

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ ,*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \}$*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \}$*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ ,*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*



**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,*



**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\begin{aligned}\dot{\mathbf{T}}(t) &= 0\mathbf{T}(t) + \kappa(t)\mathbf{N}(t) + 0\mathbf{B}(t) \\ \dot{\mathbf{N}}(t) &= -\kappa(t)\mathbf{T}(t) + 0\mathbf{N}(t) + \tau(t)\mathbf{B}(t) \\ \dot{\mathbf{B}}(t) &= 0\mathbf{T}(t) - \tau(t)\mathbf{N}(t) + 0\mathbf{B}(t)\end{aligned}$$

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations,

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, □

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$\mathbf{e}_1(t_0)$ ,  $\mathbf{e}_2(t_0)$ , and  $\mathbf{e}_3(t_0)$ .

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$\mathbf{e}_1(t_0) = \mathbf{E}_1$ ,  $\mathbf{e}_2(t_0)$ , and  $\mathbf{e}_3(t_0)$ .

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0).$$

□



**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$$

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0 \text{ (exercise!)} \quad \square$$

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  □

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!!) □

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration □)

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!) □



**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!) □

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$$\mathbf{B}(t)$$

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$$\mathbf{B}(t) \text{ unit}$$

□

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$\mathbf{B}(t)$  unit and orthogonal □

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$\mathbf{B}(t)$  unit and orthogonal to  $\mathbf{T}(t)$  and  $\mathbf{N}(t)$ . □

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$\mathbf{B}(t)$  unit and orthogonal to  $\mathbf{T}(t) = \mathbf{e}_1(t)$  and  $\mathbf{N}(t) = \mathbf{e}_2(t)$ . □

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$\mathbf{B}(t)$  unit and orthogonal to  $\mathbf{T}(t) = \mathbf{e}_1(t)$  and  $\mathbf{N}(t) = \mathbf{e}_2(t)$ .

$$\mathbf{e}_3(t)$$

□



**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$\mathbf{B}(t)$  unit and orthogonal to  $\mathbf{T}(t) = \mathbf{e}_1(t)$  and  $\mathbf{N}(t) = \mathbf{e}_2(t)$ .

$\mathbf{e}_3(t)$  unit □

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$\mathbf{B}(t)$  unit and orthogonal to  $\mathbf{T}(t) = \mathbf{e}_1(t)$  and  $\mathbf{N}(t) = \mathbf{e}_2(t)$ .

$\mathbf{e}_3(t)$  unit and orthogonal □

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$\mathbf{B}(t)$  unit and orthogonal to  $\mathbf{T}(t) = \mathbf{e}_1(t)$  and  $\mathbf{N}(t) = \mathbf{e}_2(t)$ .

$\mathbf{e}_3(t)$  unit and orthogonal to  $\mathbf{e}_1(t)$  and  $\mathbf{e}_2(t)$ . □

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$\mathbf{B}(t)$  unit and orthogonal to  $\mathbf{T}(t) = \mathbf{e}_1(t)$  and  $\mathbf{N}(t) = \mathbf{e}_2(t)$ .

$\mathbf{e}_3(t)$  unit and orthogonal to  $\mathbf{e}_1(t)$  and  $\mathbf{e}_2(t)$ . only two choices, and negatives of each other. So one is  $\mathbf{e}_1(t) \times \mathbf{e}_2(t)$ , other is  $-\mathbf{e}_1(t) \times \mathbf{e}_2(t)$ .  $\square$

**Theorem.** *Given,*

1. *functions  $\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}$ ,  $\tilde{\kappa}(t) > 0$  for all  $t$ , and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}$*
2.  *$p \in \mathbb{R}^3$ ,  $t_0 \in (\alpha, \beta)$ ,*
3. *an orthonormal basis  $\{\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3\}$  based at  $p$ , such that  $\mathbf{E}_3 = \mathbf{E}_1 \times \mathbf{E}_2$ .*

*there is a unit speed parametrization,  $\gamma : (\alpha, \beta) \rightarrow \mathbb{R}^3$ , so that,*

1.  *$\tilde{\kappa} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its curvature function and  $\tilde{\tau} : (\alpha, \beta) \rightarrow \mathbb{R}^3$  is its torsion function*
2.  *$p = \gamma(t_0)$*
3.  *$\mathbf{E}_1 = \mathbf{T}(t_0)$ ,  $\mathbf{E}_2 = \mathbf{N}(t_0)$ ,  $\mathbf{E}_3 = \mathbf{B}(t_0)$*

*Proof.*

$$\dot{\mathbf{e}}_1(t) = 0\mathbf{e}_1(t) + \kappa(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_2(t) = -\kappa(t)\mathbf{e}_1(t) + 0\mathbf{e}_2(t) + \tau(t)\mathbf{e}_3(t)$$

$$\dot{\mathbf{e}}_3(t) = 0\mathbf{e}_1(t) - \tau(t)\mathbf{e}_2(t) + 0\mathbf{e}_3(t)$$

By the theory of differential equations, always has a solution, unique if we fix,

$$\mathbf{e}_1(t_0) = \mathbf{E}_1, \mathbf{e}_2(t_0) = \mathbf{E}_2, \text{ and } \mathbf{e}_3(t_0) = \mathbf{E}_3.$$

$(\mathbf{e}_i \cdot \mathbf{e}_j)' = 0$  (exercise!), so constant, so  $\{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}$  is orthonormal for *all*  $t$

Can find  $\gamma(t)$ , so that,  $\mathbf{T}(t) = \dot{\gamma}(t) = \mathbf{e}_1(t)$  and  $\gamma(t_0) = p$  (exercise!! Integration (anti-derivative)!)

$$\kappa(t)\mathbf{N}(t) = \dot{\mathbf{T}}(t) = \dot{\mathbf{e}}_1(t) = \kappa(t)\mathbf{e}_2(t)$$

$$\text{So, } \mathbf{N}(t) = \mathbf{e}_2(t)$$

$\mathbf{B}(t)$  unit and orthogonal to  $\mathbf{T}(t) = \mathbf{e}_1(t)$  and  $\mathbf{N}(t) = \mathbf{e}_2(t)$ .

$\mathbf{e}_3(t)$  unit and orthogonal to  $\mathbf{e}_1(t)$  and  $\mathbf{e}_2(t)$ . only two choices, and negatives of each other. So one is  $\mathbf{e}_1(t) \times \mathbf{e}_2(t)$ , other is  $-\mathbf{e}_1(t) \times \mathbf{e}_2(t)$ . Can distinguish using dot

products...

