TABLE **2-1** THREE BASIC ORTHOGONAL COORDINATE SYSTEMS

		Cartesian Coordinates (x, y, z)	Cylindrical Coordinates (r, ϕ, z)	Spherical Coordinates (R, θ, ϕ)
Base Vectors	$\mathbf{a}_{u_1}$	$\mathbf{a}_x$	$\mathbf{a}_r$	$\mathbf{a}_R$
	$\mathbf{a}_{u_2}$	$\mathbf{a}_y$	$\mathbf{a}_\phi$	$\mathbf{a}_\theta$
	$\mathbf{a}_{u_3}$	$\mathbf{a}_z$	$\mathbf{a}_z$	$\mathbf{a}_\phi$
Metric Coefficients	h_1	1	1	1
	h_2	1	r	R
	h_3	1	1	$R\sin\theta$
Differential Volume	dv	$dx\,dy\,dz$	$r\,dr\,d\phi\,dz$	$R^2\sin\theta\,dR\,d\theta\,d\phi$

	Cartesian Coordinates	Cylindrical Coordinates	Spherical Coordinates
Coordinate variables	x,y,z	r,ϕ,z	R,θ,ϕ
Vector representation, A =	$\hat{\mathbf{x}}A_x+\hat{\mathbf{y}}A_y+\hat{\mathbf{z}}A_z$	$\hat{\mathbf{r}}A_r+\hat{\boldsymbol{\phi}}A_\phi+\hat{\mathbf{z}}A_z$	$\hat{\mathbf{R}}A_R+\hat{\boldsymbol{\theta}}A_\theta+\hat{\boldsymbol{\phi}}A_\phi$
Magnitude of A, $\lvert A\rvert$ =	$\sqrt[+]{A_x^2+A_y^2+A_z^2}$	$\sqrt[+]{A_r^2+A_\phi^2+A_z^2}$	$\sqrt[+]{A_R^2+A_\theta^2+A_\phi^2}$
Position vector $\overrightarrow{OP_1}$ =	$\hat{\mathbf{x}}x_1+\hat{\mathbf{y}}y_1+\hat{\mathbf{z}}z_1$, for $P(x_1,y_1,z_1)$	$\hat{\mathbf{r}}r_1+\hat{\mathbf{z}}z_1$, for $P(r_1,\phi_1,z_1)$	$\hat{\mathbf{R}}R_1$, for $P(R_1,\theta_1,\phi_1)$
Base vectors properties	$\hat{\mathbf{x}}\cdot\hat{\mathbf{x}}=\hat{\mathbf{y}}\cdot\hat{\mathbf{y}}=\hat{\mathbf{z}}\cdot\hat{\mathbf{z}}=1$ $\hat{\mathbf{x}}\cdot\hat{\mathbf{y}}=\hat{\mathbf{y}}\cdot\hat{\mathbf{z}}=\hat{\mathbf{z}}\cdot\hat{\mathbf{x}}=0$ $\hat{\mathbf{x}}\times\hat{\mathbf{y}}=\hat{\mathbf{z}}$ $\hat{\mathbf{y}}\times\hat{\mathbf{z}}=\hat{\mathbf{x}}$ $\hat{\mathbf{z}}\times\hat{\mathbf{x}}=\hat{\mathbf{y}}$	$\hat{\mathbf{r}}\cdot\hat{\mathbf{r}}=\hat{\boldsymbol{\phi}}\cdot\hat{\boldsymbol{\phi}}=\hat{\mathbf{z}}\cdot\hat{\mathbf{z}}=1$ $\hat{\mathbf{r}}\cdot\hat{\boldsymbol{\phi}}=\hat{\boldsymbol{\phi}}\cdot\hat{\mathbf{z}}=\hat{\mathbf{z}}\cdot\hat{\mathbf{r}}=0$ $\hat{\mathbf{r}}\times\hat{\boldsymbol{\phi}}=\hat{\mathbf{z}}$ $\hat{\boldsymbol{\phi}}\times\hat{\mathbf{z}}=\hat{\mathbf{r}}$ $\hat{\mathbf{z}}\times\hat{\mathbf{r}}=\hat{\boldsymbol{\phi}}$	$\hat{\mathbf{R}}\cdot\hat{\mathbf{R}}=\hat{\boldsymbol{\theta}}\cdot\hat{\boldsymbol{\theta}}=\hat{\boldsymbol{\phi}}\cdot\hat{\boldsymbol{\phi}}=1$ $\hat{\mathbf{R}}\cdot\hat{\boldsymbol{\theta}}=\hat{\boldsymbol{\theta}}\cdot\hat{\boldsymbol{\phi}}=\hat{\boldsymbol{\phi}}\cdot\hat{\mathbf{R}}=0$ $\hat{\mathbf{R}}\times\hat{\boldsymbol{\theta}}=\hat{\boldsymbol{\phi}}$ $\hat{\boldsymbol{\theta}}\times\hat{\boldsymbol{\phi}}=\hat{\mathbf{R}}$ $\hat{\boldsymbol{\phi}}\times\hat{\mathbf{R}}=\hat{\boldsymbol{\theta}}$
Dot product, A·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, A × B =	$\begin{vmatrix}\hat{\mathbf{x}} & \hat{\mathbf{y}} & \hat{\mathbf{z}}\\ A_x & A_y & A_z\\ B_x & B_y & B_z\end{vmatrix}$	$\begin{vmatrix}\hat{\mathbf{r}} & \hat{\boldsymbol{\phi}} & \hat{\mathbf{z}}\\ A_r & A_\phi & A_z\\ B_r & B_\phi & B_z\end{vmatrix}$	$\begin{vmatrix}\hat{\mathbf{R}} & \hat{\boldsymbol{\theta}} & \hat{\boldsymbol{\phi}}\\ A_R & A_\theta & A_\phi\\ B_R & B_\theta & B_\phi\end{vmatrix}$
Differential length, $d\mathbf{l}$ =	$\hat{\mathbf{x}}\,dx+\hat{\mathbf{y}}\,dy+\hat{\mathbf{z}}\,dz$	$\hat{\mathbf{r}}\,dr+\hat{\boldsymbol{\phi}}r\,d\phi+\hat{\mathbf{z}}\,dz$	$\hat{\mathbf{R}}\,dR+\hat{\boldsymbol{\theta}}R\,d\theta+\hat{\boldsymbol{\phi}}R\sin\theta\,d\phi$
Differential surface areas	$ds_x=\hat{\mathbf{x}}\,dy\,dz$ $ds_y=\hat{\mathbf{y}}\,dx\,dz$ $ds_z=\hat{\mathbf{z}}\,dx\,dy$	$ds_r=\hat{\mathbf{r}}r\,d\phi\,dz$ $ds_\phi=\hat{\boldsymbol{\phi}}\,dr\,dz$ $ds_z=\hat{\mathbf{z}}r\,dr\,d\phi$	$ds_R=\hat{\mathbf{R}}R^2\sin\theta\,d\theta\,d\phi$ $ds_\theta=\hat{\boldsymbol{\theta}}R\sin\theta\,dR\,d\phi$ $ds_\phi=\hat{\boldsymbol{\phi}}R\,dR\,d\theta$
Differential volume, $d\mathcal{V}$ =	$dx\,dy\,dz$	$r\,dr\,d\phi\,dz$	$R^2\sin\theta\,dR\,d\theta\,d\phi$

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