

### EXERCISES AND HOMEWORK PROBLEMS

Problems 1-10 involve computing the following derivatives thoroughly and then using your results to solve the related problems listed below. Use the Chain Rule.

1. Given the spherical coordinates of any point, use an appropriate form of the "Distance and Directional" Theorems, give the name and value of  $\mathbf{e}_r$ .

2. Knowing the location of the gradient and its direction, compute the directional derivative in the direction

(a)  $\mathbf{e}_r$  (b)  $\mathbf{e}_\theta$  (c)  $\mathbf{e}_\phi$  (d)  $\mathbf{e}_\rho$  (e)  $\mathbf{e}_\sigma$  (f)  $\mathbf{e}_\tau$

for  $\mathbf{e}_r$  (a)  $\mathbf{e}_r = \frac{1}{\sqrt{2}}(\mathbf{i} + \mathbf{j})$  (b)  $\mathbf{e}_\theta = \frac{1}{\sqrt{2}}(\mathbf{j} - \mathbf{k})$  (c)  $\mathbf{e}_\phi = \frac{1}{\sqrt{2}}(\mathbf{i} - \mathbf{j})$  (d)  $\mathbf{e}_\rho = \frac{1}{\sqrt{2}}(\mathbf{i} + \mathbf{j})$  (e)  $\mathbf{e}_\sigma = \frac{1}{\sqrt{2}}(\mathbf{j} - \mathbf{k})$  (f)  $\mathbf{e}_\tau = \frac{1}{\sqrt{2}}(\mathbf{i} - \mathbf{j})$

Compute the following with a calculator:

(a)  $\mathbf{e}_r \cdot \mathbf{e}_\theta = \frac{1}{\sqrt{2}}(\mathbf{j} - \mathbf{k}) \cdot \frac{1}{\sqrt{2}}(\mathbf{j} - \mathbf{k}) = \frac{1}{2}(1 + 1) = 1$  (b)  $\mathbf{e}_\theta \cdot \mathbf{e}_\phi = \frac{1}{\sqrt{2}}(\mathbf{j} - \mathbf{k}) \cdot \frac{1}{\sqrt{2}}(\mathbf{i} - \mathbf{j}) = \frac{1}{2}(-1) = -\frac{1}{2}$

3. The directional derivative of  $\sin(x^2 + y^2 + z^2)$  in the direction  $\mathbf{e}_r$  is  $\frac{2}{\sqrt{2}} \sin(x^2 + y^2 + z^2)$ .

4. The gradient of  $\sin(x^2 + y^2 + z^2)$  at the point  $(1, 1, 1)$  is  $2(\mathbf{i} + \mathbf{j} + \mathbf{k}) \sin(3)$ .

5. Find  $\nabla \cdot \mathbf{e}_r$  in spherical coordinates. Use the formula  $\nabla \cdot \mathbf{e}_r = \frac{2}{r}$ .

(a)  $\nabla \cdot \mathbf{e}_r = \frac{2}{r}$  (b)  $\nabla \cdot \mathbf{e}_\theta = -\frac{1}{r^2}$  (c)  $\nabla \cdot \mathbf{e}_\phi = -\frac{1}{r^2 \sin^2 \theta}$  (d)  $\nabla \cdot \mathbf{e}_\rho = \frac{2}{r}$  (e)  $\nabla \cdot \mathbf{e}_\sigma = -\frac{1}{r^2}$  (f)  $\nabla \cdot \mathbf{e}_\tau = -\frac{1}{r^2 \sin^2 \theta}$

(a)  $\nabla \cdot \mathbf{e}_r = \frac{2}{r}$  (b)  $\nabla \cdot \mathbf{e}_\theta = -\frac{1}{r^2}$  (c)  $\nabla \cdot \mathbf{e}_\phi = -\frac{1}{r^2 \sin^2 \theta}$  (d)  $\nabla \cdot \mathbf{e}_\rho = \frac{2}{r}$  (e)  $\nabla \cdot \mathbf{e}_\sigma = -\frac{1}{r^2}$  (f)  $\nabla \cdot \mathbf{e}_\tau = -\frac{1}{r^2 \sin^2 \theta}$

6. Express the following vectors in the following standard form, giving the final answer with the correct number of sig figs:

(a)  $\mathbf{e}_r = \frac{1}{\sqrt{2}}(\mathbf{i} + \mathbf{j})$  (b)  $\mathbf{e}_\theta = \frac{1}{\sqrt{2}}(\mathbf{j} - \mathbf{k})$  (c)  $\mathbf{e}_\phi = \frac{1}{\sqrt{2}}(\mathbf{i} - \mathbf{j})$  (d)  $\mathbf{e}_\rho = \frac{1}{\sqrt{2}}(\mathbf{i} + \mathbf{j})$  (e)  $\mathbf{e}_\sigma = \frac{1}{\sqrt{2}}(\mathbf{j} - \mathbf{k})$  (f)  $\mathbf{e}_\tau = \frac{1}{\sqrt{2}}(\mathbf{i} - \mathbf{j})$

7. The surface of a sphere is given by  $r = 2$ . Use the divergence theorem to find the total flux of  $\mathbf{e}_r$  through all faces of the shell.

(a)  $\nabla \cdot \mathbf{e}_r = \frac{2}{r} = \frac{2}{2} = 1$  (b)  $\nabla \cdot \mathbf{e}_\theta = -\frac{1}{r^2} = -\frac{1}{4}$  (c)  $\nabla \cdot \mathbf{e}_\phi = -\frac{1}{r^2 \sin^2 \theta} = -\frac{1}{4 \sin^2 \theta}$  (d)  $\nabla \cdot \mathbf{e}_\rho = \frac{2}{r} = 1$  (e)  $\nabla \cdot \mathbf{e}_\sigma = -\frac{1}{r^2} = -\frac{1}{4}$  (f)  $\nabla \cdot \mathbf{e}_\tau = -\frac{1}{r^2 \sin^2 \theta} = -\frac{1}{4 \sin^2 \theta}$

8. The total flux of the vector field  $\mathbf{e}_r$  is  $4\pi$ .

# Gen Chem 151 Final Exam Review Guide

**Mike Jess**



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