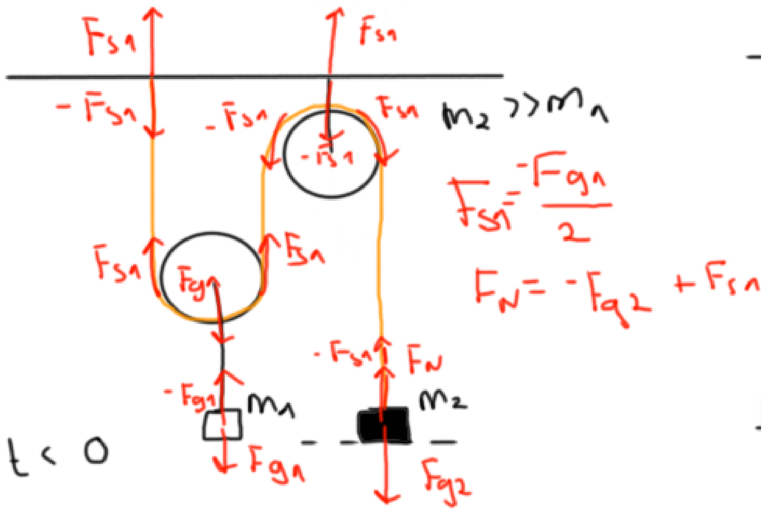
3. Exercise sheet to Experimental Physics (WS 20/21)

Name(n): Joshua Detrois, Leo Knapp, Juan Provencio

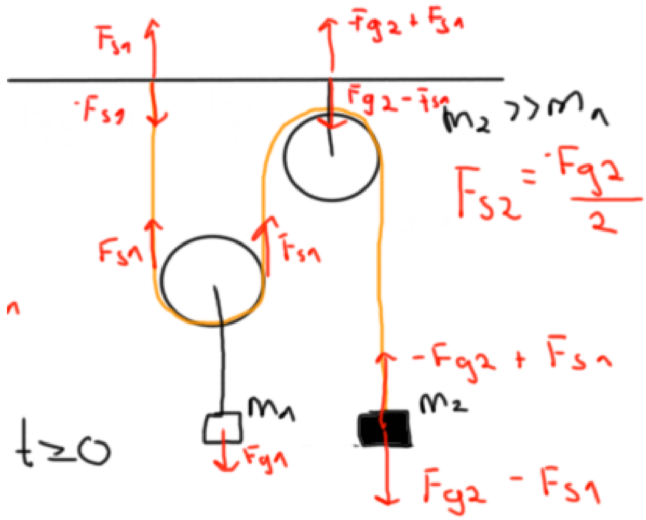
Group: F

Points: ___/___/___ Σ___

3.1 Exercise 1



a)



b)

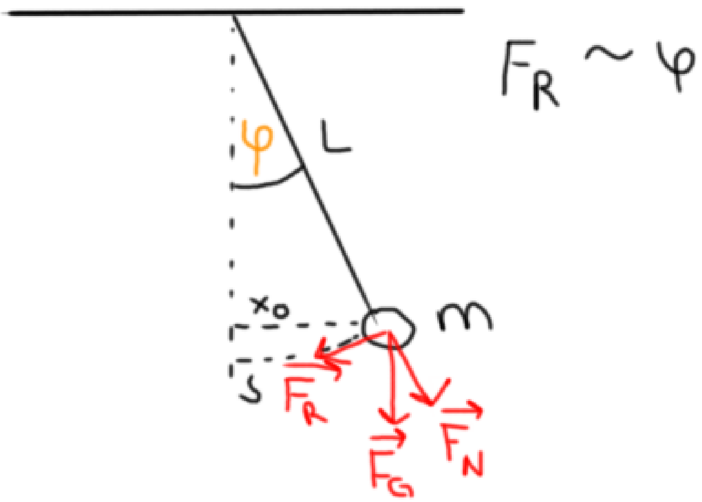
c)

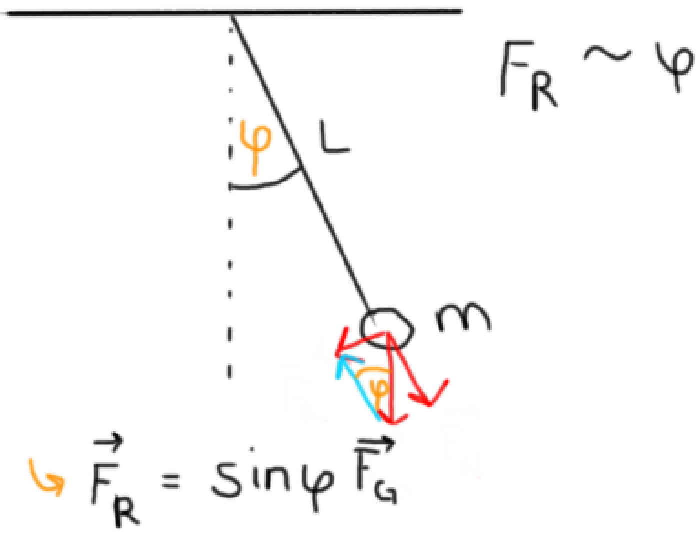
d) $\ddot{z} = \dfrac{g(m_2 - \frac{1}{2}m_1)}{m1 + m2} = \dfrac{g(\frac{1}{2}m)}{2m} = \dfrac{9.81m/s^2}{4} = 2.45m/s^2$

e) Pulleys can be used in many areas of everyday life, they are especially significant in activities that require the movement of massive objects, such as construction. The Forces required to lift things are way smaller, however, the energy required is the same. This means that the price must be paid some other way. By using pulleys, the amount of force you save is inversely proportional to the path that you must lift the object, so if something requires less force to move it, then it must be moved a further distance.

3.2 Exercise 2: Mathematical pendulum and gravitational acceleration on Earth

a) Sketch





Given:

- $F_G = mg$
- For small angles φ, $\sin\varphi \approx \varphi$ is valid

$\vec{F_R}(\varphi) = -mg\sin(\varphi)$ or $\vec{F_R}(\varphi) = -mg\varphi(t)$

$\vec{F_R} = m\vec{a_R}$

$\rightarrow \vec{a_R} = \frac{\vec{F_R}}{m} = \frac{-mg\varphi(t)}{m} = -g\varphi(t)$ with

$\vec{a_R} = l\ddot{\varphi}(t)$

$\varphi(t) = \frac{\vec{F_R}}{\vec{F_G}} = \frac{ml\ddot{\varphi}(t)}{mg} = \frac{l}{g}\ddot{\varphi}(t)$

b) Given:

- $\varphi(t) = A\sin(\omega t + \alpha)$
- $\dot{\varphi}(t) = A\omega\cos(\omega t + \alpha)$
- $\varphi(0) = \varphi_0$ i.e. $\varphi(0) = \varphi_{max}$
- $\dot{\varphi}(0) = 0$

$\dot{\varphi}(0) = 0 = A\omega\cos(\omega 0 + \alpha)$

$\rightarrow \arccos 0 = \alpha$

$\rightarrow \alpha = \frac{\pi}{2}$

$\varphi_0 = A\sin\frac{\pi}{2}$

$\rightarrow A = \varphi_0$

Now we can write the equation as:

$\varphi(t) = \varphi_0\sin(\omega t + \frac{\pi}{2})$

c) Given:

- $\omega = \frac{2\pi}{T}$
- For small angles φ, $x_0 \approx s$ is also valid
- $a = \frac{-\vec{F_R}}{m} = \frac{-mg\sin\varphi}{m} = -g\varphi(t)$

$\rightarrow s(t) = L\sin\varphi$ with $\varphi = \omega t$

$\rightarrow a = \frac{-gs(t)}{L}$

$a = \ddot{s}(t) = -L\omega^2\sin wt$

$\rightarrow \frac{-gs(t)}{L} = -L\omega^2\sin wt$

Insert $s(t)$ in a:

$\rightarrow -g\sin\omega t = -L\omega^2\sin\omega t$

$\rightarrow -g = L\omega^2$

$\rightarrow \omega = \sqrt{\frac{L}{g}}$

d) Given:

- $g_{Paris} = 9.810 m/s^2$
- $T = 2\pi\sqrt{\frac{L}{g}}$

$$\rightarrow g = \frac{2^2\pi^2 L}{T^2}$$

- In Cayenne, it takes the pendulum clock $150s$ longer to reach the number of oscillations that the clock makes in one day in Paris

Number of oscillations N:

$$N = \frac{86400s}{T} = \frac{86400s}{2\pi\sqrt{\frac{l}{g}}}$$

let $l = 1m$

$$\rightarrow N = \frac{86400s}{2\pi\sqrt{g}}$$

The clock in Cayenne takes $86400s + 150s$ to complete N oscillations:

$$\rightarrow T = \frac{86550s}{N} = \frac{86550}{(\frac{86400s}{2\pi\sqrt{g}})} \rightarrow \text{Insert in g:}$$

$$g = \frac{2^2\pi^2 1m}{(\frac{86550s}{(\frac{86400s}{2\pi\sqrt{g}})})^2}$$

$$g_{Cayenne} = 9.776m/s^2$$

3.3 Exercise 3

a) Given:

- $L = 20m$
- $\lambda = \frac{M}{L}$
- $x(0) = 0.1L$

The total force is the difference between the Force on the right and the one on the left

$$F = F_r - F_l$$

$$\rightarrow F = 2\Delta x\lambda g + x_0\lambda g$$

$$a = \frac{2\Delta x\lambda g + x_0\lambda g}{M}$$

$$= \frac{2\Delta xg + x_0 g}{L}$$

$$= \frac{2\Delta xg}{20m} + \frac{2mg}{20m}$$

$$= \frac{\Delta xg}{10m} + \frac{g}{10m}$$

$$\rightarrow \ddot{x} = \frac{\Delta xg}{10m} + \frac{g}{10m}$$

$$\ddot{x} - \frac{gx}{10m} = \frac{g}{10m}$$

b) $x(t) = C_1 e^{\sqrt{\frac{g}{10}}t} + C_2 e^{-\sqrt{\frac{g}{10}}t} - 1$

$x(0) = x_0 = C_1 + C_2 - 1$

$\dot{x}(0) = 0 = \sqrt{\frac{g}{10}} C_1 - \sqrt{\frac{g}{10}} C_2$

$\rightarrow C_1 = C_2 = C$

$x_0 = 2C - 1$

$x(t) = (\frac{x_0}{2} + \frac{1}{2}) e^{\sqrt{\frac{g}{10}}t} + (\frac{x_0}{2} + \frac{1}{2}) e^{-\sqrt{\frac{g}{10}}t} - 1$

c) $0.2L = 0.2 \cdot 20m = 4m$

$\rightarrow 4 = (\frac{x_0}{2} + \frac{1}{2})(e^{\sqrt{\frac{g}{10}}t} + e^{-\sqrt{\frac{g}{10}}t}) - 1$

$\rightarrow \frac{10}{3} = e^{\sqrt{\frac{g}{10}}t} + e^{-\sqrt{\frac{g}{10}}t}$

$t = 1.1092s$