$f(x) = 0$

Pelota $\rightarrow$ No hay fricción $\rightarrow$ Fricción

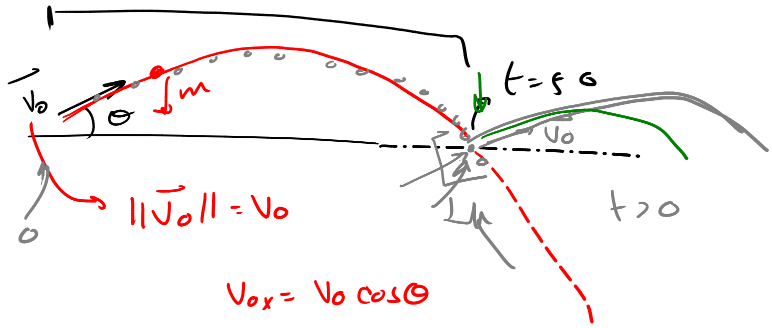
$$\boxed{m\ddot{\vec{r}} = \vec{F} = -mg\,\hat{e}_y + \gamma v^2 \hat{v}}$$

$\hat{e}_y = \hat{y} = \hat{j} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$

$\hat{e}_x = \hat{x} = \hat{i} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$

$\vec{r}(t) = x(t)\,\hat{e}_x + y(t)\,\hat{e}_y$

$m\ddot{\vec{r}} = \vec{F} = -mg\,\boxed{\hat{e}_y}$



$\boxed{m\ddot{x} = 0} \rightarrow x(t) = x_0 + v_{0x}\, t$

$\boxed{m\ddot{y} = -mg}$ $\quad a = -g$

$\rightarrow y(t) = y_0 + v_{0y}\, t - \frac{1}{2} g t^2$

$v_{0x} = v_0 \cos\theta$

$v_{0y} = v_0 \sin\theta$

$y = 0$

$\boxed{x_1 \neq x_0}$

g

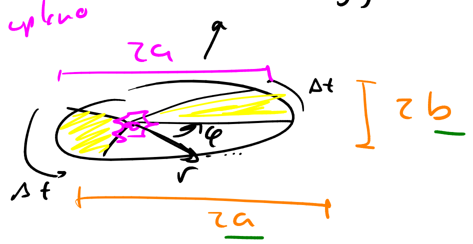
```
def x(t, theta, x0):
    return x0 + v0 * np.cos(theta) * t

def y(t, theta, y0):
    return y0 + v0 * np.sin(theta) * t - 0.5 * (9.81) * t * t

t = np.linspace(0, 100, 500)
```

Newton $\quad m\ddot{\vec{r}} = \overbrace{G\frac{Mm}{r^2}\hat{e}_r}^{\vec{F}} \longrightarrow$ L. G. U. de Newton

2^{da} ley

elipses $\longrightarrow$ 1^{ra} ley de Kepler   en un plano

$\longrightarrow$ 2^{da} ley de Kepler



$r(t)$

$\varphi(t)$

$\longrightarrow$ 3^{a} ley de Kepler $\quad T^2 \sim a^3$

$\frac{dr}{dt} = \frac{dr}{d\varphi}$

$r(\varphi) = \dfrac{A}{1 + e\cos\varphi}$ $\longrightarrow$ secciones cónicas en coordenadas polares

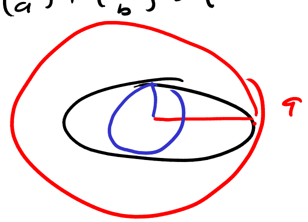
$\rightarrow$ $e = \sqrt{1 - (b/a)^2} = 0$

$\rightarrow$ Círculos $\rightarrow$ $x^2 + y^2 = r^2$

$0 < e < 1$ $\rightarrow$ Elipses $\rightarrow$ $\left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2 = 1$

$e = 1$ $\rightarrow$ Parábolas

$e > 1$ $\rightarrow$ Hipérbolas



$r(\varphi) \longrightarrow$ geométricas de las órbita $\qquad e \simeq 0.98 \to a, b$

$r(t) \longrightarrow \qquad E = \frac{1}{2}m\dot{r}^2 - \frac{GMm}{r}$

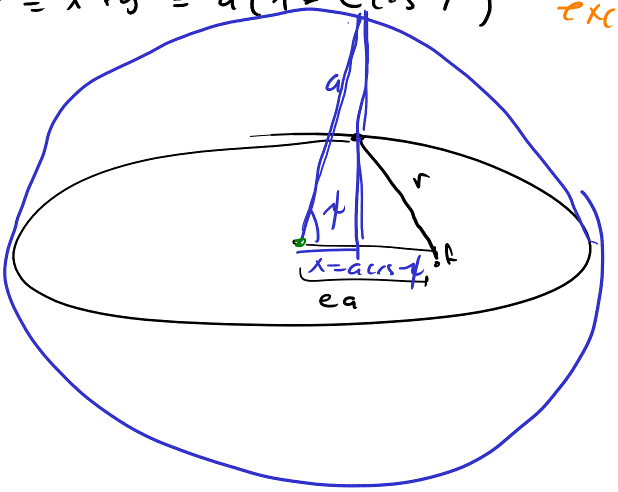
$$\dot{r} = \left(E + \frac{GMm}{r}\right)^{1/2}\left(\frac{2}{m}\right)^{1/2} = \frac{dr}{dt}$$

$$\frac{r^2}{r^2}\int dt \left(\frac{m}{2}\right)^{1/2}\frac{dr/dt}{\left(E + \frac{GMm}{r}\right)^{1/2}} = \int dt = dt$$

$x = a\cos\psi \longrightarrow r^2 = x^2 + y^2 = a^2(1 - e\cos\psi)^2$ geométrico

$y = b\sin\psi$ $\qquad$ excentricidad anómala

$r = a(1 - e\cos\psi)$



$$\frac{y^2}{b^2} = 1 - \frac{x^2}{a^2} = 1 - \cos^2\psi = \sin^2\psi$$

$$\int dt = \alpha\int_0^{\psi}(1 - e\cos\psi)\,d\psi \to t = \alpha(\psi + e\sin\psi)$$

t $\qquad$ $\alpha = 1/\omega$

Ec. de Kepler → Movimiento planetario

$$\boxed{\omega t = \psi(t) + e\sin\psi(t)} \longrightarrow \begin{cases} x = a\cos\psi \\ y = b\sin\psi \end{cases}$$

psi

Psicología

Ψ

$\psi = \psi(t)$

$0 < \omega t < 2\pi$

$\rightarrow \boxed{0 < t < \frac{2\pi}{\omega}} \rightarrow$ lista de tiempo

$$\psi - e\cos\psi - \omega t = 0$$

si $t=0$: $\boxed{\psi - e\cos\psi = f(\psi) = 0}$ → raiz   si $t=0$, $\psi = 0.15573$

si $t = \frac{\pi}{\omega}$: $\boxed{\psi - e\cos\psi - \pi = g(\psi) = 0}$ → raiz   si $t = \frac{\pi}{\omega}$, $\psi = 7.3521$

si $t = \frac{\pi 2}{\omega}$: $\psi - e\cos\psi - 2\pi = h(\psi) = 0$ → raiz   si $t = 2\pi$ → $\psi =$

```
→ time = np.linspace(0, 2π, 50)     # sup. ω = 1
→ psi_sol = []
for t in time:

    def f(psi):

        return psi - 0.8 * - t

→   psi_sol.append(bisecfun(f, [0,2π], tol, nmax))
```

$psi\_sol = [\psi_0, \psi_1, \psi_2, \dots, \psi_{50}]$