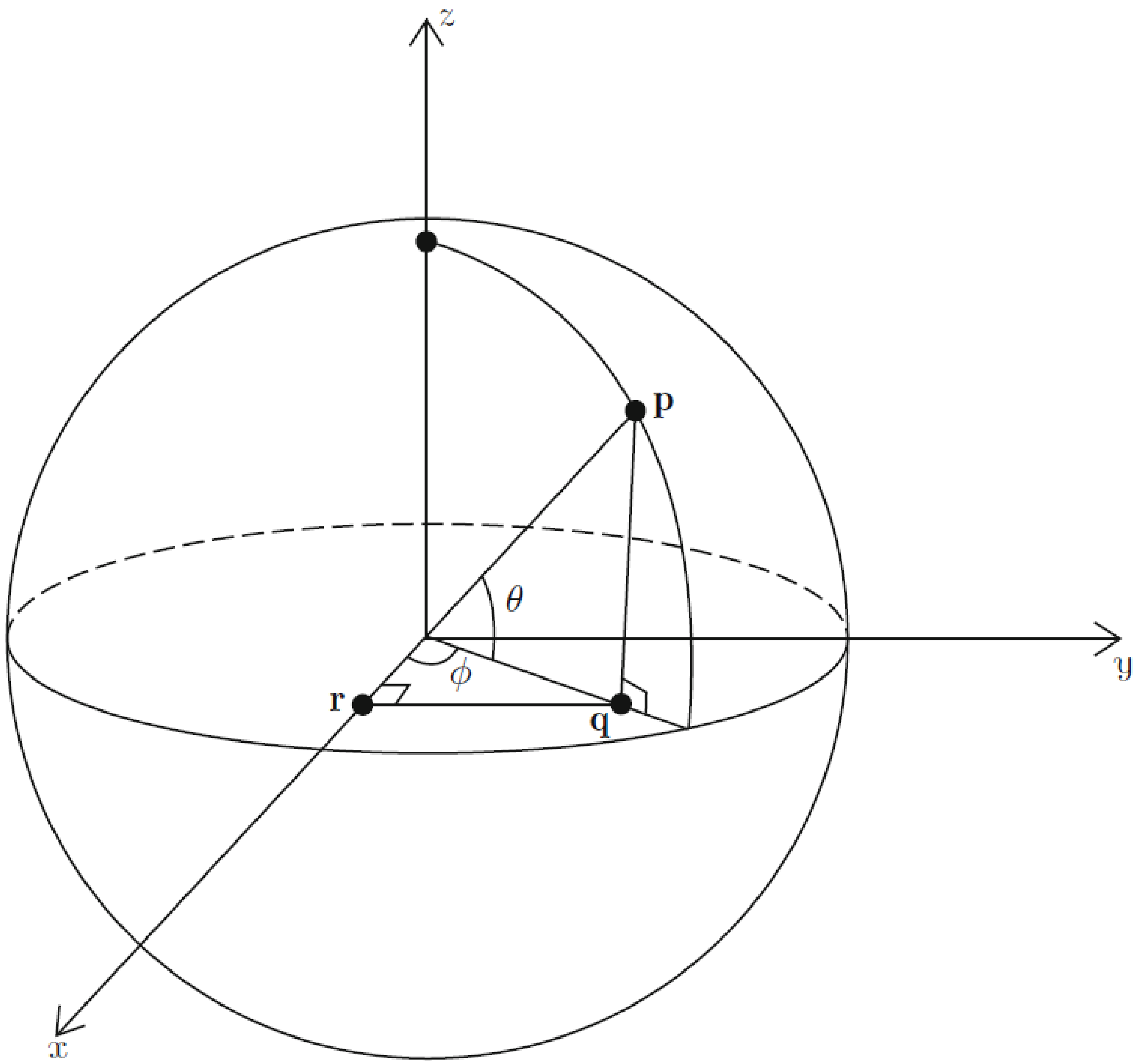
$$x = \cos\theta\cos\phi$$

$$y = \cos\theta\sin\phi$$

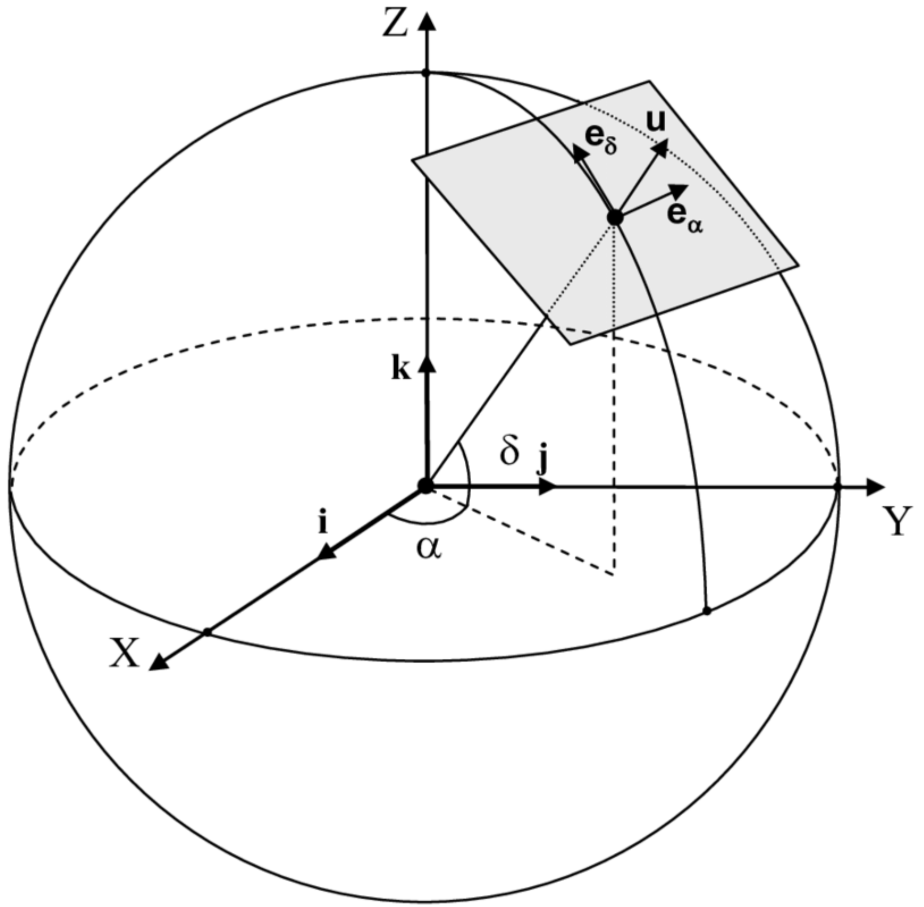
$$z = \sin\theta$$



$$e_\theta = \frac{\partial x}{\partial \theta} e_x + \frac{\partial y}{\partial \theta} e_y + \frac{\partial z}{\partial \theta} e_z$$

$$e_\phi = \frac{\partial x}{\partial \phi} e_x + \frac{\partial y}{\partial \phi} e_y + \frac{\partial z}{\partial \phi} e_z$$

$$\frac{dx}{dt} e_x + \frac{dy}{dt} e_y + \frac{dz}{dt} e_z = \frac{d\theta}{dt} e_\theta + \frac{d\phi}{dt} e_\phi$$



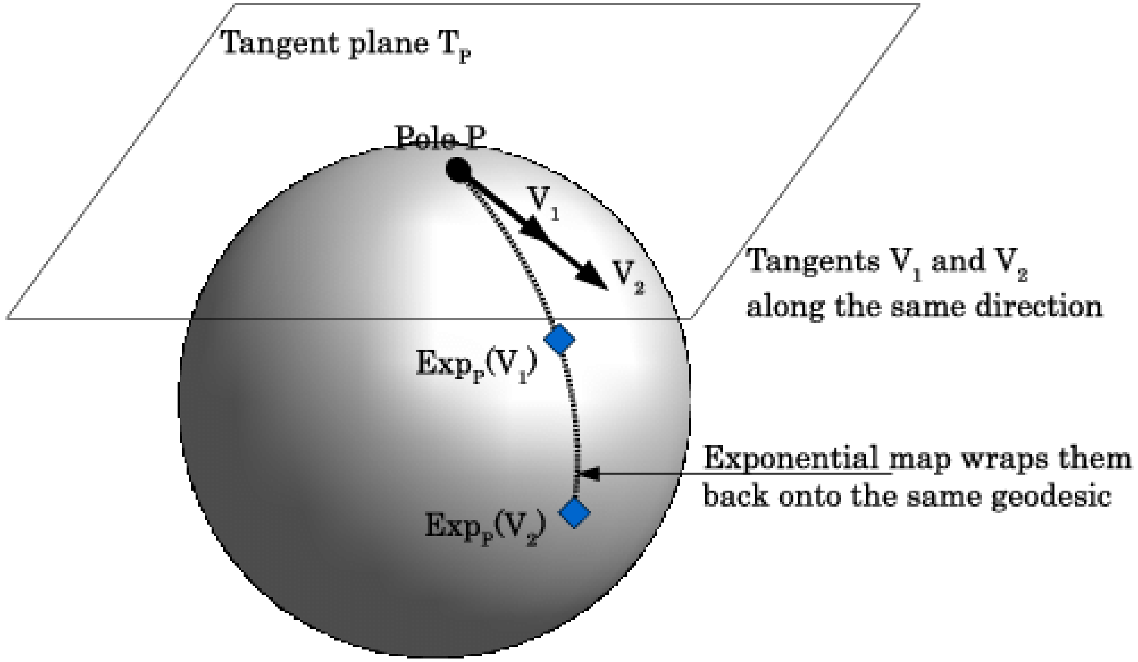
$$L(x,\dot{x}) = \sqrt{\sum g_{\alpha\beta}(x)\dot{x}_\alpha \dot{x}_\beta}$$

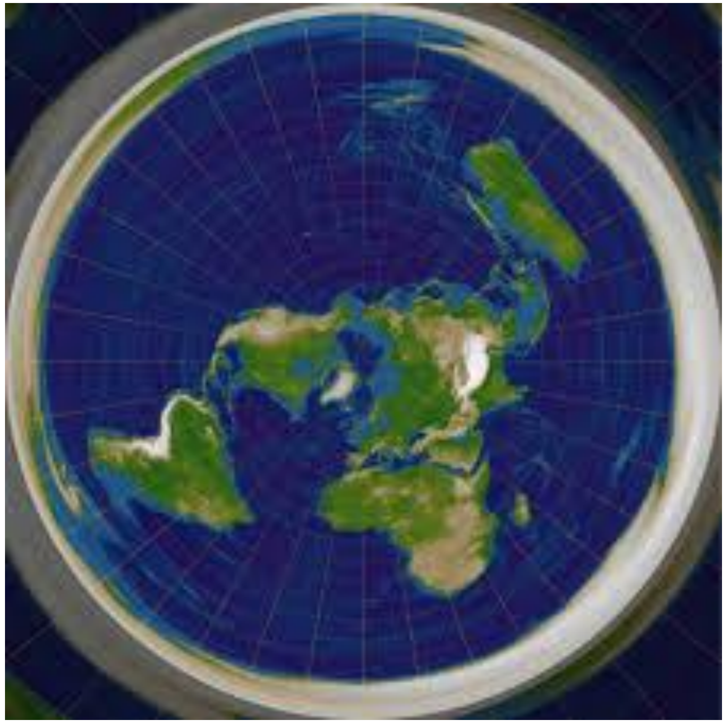
$$\int_{t_1}^{t_2} L\big(x(t),\dot{x}(t)\big)\,dt$$

$$\frac{\partial L}{\partial x} - \frac{d}{dt}\frac{\partial L}{\partial \dot{x}} = 0$$

$$\Gamma_{\lambda\alpha\beta} = \frac{1}{2}\left(\partial_\alpha g_{\beta\lambda} + \partial_\beta g_{\alpha\lambda} - \partial_\lambda g_{\alpha\beta}\right), \qquad \Gamma^\lambda_{\alpha\beta} = \sum_\eta g^{\lambda\eta}\Gamma_{\eta\alpha\beta}$$

$$\frac{d^2x^\lambda}{dt^2} + \sum_{\alpha,\beta} \Gamma^\lambda_{\alpha\beta}\frac{dx^\alpha}{dt}\frac{dx^\beta}{dt} = 0$$


Tangent plane T_P
Pole P
V_1
V_2
Tangents V_1 and V_2
along the same direction
$Exp_P(V_1)$
Exponential map wraps them
back onto the same geodesic
$Exp_P(V_2)$



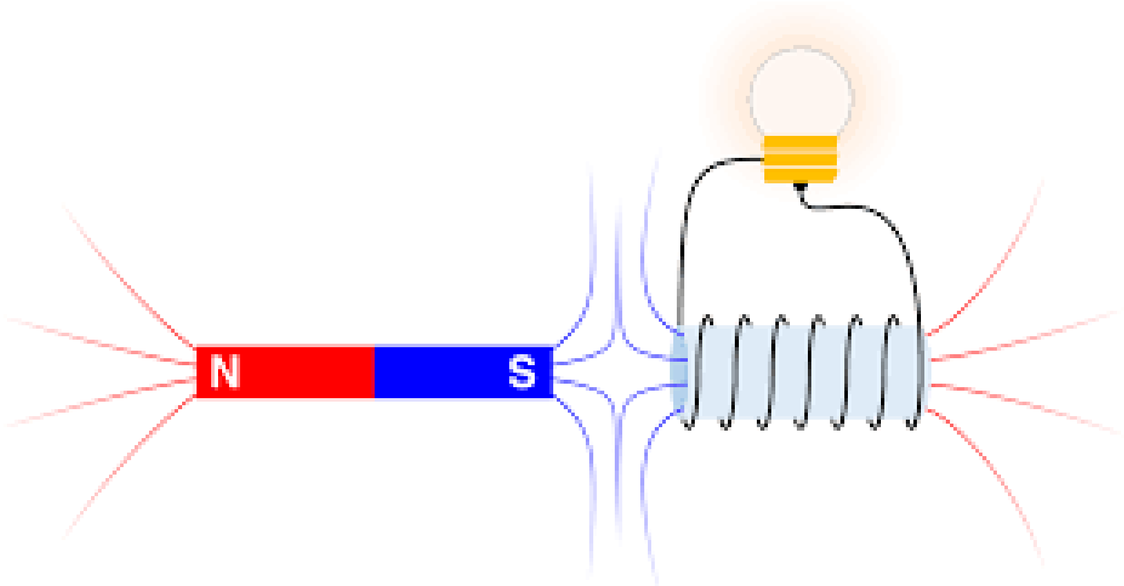
$$R^{\rho}{}_{\sigma\mu\nu} = \partial_{\mu}\Gamma^{\rho}{}_{\nu\sigma} - \partial_{\nu}\Gamma^{\rho}{}_{\mu\sigma} + \Gamma^{\rho}{}_{\mu\lambda}\Gamma^{\lambda}{}_{\nu\sigma} - \Gamma^{\rho}{}_{\nu\lambda}\Gamma^{\lambda}{}_{\mu\sigma}$$

$$\nabla_\lambda T^\alpha = \partial_\lambda T^\alpha + \Gamma^\alpha_{\lambda\eta} T^\eta$$

$$\nabla_\lambda T_\alpha = \partial_\lambda T_\alpha - \Gamma^\eta_{\lambda\alpha} T_\eta$$

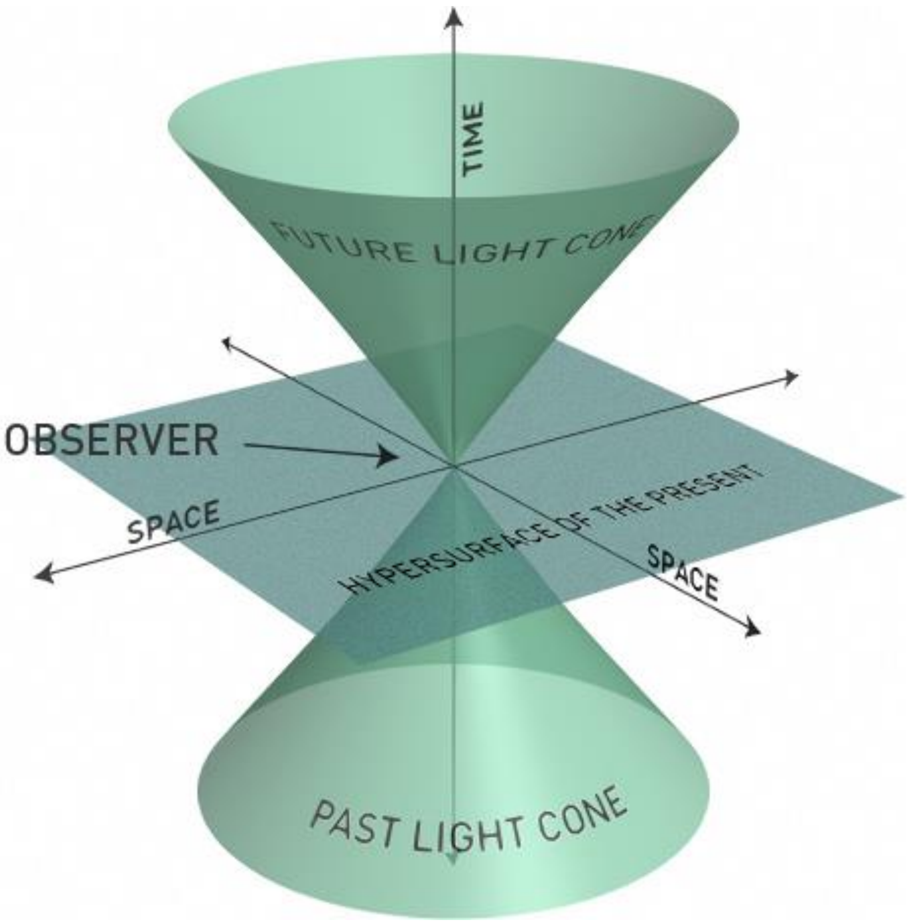
$$\nabla_\lambda T^{\alpha_1\alpha_2\alpha_3}_{\beta_1\beta_2} = \partial_\lambda T^{\alpha_1\alpha_2\alpha_3}_{\beta_1\beta_2} + \Gamma^{\alpha_1}_{\lambda\eta} T^{\eta\alpha_2\alpha_3}_{\beta_1\beta_2} + \Gamma^{\alpha_2}_{\lambda\eta} T^{\alpha_1\eta\alpha_3}_{\beta_1\beta_2} + \Gamma^{\alpha_3}_{\lambda\eta} T^{\alpha_1\alpha_2\eta}_{\beta_1\beta_2} - \Gamma^\eta_{\lambda\beta_1} T^{\alpha_1\alpha_2\alpha_3}_{\eta\beta_2} - \Gamma^\eta_{\lambda\beta_2} T^{\alpha_1\alpha_2\alpha_3}_{\beta_1\eta}$$

$$
\begin{aligned}
\nabla \cdot \vec{E} &= \frac{\rho}{\epsilon_0} \\
\nabla \cdot \vec{B} &= 0 \\
\nabla \times \vec{E} &= -\frac{\partial \vec{B}}{\partial t} \\
\nabla \times \vec{B} &= \mu_0 \vec{J} + \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t}
\end{aligned}
$$


N
S

$$t' = \gamma\left(t - \frac{vx}{c^2}\right)$$
$$x' = \gamma(x - vt)$$
$$y' = y$$
$$z' = z$$

$$
\begin{aligned}
E'_x &= E_x & B'_x &= B_x \\
E'_y &= \gamma\left(E_y - vB_z\right) & B'_y &= \gamma\left(B_y + \frac{v}{c^2}E_z\right) \\
E'_z &= \gamma\left(E_z + vB_y\right) & B'_z &= \gamma\left(B_z - \frac{v}{c^2}E_y\right).
\end{aligned}
$$


TIME
FUTURE LIGHT CONE
OBSERVER
SPACE
HYPERSURFACE OF THE PRESENT
SPACE
PAST LIGHT CONE

$$F^{\mu\nu} = \begin{pmatrix} 0 & -E_x/c & -E_y/c & -E_z/c \\ E_x/c & 0 & -B_z & B_y \\ E_y/c & B_z & 0 & -B_x \\ E_z/c & -B_y & B_x & 0 \end{pmatrix} \qquad G^{\mu\nu} = \begin{pmatrix} 0 & -B_x & -B_y & -B_z \\ B_x & 0 & E_z/c & -E_y/c \\ B_y & -E_z/c & 0 & E_x/c \\ B_z & E_y/c & -E_x/c & 0 \end{pmatrix}$$

$$J^{\alpha} = (c\rho, J_x, J_y, J_z)$$

$$\Gamma^{\lambda}_{\alpha\beta} = \frac{1}{2} g^{\lambda\eta}\left(\partial_{\alpha} g_{\beta\lambda} + \partial_{\beta} g_{\alpha\lambda} - \partial_{\lambda} g_{\alpha\beta}\right)$$

$$\partial_{\lambda} g_{\alpha\beta} = g_{\alpha\eta}\Gamma^{\eta}_{\lambda\beta} + g_{\beta\eta}\Gamma^{\eta}_{\lambda\alpha}$$

$$\nabla g = 0$$

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \kappa T_{\mu\nu}.$$

$$\kappa = \frac{8\pi G}{c^4},$$