

1. **SPHERICAL COORDINATES, II**

Consider spherical coordinates (r, θ, ϕ) and the adapted orthonormal basis

$$\{\hat{\mathbf{e}}_1, \hat{\mathbf{e}}_2, \hat{\mathbf{e}}_3\} = \{\hat{\mathbf{r}}, \hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\phi}}\}$$

The “infinitesimal displacement vector” $d\vec{\mathbf{r}}$ relates this basis to an orthonormal basis of 1-forms via

$$d\vec{\mathbf{r}} = dr \hat{\mathbf{r}} + r d\theta \hat{\boldsymbol{\theta}} + r \sin \theta d\phi \hat{\boldsymbol{\phi}}$$

Both sides of this equation are really **vector valued 1-forms**.

WARNING: These conventions imply $\tan \phi = \frac{y}{x}$.

- (a) Determine the exterior derivative of each basis vector (not 1-form) above, that is, compute $d\hat{\mathbf{r}}$, $d\hat{\boldsymbol{\theta}}$, and $d\hat{\boldsymbol{\phi}}$. *What sort of a beast should you get?*
HINT: What is the position vector $\vec{\mathbf{r}}$ in this basis?
You may calculate in any coordinate system, but the final answer should be entirely in terms of spherical coordinates and basis vectors. If you are having trouble getting started, see me.
- (b) Compute $\omega_{ij} = \hat{\mathbf{e}}_i \cdot d\hat{\mathbf{e}}_j$ for $i, j = 1, 2, 3$. *What sort of a beast should you get?*
- (c) Compute $\Omega_{ij} = d\omega_{ij} + \omega_{ik} \wedge \omega_{kj}$ for $i, j = 1, 2, 3$ (and where there is an implicit sum over k). *What sort of a beast should you get?*

2. **SPHERICAL COORDINATES, III**

Consider the sphere of radius r , in spherical coordinates (θ, ϕ) , with line element

$$ds^2 = r^2 (d\theta^2 + \sin^2 \theta d\phi^2)$$

- (a) Find the connection 1-forms ω_{ij} in this basis.
- (b) Compute $\Omega_{ij} = d\omega_{ij} + \omega_{ik} \wedge \omega_{kj}$ for $i, j = 1, 2$ (and where there is an implicit sum over k).
- (c) Compare your answers (and your computations) with those from Problem 1.