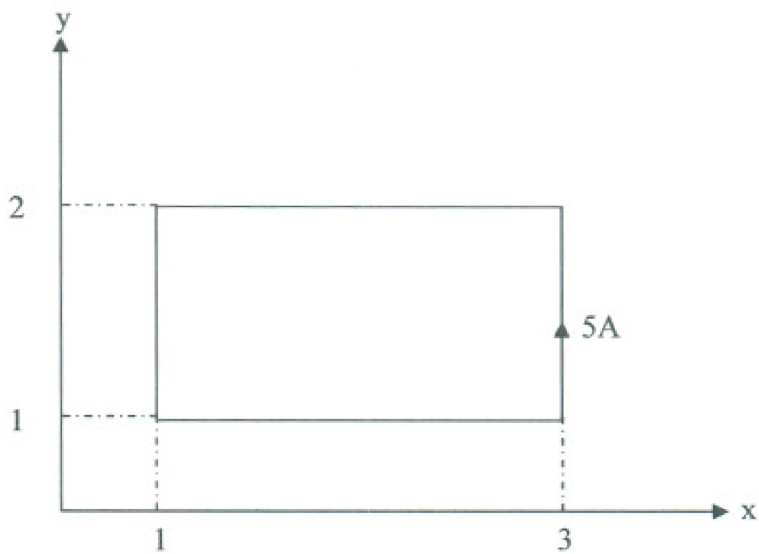
(3 marks)

(c) Write the Maxwell's equations related to electrostatic field.

(4 marks)



Rajah S4 / Figure Q4



Rajah S6 / Figure Q6

Formula

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

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

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

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

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

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

Gradient

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

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

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

Divergence

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

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

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

Curl

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

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

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

Laplacian

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

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

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

	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, $\overrightarrow{dv}$	$dx\,dy\,\,dz$	$r\,dr\,d\phi\,dz$	$R^2\sin\theta\,dR\,d\theta\,d\phi$

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