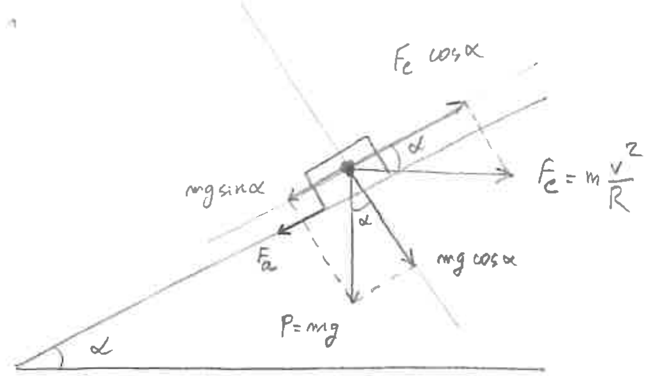
1.

a)



$$\cancel{m}g\sin\alpha + \overbrace{f_a}^{f_a}\cancel{m}g\cos\alpha = \cancel{m}\frac{v^2}{R}\cos\alpha$$

$$g(\sin\alpha + f_a\cos\alpha) = \frac{v^2}{R}\cos\alpha$$

α pequeno $\rightarrow$ $\sin\alpha \simeq \tan\alpha \simeq S_e$, $\cos\alpha \simeq 1$

$$\boxed{\tan\alpha + f_a = \frac{v^2}{9.8\,R}}$$

g em m/s^2, v em m/s

$$1\ m/s = \frac{0.001}{\frac{1}{3600}}\ km/h = 3.6\ km/h$$

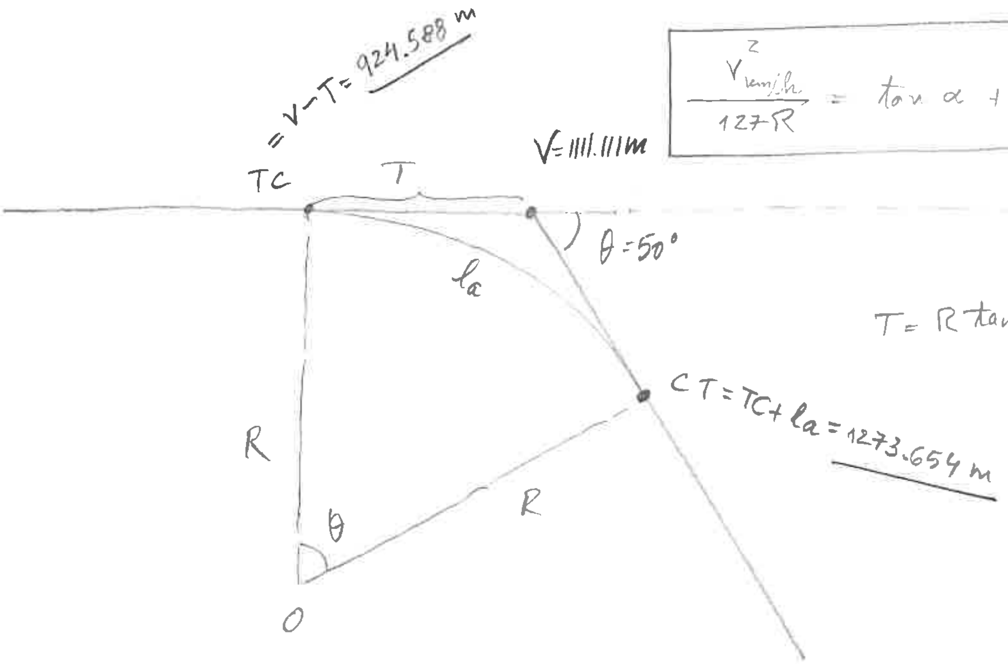
$$1\ km/h = \frac{1}{3.6}\ m/s$$

$$\frac{V_{km/h}^2}{9.8 \times 3.6^2 R} = \tan\alpha + f_a$$

$$\frac{V_{km/h}^2}{127.008\,R} = \tan\alpha + f_a$$

b)

$$\boxed{\frac{V_{km/h}^2}{127\,R} = \tan\alpha + f_a}$$



$$T = R\tan\frac{\theta}{2} = 186.523\ m$$

$$R_m = \frac{V_{km/h}^2}{127(\tan\alpha + f_a)} = \frac{105^2}{127(0.07 + 0.15)} = 394.596\ m \rightarrow R = 400\ m$$

- $L_s^{min}(m) = \dfrac{V_{km/h}^3}{46.656\, R\, \frac{dac}{dt}} = \dfrac{105^3}{46.656 \times 400 \times 0.6} = 103.383$ m

- $l_a^{inicial} = R\theta = 400 \times \dfrac{50}{180} \times \pi = 349.066$ m

- $L_s^{max}(m)$: $\theta - 2\Delta^{max} = 0 \rightarrow \Delta^{max} = \dfrac{\theta}{2} = 25°$

  $L_s^{max} = 2R\Delta^{max} = 349.066$ m

- recomenda-se $L_s = 2 \times L_s^{min} = 206.766$ m

- $\Delta = \dfrac{L_s}{2R} = 0.2584575$ rad $= 14.808524$

- $l_a^{final} = R(\theta - 2\Delta) = 142.300$ m

- $X = L_s\left(1 - \dfrac{\Delta^2}{10} + \dfrac{\Delta^4}{216} - \dfrac{\Delta^6}{9360}\right) = 205.389$ m

  $Y = L_s\left(\dfrac{\Delta}{3} - \dfrac{\Delta^3}{42} + \dfrac{\Delta^5}{1320} - \dfrac{\Delta^7}{75600}\right) = 17.729$ m

- $\theta = Y - R(1 - \cos\Delta) = 4.443$ m

- ripagem $= \theta / \cos(\theta/2) = 4.902$ m

- $T_s = X - R\sin\Delta + R\tan\dfrac{\theta}{2} + \theta \tan\dfrac{\theta}{2} = 291.748$ m

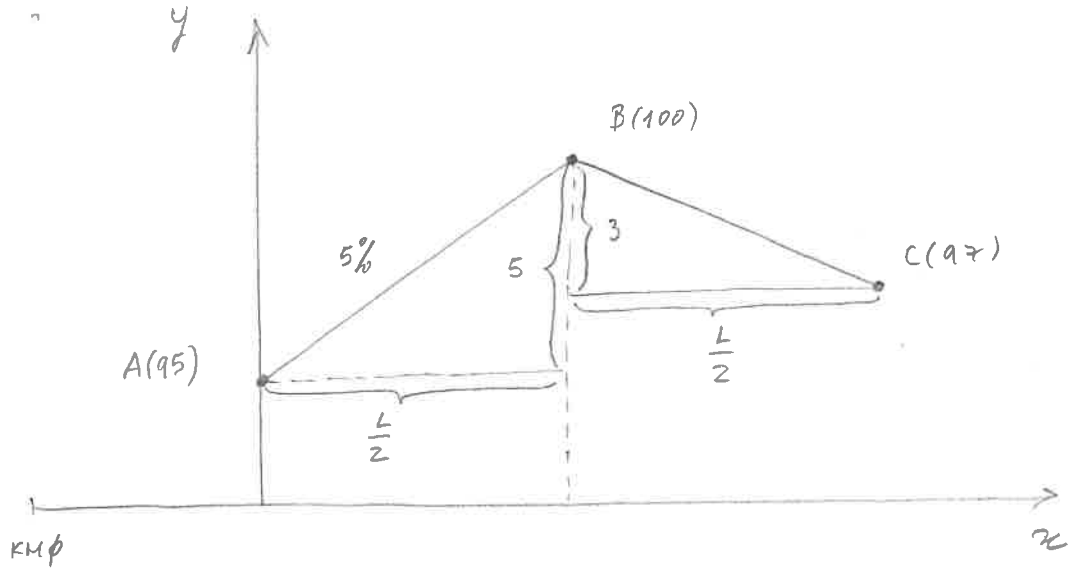
- $V = 1111.111$ m

  $TC = V - T = 924.588$ m $CS = SC + L_a^{final} = 1168.429$ m

  $TS = V - T_s = 819.363$ m $ST = CS + L_s = 1375.195$ m

  $SC = TS + L_s = 1026.129$ m $CT = TC + l_a^{inicial} = 1273.654$ m

2.



a) $\frac{dy}{dx} = 5\% = 0.05 = \frac{100-95}{\frac{L}{2}} \Rightarrow \frac{L}{2} = \frac{5}{0.05} \Rightarrow L = 200\ m$

b) $\frac{dy}{dx} = \frac{97-100}{\frac{L}{2}} = \frac{-3}{100} = -3\%$

c) $\frac{d^2y}{dx^2} = r = \text{const}$ ao longo da curva parabólica vertical

$$\downarrow$$

$$\frac{dy}{dx} = rx + H; \begin{cases} \text{em A: } 0.05 = H \\ \text{em B: } -0.03 = 200r + 0.05 \Rightarrow r = \frac{-0.08}{200} = -0.0004 \Rightarrow \frac{dy}{dx} = -0.0004x + 0.05 \end{cases}$$

no ponto máximo da curva, $\frac{dy}{dx} = 0 \Rightarrow 0.0004\, x_M = 0.05 \Rightarrow x_M = \frac{0.05}{0.0004} = 125\ m$

$$y = -0.0004\frac{x^2}{2} + 0.05x + y_A = -0.0002x^2 + 0.05x + 95$$

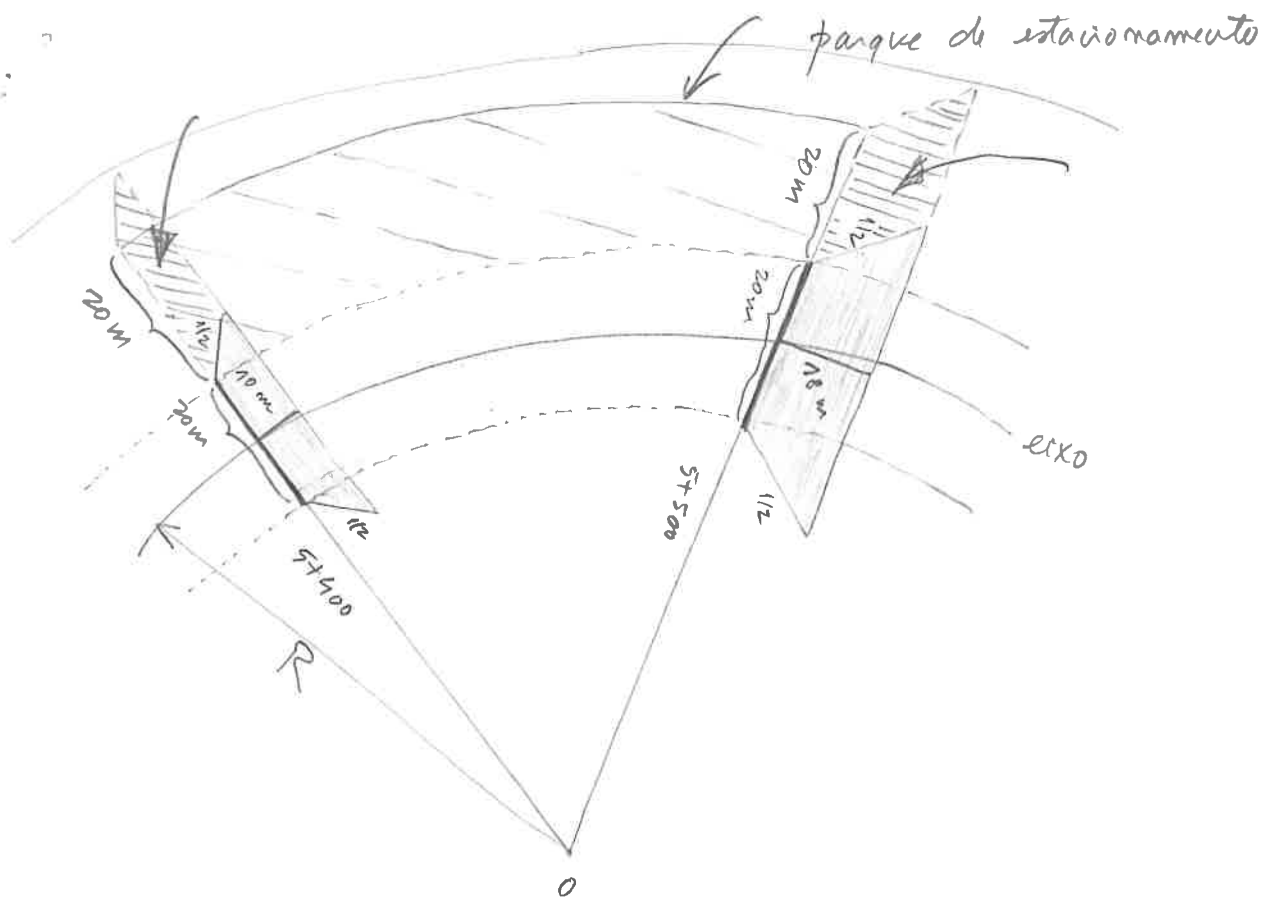
$$y_M = -0.0002x_M^2 + 0.05x_M + 95 = 98.125\ m$$

d) $\text{Km } M = \text{km } B - 100 + 125 = 12370.678\ m$

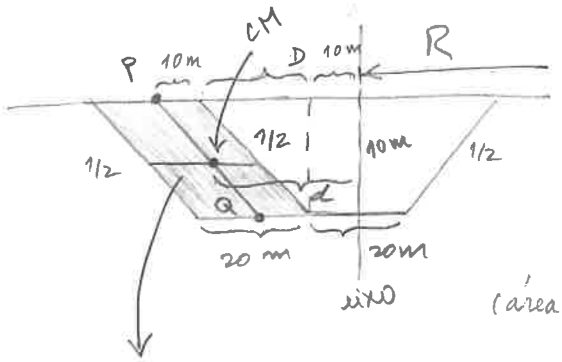
e) sendo $S > L$, $L_{min} = 2 \times 250 - \frac{200(\sqrt{1.0} + \sqrt{0.15})^2}{|5-(-3)|} = 451.885\ m$

para se garantir $S = 250\ m$, o desenvolvimento da curva vertical deverá ser ≥ 451.885, pelo que neste caso, sendo $L = 200\ m$, não é possível garantir a distância de visibilidade pretendida.

3.



5+400



(área paralelipípedo = base × altura)

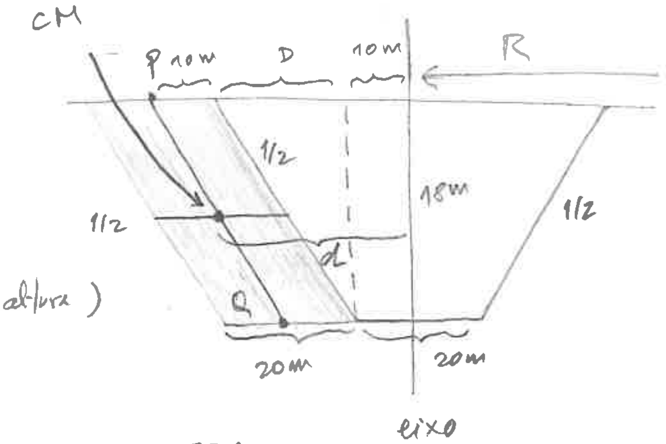
$$A^{5400} = 10\times 20 = 200\ m^2$$

$$\frac{1}{2} = \frac{10}{D} \Rightarrow D = 20\ m$$

$$d = \frac{x_P + x_Q}{2} = \frac{(10+20+10)+(10+10)}{2} = 30m$$

$$A_c^{5400} = A\left(1+\frac{d}{R}\right) = 200\left(1+\frac{30}{750}\right) = 208\ m^2$$

5+500



$$A^{5500} = 20\times 18 = 360\ m^2$$

$$\frac{1}{2} = \frac{18}{D} \Rightarrow D = 36\ m$$

$$d = \frac{x_P + x_Q}{2} = \frac{(10+36+10)+(10+10)}{2} = 38\ m$$

$$A_c^{5500} = A\left(1+\frac{d}{R}\right) = 360\left(1+\frac{38}{750}\right) = 378.24\ m$$

$$V = \frac{A_c^{5400} + A_c^{5500}}{2}\times 100 = \frac{208+378.24}{2}\times 100 = 29\,312\ m^3$$

4. $R_{P_1P_2} = \operatorname{atan}\dfrac{M_2 - M_1}{P_2 - P_1} = \operatorname{atan}\dfrac{29688.444 - 29231.824}{11760.582 - 12031.688} = \operatorname{atan}\dfrac{456.620}{-271.106} = 120°.6986$

suponde
$$\begin{cases} R_{P_1A'} = 150° \\ M_{A'} = M_{P_1} + d_1 \sin R_{P_1A'} = 29231.824 + 121.014 \times \sin 150° = 29292.331\ m \\ P_{A'} = P_{P_1} + d_1 \cos R_{P_1A'} = 12031.688 + 121.014 \times \cos 150° = 11926.887\ m \end{cases}$$

$$\begin{cases} R_{A'B'} = R_{P_1A'} - 180° + \alpha_1 = 90°.6251 \\ M_{B'} = M_{A'} + d_2 \sin R_{A'B'} = 29292.331 + 262.428 \times \sin 90°.6251 = 29554.743\ m \\ P_{B'} = P_{A'} + d_2 \cos R_{A'B'} = 11926.887 + 262.428 \times \cos 90°.6251 = 11924.024\ m \end{cases}$$

$$\begin{cases} R_{B'C'} = R_{A'B'} - 180° + \alpha_2 = 50°.9685 \\ M_{C'} = M_{B'} + d_3 \sin R_{B'C'} = 29554.743 + 223.208 \times \sin 50°.9685 = 29728.131\ m \\ P_{C'} = P_{B'} + d_3 \cos R_{B'C'} = 11924.024 + 223.208 \times \cos 50°.9685 = 12064.589\ m \end{cases}$$

$$\begin{cases} R_{C'P'_2} = R_{B'C'} - 180° + \alpha_3 = 164°.5236 \\ M_{P'_2} = M_{C'} + d_4 \sin R_{C'P'_2} = 29728.131 + 110.798 \times \sin 164°.5236 = 29757.696\ m \\ P_{P'_2} = P_{C'} + d_4 \cos R_{C'P'_2} = 12064.589 + 110.798 \times \cos 164°.5236 = 11957.808\ m \end{cases}$$

$$R_{P_1P'_2} = \operatorname{atan}\frac{M_{2'} - M_1}{P_{2'} - P_1} = \operatorname{atan}\frac{29757.696 - 29231.824}{11957.808 - 12031.688} = \operatorname{atan}\frac{525.872}{-73.880} = 97°.9972$$

$$R_{P_1P'_2} + w = R_{P_1P_2} \rightarrow w = 22°.7014$$

$$\begin{cases} M_A = M_{P_1} + d_1 \sin(150° + 22.7014) = \underline{29247.198\ m} \\ P_A = P_{P_1} + d_1 \cos(150° + 22°.7014) = \underline{11911.655\ m} \end{cases}$$

$$\begin{cases} M_B = M_A + d_2 \sin(90°.6251 + 22°.7014) = \underline{29488.176\ m} \\ P_B = P_A + d_2 \cos(90°.6251 + 22°.7014) = \underline{11807.741\ m} \end{cases}$$

$$\begin{cases} M_C = M_B + d_3 \sin(50°.9685 + 22°.7014) = \underline{29702.379\ m} \\ P_C = P_B + d_3 \cos(50°.9685 + 22°.7014) = \underline{11870.501\ m} \end{cases}$$

$$\begin{cases} M_{P_2} = M_C + d_4 \sin(164°.5236 + 22°.7014) = \underline{\underline{29688.444\ m}} \\ P_{P_2} = P_C + d_4 \cos(164°.5236 + 22°.7014) = \underline{\underline{11760.583\ m}} \end{cases}$$