RAILWAY ENGINEERING

PROF. RICCARDO LICCIARDELLO

RAILWAY PROJECT

ANALYZING THE RAILWAY LINE OF THE

CASTEL LAGOPESOLE – POTENZA CENTRALE

STUDENT:

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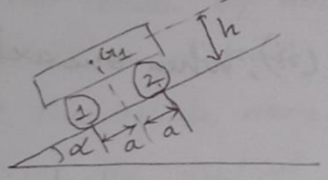
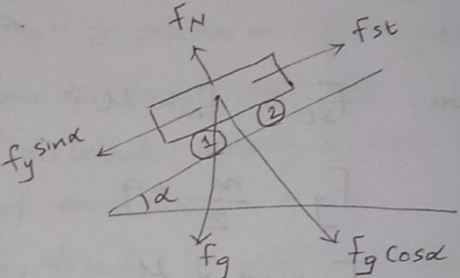
Project WORK - I.

Calculation of Maximum slope

A Two-axle vehicle with is @ standstill on a slope

1. Calculate the ~~maximum~~ maxi-slope [°/°] both axles are braked.
2. Calculate the maximum-slope in standstill condition, when the only one axle is braked.





μ (or) $\phi = 0.2$

$h = 1.2m$

$a = 1.4m.$

Applying Equilibrium Conditions

$\Sigma F = 0$ $\qquad f_g \sin\alpha = f_{st} \rightarrow (1)$

$\qquad f_g \cos\alpha = f_N \rightarrow (2)$

Where, $f_{st} = f_N \times \mu \rightarrow (3)$ (Normal Force × friction)

$f_g = m \times \underset{g \text{ substitute}}{a}$ (mass × acceleration).

$(3) \Rightarrow \quad f_{st} = f_g \cos\alpha \times \mu$

$F_{st} = m \times g \times \cos\alpha \times \mu.$

$f_g \sin\alpha = mg\cos\alpha \times \mu.$

$\cancel{mg} \sin\alpha = \cancel{mg} \cos\alpha \times \mu$

$\frac{\sin\alpha}{\cos\alpha} = \mu$

$\tan\alpha = \mu$

$\alpha = \tan^{-1}(\mu) \Rightarrow \tan^{-1}(0.2)$

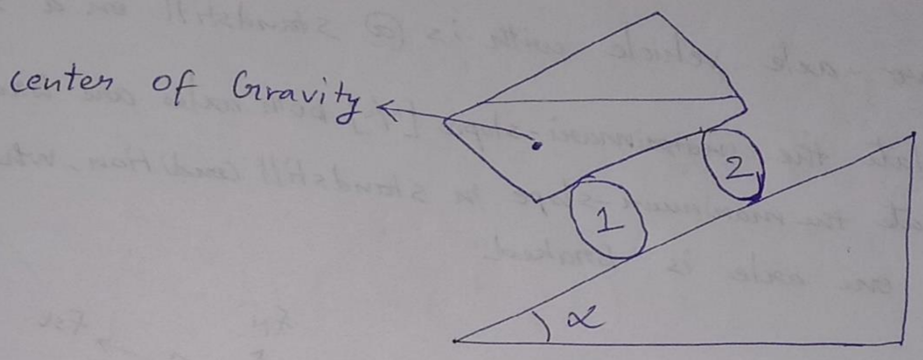
$\alpha = 11.3$, (Case (i), when both axles are braked)

Applying Equilibrium Conditions,

$\Sigma F=0$,

$$F_g \sin\alpha = F_{st} \rightarrow (4)$$

$$F_g \cos\alpha = F_N \rightarrow (5)$$



Where, $F_{st} = F_N \times \mu$

$$F_g = \frac{m}{2} \times g$$

$$F_{st} = F_g \cos\alpha \times \mu$$

$$F_{st} = \frac{m}{2} \times g \times \cos\alpha \times \mu$$

$$F_g \sin\alpha = F_{st}$$

$$m \times g \sin\alpha = \left(\frac{m}{2} \times g\right) \times \cos\alpha \times \mu$$

$$\frac{\cancel{m} \times \cancel{g} \sin\alpha}{\frac{\cancel{m}}{2} \times \cancel{g} \times \cos\alpha} = \mu$$

$$2 \tan\alpha = \mu$$

$$\alpha = \tan^{-1}(\mu/2)$$

$$\alpha = 5.71.$$

[Case (ii), when one axle is brake

When the vehicle is gettin down in a slope, the load on the vehicle is more on the rear wheel, when comp to ~~to~~ front wheel.

$$W_{rear\ wheel} > W_{front\ whe}$$

So, Applying break only for the rear wheel is safer.

But for shear forle,

$$F_{st} = m \times g.$$

Because, it acts opposite direction for the total load of the vehicle.

Project WORK - II

Calculation of force on flange in a curve. Consider a railway vehicle with two axles and idealysed cylindrical wheels. During low-speed cornering (negligible inertia), the flange of the front wheel (A) is in lateral contact with the rail and receives a force h_1.

→ The flange of other wheels are not in contact with the rail ("free attitude"). The wheel set is torsionally rigid.

→ The centre of rotation "O" is placed on the longitudinal axis @ a distance x from the front axle AB.

→ The vehicle mass M is distributed equally on each wheel. P is the vertical force of each wheel.

→ Calculate the value of h_1 & h_1/P for different values of co-efficient of friction.

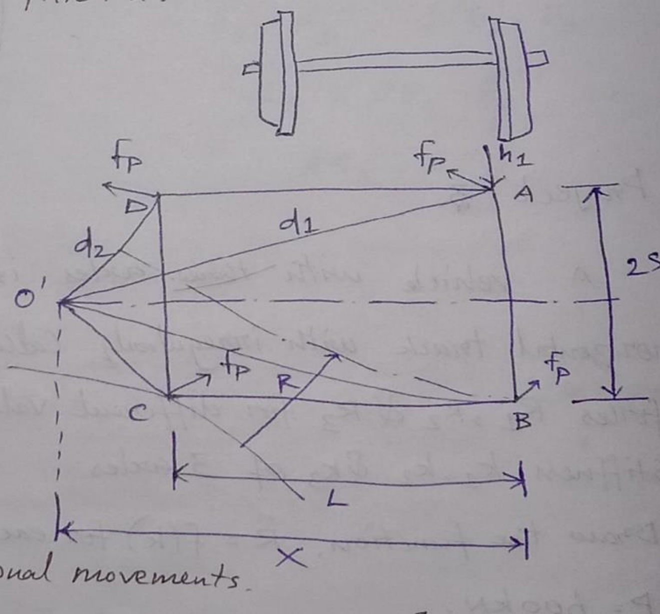
$X = 2.75m$

$L = 2.50m.$

$2S = 1.5m$

$f = 0.1$ to 0.3

$M = 8$ tonnes



We have D.O.F = 3. (Degrees of freedom)

Relate to both Translational & Rotational movements.

$\Sigma F_z = 0$ [Forces from wheels & Rails].

$\Sigma F_y = 0$ [all lateral forces, speed$_{Low}$ = C.F is less Centrifugal force]

$\Sigma F_x = 0$ [Negligible due to low rolling resistance].

Applying Momentum Conditions,

$$\Sigma m_a + \Sigma m_h = 0$$

By using Pythogoros Theorem

$$d_1 = \sqrt{x^2 + s^2}$$

$$d_2 = \sqrt{(x-L)^2 + s^2}$$

$$\Sigma f d_i P_i - h_1 x = 0.$$

$$d_1 = 2.85m.$$

$$d_2 = 0.79m.$$

$$f d_A P_A + f d_B P_B + f d_C P_C + f d_D P_D = h_1 x$$

$$h_1 = \frac{[f d_A P_A + f d_B P_B + f d_C P_C + f d_D P_D]}{x}$$

Here, $d_A = d_B = d_1 = 2.85m.$

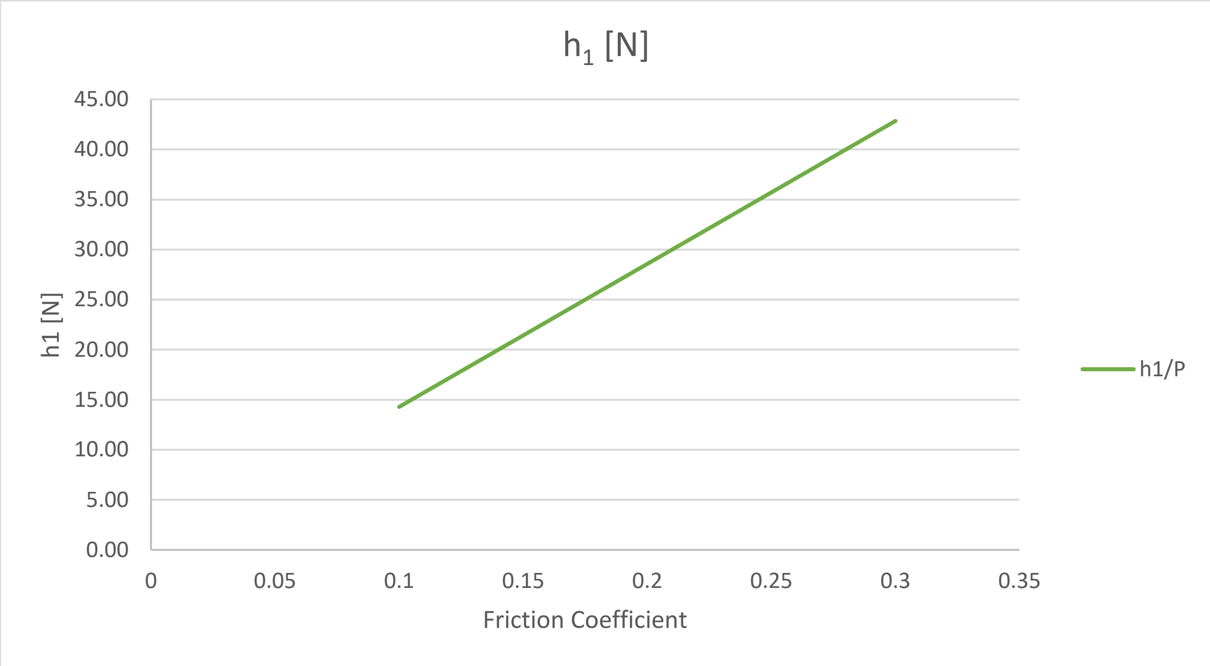
$d_C = d_D = d_2 = 0.79m.$

$x = 2.75m.$

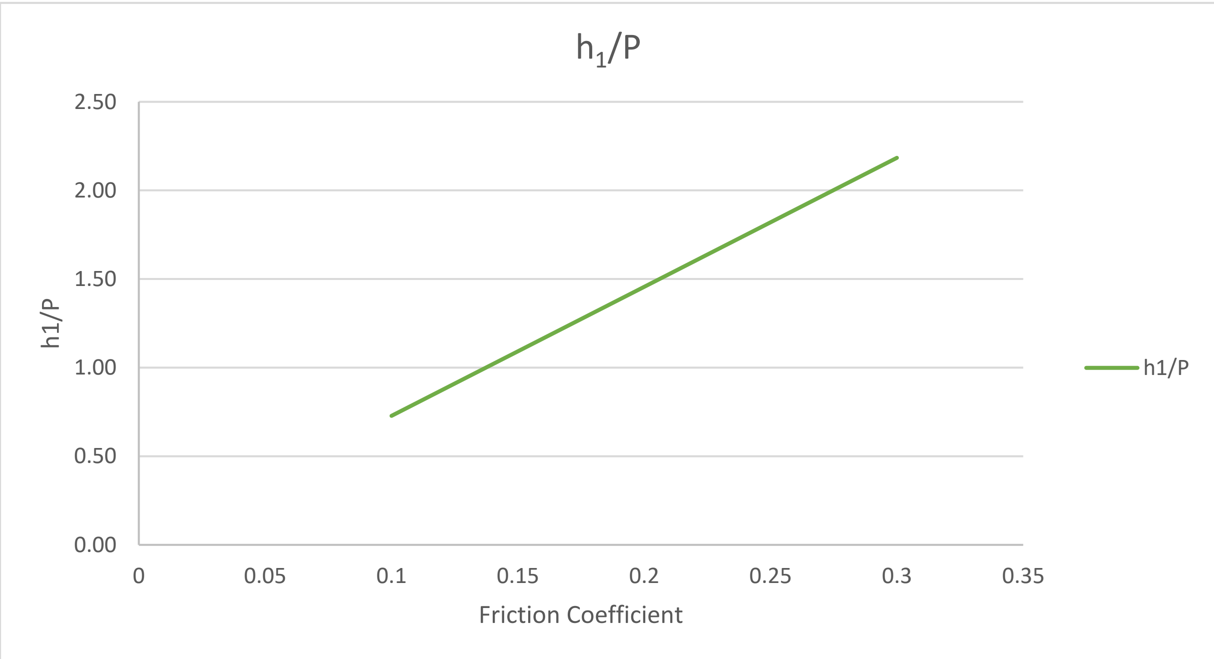
$P = 20kN.$ $\Rightarrow$ $\left\{ \begin{array}{l} m = 8 \text{ tonnes.} \\ P = \frac{8 \times 9.81}{4} \Rightarrow 20 kN \text{ (approx)} \end{array} \right.$

P shares equally (four wheels).

S.no	f	d_1 [m]	d_2 [m]	P [N]	x [m]	h_1 [N]	h_1/P
1	**0.1**	2.85	0.79	20	2.75	14.28	**0.73**
2	**0.125**	2.85	0.79	20	2.75	17.85	**0.91**
3	**0.15**	2.85	0.79	20	2.75	21.43	**1.09**
4	**0.175**	2.85	0.79	20	2.75	25.00	**1.27**
5	**0.2**	2.85	0.79	20	2.75	28.57	**1.46**
6	**0.225**	2.85	0.79	20	2.75	32.14	**1.64**
7	**0.25**	2.85	0.79	20	2.75	35.71	**1.82**
8	**0.275**	2.85	0.79	20	2.75	39.28	**2.00**
9	**0.3**	2.85	0.79	20	2.75	42.85	**2.18**



h1 [N]
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
h1 [N]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Friction Coefficient
h1/P



h1/P
2.50
2.00
1.50
1.00
0.50
0.00
h1/P
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Friction Coefficient
h1/P

Project - 3.

A vehicle with three axles is stationary on a horizontal track with irregularity. Calculate the vertical contact forces R_1, R_2 & R_3 for different values of the suspension stiffness k_1, k_2 & k_3 of 3 axles.

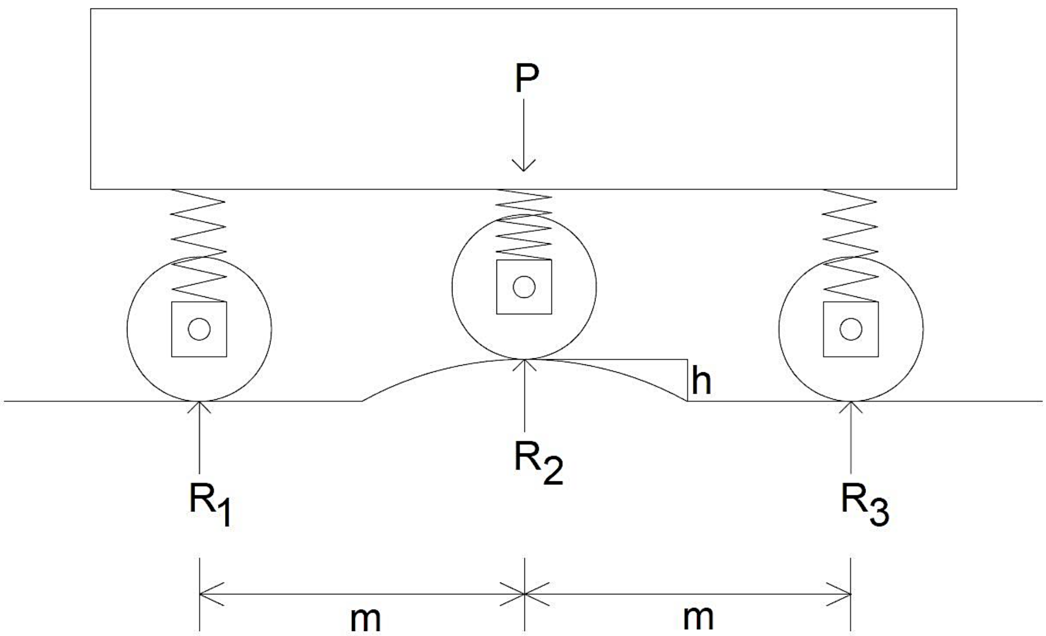
Draw the function, $R = f(k)$ for each axle.

$P = 600\,kN$.

$k_1 = k_2 = k_3 = 1,\ 10,\ 50\ kN/mm$

$m = 1500\,mm = 1.5\,m$.

$h = 2\,mm = 0.002\,m$.



Axle load distribution,

Equilibrium condition,

$\Sigma F = 0 \quad ; \quad R_1 + R_2 + R_3 = P$

$\Sigma M = 0 \quad ; \quad R_3(m+m) + R_2 \times m = P \times m.$

$R_1 = k_1 \times E_1$

$R_2 = k_2 \times (E_2 + h)$

$R_3 = k_3 \times E_3$

$k_1 E_1 + k_2 (E_2 + h) + k_3 E_3 = 600$

$R_3(2m) + R_2 m = Pm$

$\div$ By m

$2R_3 + R_2 = P$

$2k_3 E_3 + k_2 (E_2 + h) = 600$

where, $R_1 = R_3$

$k_1 . E_1 = k_3 . E_3$

if, $k_1 = k_3 = 1$

$\boxed{E_1 = E_3}$

Geometric congraity condition.

$$\frac{E_1 - E_3}{m+m} = \frac{E_2 - E_3}{m}.$$

multiplying by m.

$E_1 - E_3 = 2(E_2 - E_3).$

$E_1 = 2E_2 - E_3 \quad \therefore E_1 = E_3$

$\cancel{2} E_3 = \cancel{2} E_2$

$\boxed{E_1 = E_2 = E_3 = E}$

For, $k_1 = k_2 = k_3 = 1$ kN/mm

$\therefore \Sigma F = 0, \quad P = R_1 + R_2 + R_3$

$600 = k(E_1 + E_2 + h + E_3) \quad \therefore h = 2mm$

$\frac{600}{1} = E + E + h + E$

$600 = 3E + h.$

$E = \frac{600 - h}{3}$

$E = \frac{600 - 2}{3} = \frac{598}{3}$

$\boxed{E = 199.33 mm.}$

$R_1 = R_3 = k \times E = 1 \times 199.33 = 199.33$ kN.

$R_2 = k(E+h) = 1 \times (199.33 + 2) = 201.33$ kN.

|||ly, $k_1 = k_2 = k_3 = 10$ kN/mm.

$E = 19.33$ mm, $R_1 = R_3 = 193.33$ kN.

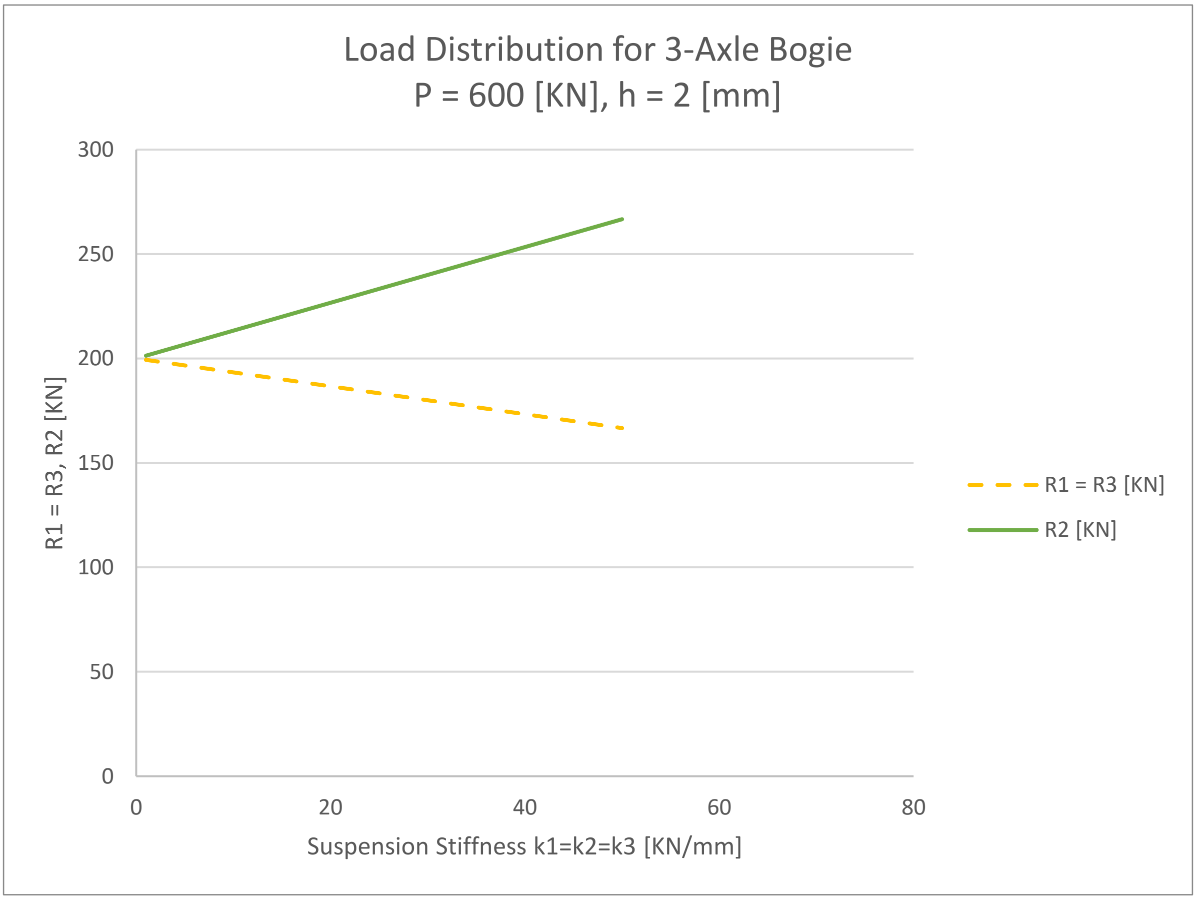
$R_2 = 213.33$ kN.

similarly, $k_1 = k_2 = k_3 = 50$ kN/mm

$E = 3.33$ mm, $R_1 = R_3 = 166.67$ kN

$R_2 = 266.67$ kN.

S.no	P [KN]	k [KN/mm]	E [mm]	$R_1 = R_3$ [KN]	R_2 [KN]
1	600	1	199.33	199.33	201.33
2	600	10	19.33	193.33	213.33
3	600	50	3.33	166.67	266.67



Project WORK - IV

Vertical acceleration & Frequenly.

a) For a Wheel travelling @ speed V on an irregular profile determine

→ Vertical Average speed.

→ Vertical Average acceleration.

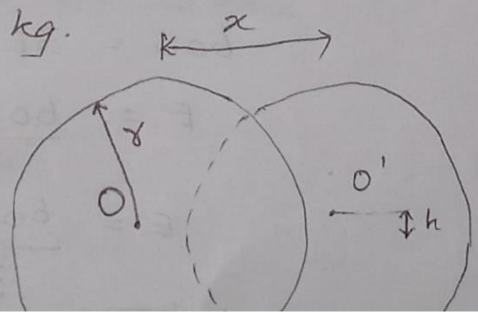
→ Vertical Average inertia force of the center of gravity.

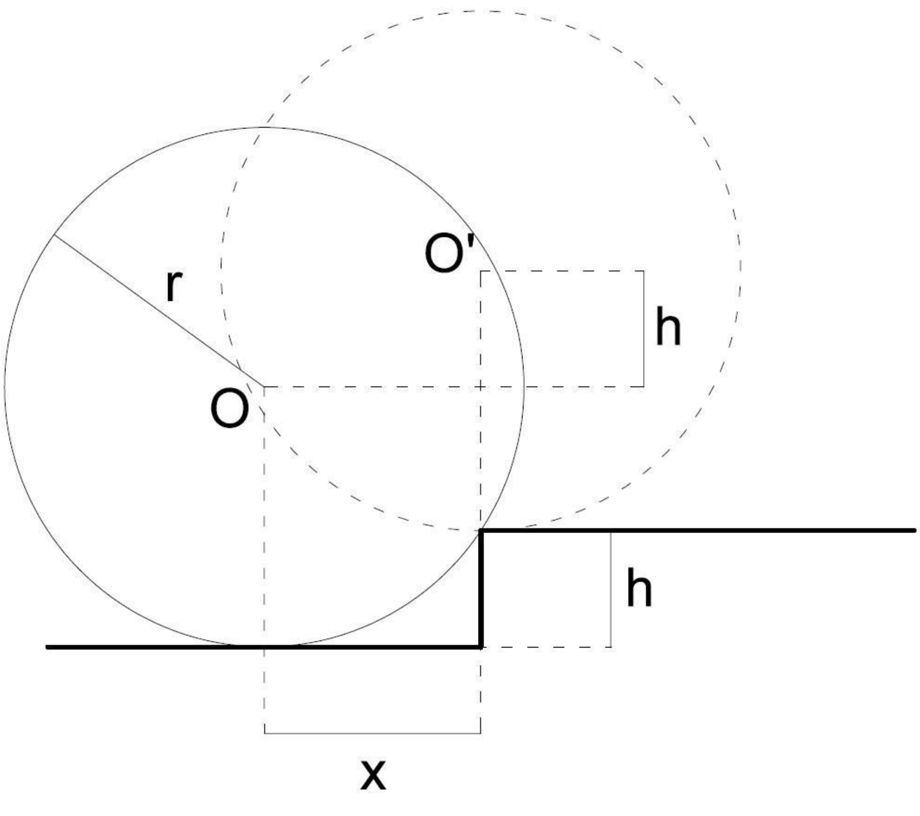
Data: Speed: V = 25, 50, 100 km/hr.

Radius of the Wheel: 0.5m.

Irregularity, h = 0,8mm

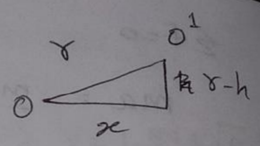
mass, M = 1000 kg.





By using pythogorus theorem,

$$x = \sqrt{r^2 - (r-h)^2}$$



$$x = \sqrt{(0.5)^2 + \left(0.5 - \frac{0.8}{1000}\right)^2}$$

$$\boxed{x = 28.3\,mm.}$$

Time needed for Displacement, $T_x = \frac{x}{V}$

Vertical speed, $V = h/T_x$.

Average vertical acceleration, $a = \frac{V}{T_x}$

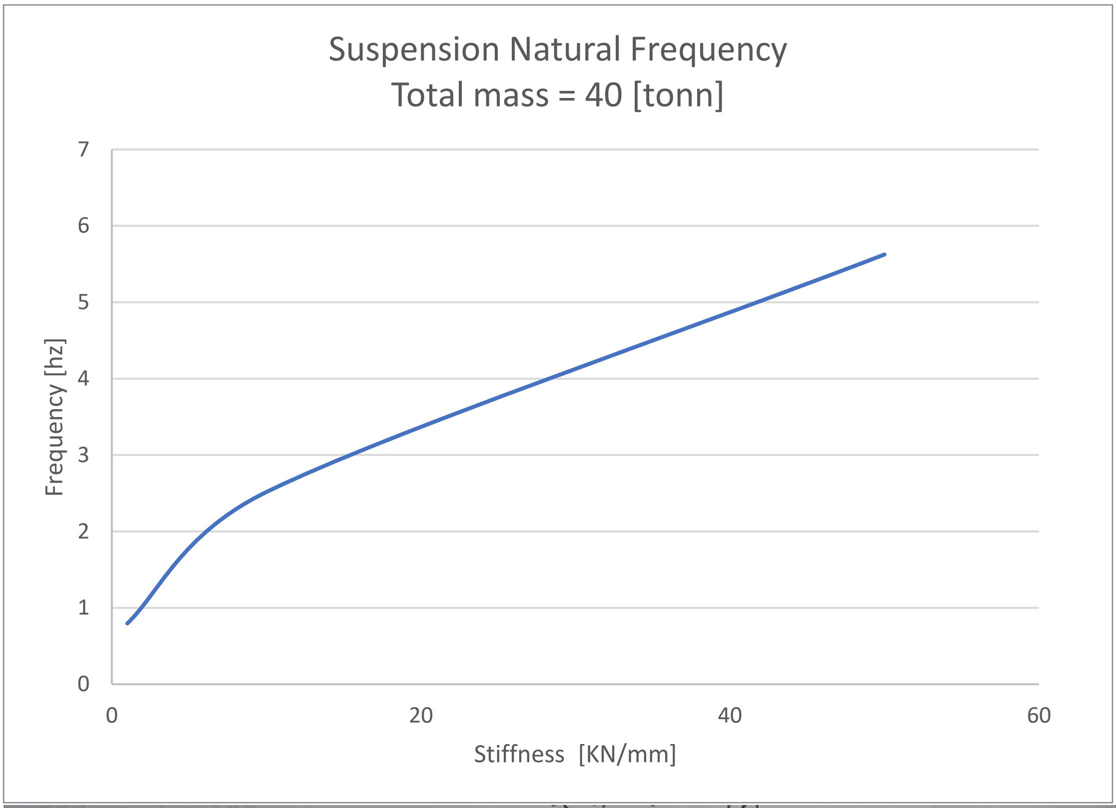
1000kg
$M = 1$ ton
$= 1 \times 10N$
$= 10N$
$M = 10N$

Vertical Average inertia forle, $f = M \times a$

Frequency, $F = \frac{1}{2\pi}\sqrt{k/m}$

S.no	M [tonn]	m [tonn]	V [km/hr]	V [m/s]	x [m]	h [mm]	k [KN/mm]
1	1	40	25	6.94	0.028	0.8	1
2	1	40	50	13.89	0.028	0.8	10
3	1	40	100	27.78	0.028	0.8	50

S.no	$T_x = x/V$ [s]	$V = h/T_x$ [m/s]	$a = V/T_x$ [m/s^2]	F = M * a [KN]	f = (1/2π)*(√k/m) [hz]
1	0.004	0.196	48.07	48.07	0.80
2	0.002	0.392	192.28	192.28	2.52
3	0.001	0.784	769.12	769.12	5.62



Project work - V

Running of vehicles along curves.

1.) Constrains arising from comfort

a.) Determine for std. gauge (1435 mm) the $speed_{max}$ in curves of different radius : $\left\{ \begin{array}{l} \text{in absence of cant } (h=0) \\ \text{with cant } (h=160\text{mm}) \end{array} \right.$

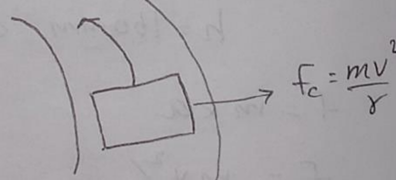
corresponding to unbalanced lateral acceleration $= 0.6,\ 0.8,\ 1.0\ m/s^2$.

Case (i) [No cant].

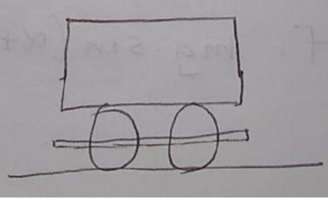
if $h=0$

II^{nd} Law of Newton.

$$F = m \times a$$



C.F (Centrifugal force) , $F = \frac{m \times v^2}{r}$



$\Sigma f = 0$

$$ma = \frac{mv^2}{R}$$

$$a = \frac{v^2}{R}$$

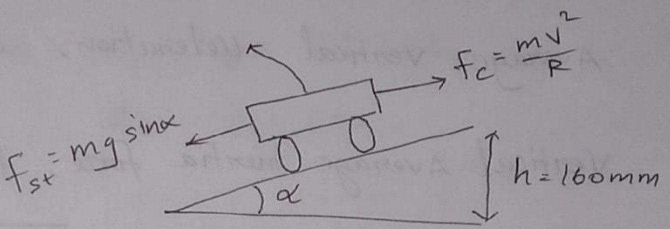
$V = \sqrt{a \times R} \Rightarrow$ @ $a = 0.6\,m/s^2 \Rightarrow V = 0.76\sqrt{R}\ m/s$

@ $a = 0.8\,m/s^2 \Rightarrow V = 0.894\sqrt{R}\ m/s$

@ $a = 1\,m/s^2 \Rightarrow V = \sqrt{R}\ m/s$.

case (ii)

$h = 160\,mm.$



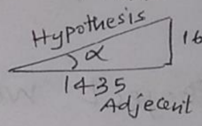
$f = m \times a$

$F \cancel{m} = \frac{mv^2}{R}$.

$\tan\alpha = h/_{\text{Std guage}} \Rightarrow 160/_{1435}$

$f = mg\sin\alpha$

$\alpha = 6.36°$



$\tan\alpha = \frac{OPP}{Adj}$

$$m \times a + mg\sin\alpha = \frac{mv^2}{R}$$

$$a + g\sin\alpha = \frac{\cancel{m} \times v^2}{R}$$

$V = \sqrt{(a + g\sin\alpha)R}$ @ $a = 0.6\,m/s^2 \Rightarrow V = 1.3\sqrt{R}\ m/s$

@ $a = 0.8\,m/s^2 \Rightarrow V = 1.37\sqrt{R}\ m/s$

@ $a = 1\,m/s^2 \Rightarrow V = 1.44\sqrt{R}\ m/s$

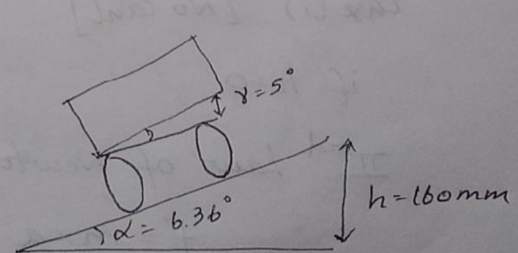
b) with Cant & a tilt of car body @ $\gamma = 5°$.

$h = 160mm$, & $\gamma = 5°$.

$f = m \times a$

$f = mv^2/R$

$f = mg \cdot \sin(\alpha + \gamma)$



$ma + mg\sin(\alpha+\gamma) = \frac{mv^2}{R}$

$V = \sqrt{[a + g\sin(\alpha+\gamma)] \times R} \Rightarrow$ @ $a = 0.6 m/s^2 \Rightarrow V = 1.593\sqrt{R}\ m/s$

@ $a = 0.8 m/s^2 \Rightarrow V = 1.655\sqrt{R}\ m/s$

@ $a = 1.0 m/s^2 \Rightarrow V = 1.714\sqrt{R}\ m/s.$

a) i) (without cant), $h=0$

@ $R = 470m \Rightarrow 0.76\sqrt{R} = 16.8 m/s.$

$0.894\sqrt{R} = 19.38 m/s.$

$\sqrt{R} = 21.67 m/s.$

(without cant), $h=0$

@ $R = 675m \Rightarrow \cancel{0.76\sqrt{R}} = \cancel{28.48 m/s}$. $0.76\sqrt{R} = 20.13 m/s$

$\cancel{1.37\sqrt{R}} =$ $0.894\sqrt{R} = 23.22 m/s$

$\sqrt{R} = 25.9 m/s.$

a) ii) (with cant), $h = 160mm$.

@ $R = 470m \Rightarrow 1.3\sqrt{R} = 28.18 m/s.$

$1.37\sqrt{R} = 29.7 m/s$

$1.44\sqrt{R} = 31.22 m/s.$

@ $R = 675m \Rightarrow 1.3\sqrt{R} = 33.77 m/s$

$1.37\sqrt{R} = 35.59 m/s$

$1.44\sqrt{R} = 37.41 m/s.$

b) (with cant), $h = 160mm + \gamma$

@ $R = 470m \Rightarrow 1.593\sqrt{R} = 34.53 m/s$

$1.655\sqrt{R} = 35.77 m/s.$

$1.714\sqrt{R} = 37.15 m/s.$

@ $R = 675m \Rightarrow 1.593\sqrt{R} = 41.38 m/s.$

$1.655\sqrt{R} = 42.99 m/s.$

$1.714\sqrt{R} = 44.53 m/s.$

if Maximum Line speed = 150 km/hr.

$$V = \frac{150}{3.6} = 41.67 \, m/s$$

	Radius (m)	Length (m)
Straight		2000
Radius of H-Curve	470	400
Straight		1700
Curve	470	500
Straight		3400
Total		8000

Minimum Travel time $\Big\}$ $t = \frac{L}{V}$.

without cant,

straight, 1. $t = \frac{2000}{41.67} = 48$ seconds.

Curve, 2. Max, $V = \begin{cases} 16.79 \, m/s \\ 19.39 \, m/s \\ 21.68 \, m/s \end{cases}$, $t = \frac{400}{21.68} = 18.45$ seconds.

straight, 3. $t = \frac{1700}{41.67} = 40.80$ seconds.

Curve, 4. Max. $V = \begin{cases} 20.12 \, m/s \\ 23.24 \, m/s \\ 25.98 \, m/s \end{cases}$, $t = \frac{500}{25.98} = 19.25$ seconds.

Straight, 5, $t = \frac{3400}{41.67} = 81.60$ seconds.

Constraints arising from overturning stability.

Calculate the value of the travel speed for different values of the C.G height $\left\{ \begin{array}{l} 1.3\,m \\ 1.5\,m \\ 1.7\,m \end{array} \right.$

Determine the overturning speed with C.G ht of 1.7m @

$R = 470m$ (without cant, $h = 0$).

$R = 470m$ ($h = 160mm$)

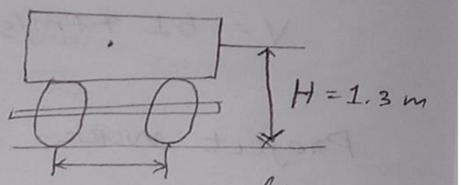
$R = 675m$ ($h = 160mm$).

overturning will occur.

if, $\frac{mv^2}{R} \le mg\tan\alpha$

$\frac{V^2}{R} \le g\tan\alpha$

$V = \sqrt{Rg\tan\alpha}$



$g = 10 m/s^2$ $\quad \tan\alpha = \frac{S}{2H}$

$\tan\alpha = \frac{1435}{2 \times 1300}$

$\tan\alpha = 0.55$ $\quad \alpha = \tan^{-1}\left(\frac{1435}{2 \times 1300}\right)$

$\alpha = 28.89$

$V = \sqrt{R \times g \times 0.55}$

$V = \sqrt{R \times 10 \times 0.55}$

$V = 2.34\sqrt{R}$

similarly, for $H = 1.5m$ & $H = 1.7m$.

$V = 2.18\sqrt{R}$ $\qquad V = 2.05\sqrt{R}$

for $R = 470m$, $h = 0$

@ $H = 1.7m$.

$V = 2.05\sqrt{R} = 2.05\sqrt{470}$

$V = 44.45 m/s$.

For $R = 470m$, $h = 160mm$

@ $H = 1.7m$, $g = 10m/s^2$

$$V = \sqrt{Rg\tan(\alpha+\gamma)}$$

$$V = \sqrt{470\times10\times\tan(22.88+6.36)}$$

$$V = 51.29\ m/sec$$

for, $R = 675m$, $h = 160mm$

@ $H = 1.7m$, $g = 10m/s^2$.

$$V = \sqrt{675\times10\times(\tan(6.36+22.88))}$$

$$V = 61.47 m/s.$$

$$\frac{V^2}{R} \le g\tan(\alpha+\gamma)$$

$$\tan\alpha = \frac{S}{2H} = \frac{1435}{2\times1700}$$

$$\tan\alpha = 0.42$$

$$\alpha = 22.88^\circ$$

$$\tan\gamma = \frac{h}{S} = \frac{160}{1435}$$

$$\tan\gamma = 0.111$$

$$\gamma = 6.36^\circ.$$

S.no	a [m/s²]	g [m/s²]	α [º]	R [m]	h [mm]	γ	V = √(a * R) [m/s] V = √((a + (g * (sinα))) * R) [m/s] V = √((a + (g * (sin(α+γ))) * R) [m/s]
1	0.6	10.00	0.0	470	0	0	16.79
2	0.8	10.00					19.39
3	1.0	10.00					21.68
4	0.6	10.00	0.0	675	0	0	20.12
5	0.8	10.00					23.24
6	1.0	10.00					25.98
7	0.6	10.00	8.9	470	160	0	50.07
8	0.8	10.00					51.00
9	1.0	10.00					51.92
10	0.6	10.00	8.9	675	160	0	60.01
11	0.8	10.00					61.12
12	1.0	10.00					62.22
13	0.6	10.00	8.9	470	160	5	69.88
14	0.8	10.00					70.55
15	1.0	10.00					71.21
16	0.6	10.00	8.9	675	160	5	83.74
17	0.8	10.00					84.54
18	1.0	10.00					85.34

V [m/s]	a [m/s^2]	R [m]	L [m]	t [s]
41.67	1.00	0	2000	48.00
16.79	0.60			
19.39	0.80	470	400	18.45
21.68	1.00			
41.67	1.00	0	1700	40.80
20.12	0.60			
23.24	0.80	675	500	19.25
25.98	1.00			
41.67	1.00	0	3400	81.60

Project work - 6.

Select the nominal power to be installed on a train

a) Determine the installed power (total engine power) to achieve:

Case (i) Constant alleleration 0.6 m/s^2 until V_{max}.

Case (ii) P_{min} to maintain V_{max}.

b) Draw the P vs V for both axles

c) Draw the Force Vs V for resistance, Inertial & Traction force

Given that:

$M' = 500$ tonnes , $\eta = 0.9$ (Eff. of Transmission)

$\gamma = 2.0 + 0.0002V^2$ | γ (N/kN), V (km/h).

V = 80, 100, 120, 200, 250, 300 km/hr.

Case (i) Acceleration, $a = \frac{T(v) - R(v)}{M'}$

For, $v = 80 km/hr$,

$$\gamma = 2.0 + 0.0002(80)^2 = 3.28 \ N/kN$$

$$R(V) = Mg.\gamma = 5000N \times 3.28 = 16.4 \ kN.$$

$$\therefore T(V) = M'a + R(V)$$

$$= 5kN \times 0.6 m/s^2 + 16.4 kN$$

$$T(V) = 316 kN.$$

Power, $N(80) = T(80) \times V$

$$= 316 \times \frac{80}{3.6} \quad \left(\frac{km/hr}{m/s} \text{ conversion}\right)$$

$$= 7.022 \text{ k watt.}$$

Installed power, $N = \frac{N(80)}{\eta_{efficiency}} = 7.805 \ kW$

Case (ii), $a = 0 m/sec^2$, $N = ?$ $V = 80 km/hr$ for maxi. Speed.

$$\gamma = 2 + 0.000(v^2) = 3.28 \ N/kN.$$

$$R(V) = Mg \times \gamma = 5000N \times 3.28 N/kN = 16.4 kN.$$

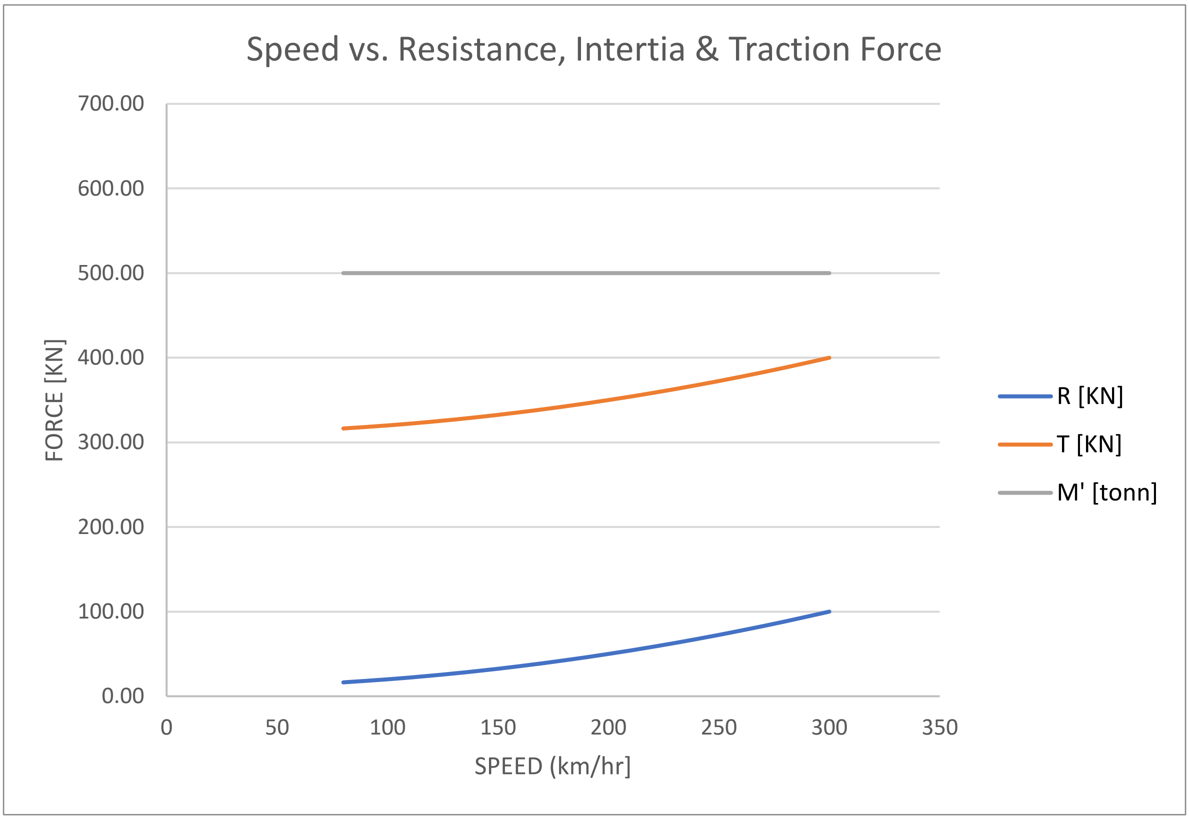
$$T(V) = M'a + R(V) = M'(0) + 16.4 kN = 16.4 kN.$$

$$\therefore N(V) = T(V) \times V = 16.4 \times \frac{80}{3.6} = 364.4 kN.$$

$$N = \frac{N(V)}{\eta_{eff}} = \frac{364.4}{0.9} = 399 \ kW.$$

S.no	V [km/hr]	V [m/s]	r [N/KN]	M' [tonn]	a [m/s^2]	R [KN]	T [KN]	Actual, N [KW]	Installed Power, N [KW], a = 0.6 [m/s^2]
1	80	22.22	3.28	500	0.6	16.40	316.40	7031	7812
2	100	27.78	4	500	0.6	20.00	320.00	8889	9877
3	120	33.33	4.88	500	0.6	24.40	324.40	10813	12015
4	140	38.89	5.92	500	0.6	29.60	329.60	12818	14242
5	160	44.44	7.12	500	0.6	35.60	335.60	14916	16573
6	180	50.00	8.48	500	0.6	42.40	342.40	17120	19022
7	200	55.56	10	500	0.6	50.00	350.00	19444	21605
8	220	61.11	11.68	500	0.6	58.40	358.40	21902	24336
9	240	66.67	13.52	500	0.6	67.60	367.60	24507	27230
10	260	72.22	15.52	500	0.6	77.60	377.60	27271	30301
11	280	77.78	17.68	500	0.6	88.40	388.40	30209	33565
12	300	83.33	20	500	0.6	100.00	400.00	33333	37037

S.no	V [km/hr]	V [m/s]	r [N/KN]	M' [tonn]	a [m/s^2]	R [KN]	T [KN]	Actual, N [KW]	Installed Power, N [KW], a=0
1	80	22.22	3.28	500	0	16.40	16.40	364	405
2	100	27.78	4	500	0	20.00	20.00	556	617
3	120	33.33	4.88	500	0	24.40	24.40	813	904
4	140	38.89	5.92	500	0	29.60	29.60	1151	1279
5	160	44.44	7.12	500	0	35.60	35.60	1582	1758
6	180	50.00	8.48	500	0	42.40	42.40	2120	2356
7	200	55.56	10	500	0	50.00	50.00	2778	3086
8	220	61.11	11.68	500	0	58.40	58.40	3569	3965
9	240	66.67	13.52	500	0	67.60	67.60	4507	5007
10	260	72.22	15.52	500	0	77.60	77.60	5604	6227
11	280	77.78	17.68	500	0	88.40	88.40	6876	7640
12	300	83.33	20	500	0	100.00	100.00	8333	9259



Speed vs. Resistance, Intertia & Traction Force
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
FORCE [KN]
0
50
100
150
200
250
300
350
SPEED (km/hr)
R [KN]
T [KN]
M' [tonn]

SPEED vs. POWER
40000
30000
20000
10000
0
POWER [KW]
0
50
100
150
200
250
300
350
SPEED (km/hr)
Installed Power, N [KW], a=0.6 m/s2
Installed Power, N [KW], a=0

Project Work - 7.

Determine the mass of the locomotive M, capable of pulling a rake of trailing vehicles on a slope with standing start.

Given that. acceleration, @ start up = $0.01 m/sec^2$.

Coefficient of adhesion wheel (rail) = $\nabla\phi = 0.2$.

Coefficient of mass of the locomotive to account for its rotating mass $\}$, $\delta_l = 0.15$.

Coefficient of mass of the trailing vehicles to account for its rotating mass $\}$, $\delta = 0.05$.

SP. resistance to motion @ $V=0$; $\mu = 2.5 N/kN$

Trailing vehicle mass, M = 1000 tonnes.

slope of the line, $i = 30\%$.

We have the following formula for the traction force of a locomotive & trailer on the surface with the slope of (i),

$$T = \phi P_l = (P_l + P)(\mu + i) + (M_l(1+\delta_l) + M(1+\delta))a$$

T = Traction force @ the wheels

P_l = Locomotive weight

P = Trailer weight

$T_{max} = \phi P_l$

$= \phi \times M_l \times g$

$= 0.2 \times 9.81 \times M_l$

$T_{max} = 1.962 M_l$.

WKT

$$\left.\begin{array}{l}\text{Resistance of}\\ \text{Train}\end{array}\right\} \text{depends upon} \left\langle \begin{array}{l}\text{Total weight of train}\\ \text{speed of the train}\\ \text{slope of the line}\end{array}\right.$$

For, The Formula of Resistance, $r = a + bV + cV^2$.

@ $V = 0$ $r = a$

@ 0 = speed — resistance = a = slope resistance + sp. resistance to motion

$= 30 + 2.5$

$r = a = 32.5\ N/kN$

Now, Total resistance related to total Mass & 'r'.

$R = (M_l + M_t) \times g \times r$.

$R = (M_l + 1000) \times 9.81 \times 32.5$

$R = 0.138 M_l + 318$

For, Inertia Force,

$F = [M_l (1 + \delta_l) + M(1 + \delta)] a$

$F = [M_l [1 + 0.15) + 1000 (1 + 0.05)] \times 0.01$

$F = 0.0115 M_l + 10.5$.

Finally,

$T - R = F$

$1.962 M_l - 0.138 M_l + 318 = 0.0115 M_l + 10.5$.

$M_l = 201.832$ ton.

Then, $F = 0.0115 M_l + 10.5 = 12.82\ kN$.

$R = 0.138 M_l + 318 = 345.85\ kN$.

$T = 1.962 M_l = 395.99\ kN$.

Project work - 8.

Construction of T-V curve for Diesel Engine

Determine.

→ The power corresponding to maxi^m rotation speed of the engine.

→ The transmission ratio γ for a 5 gear transmission.

→ The Tractive force @ maximum rotation speed for each gear.

Draw the relationship b/w T vs V in each gear.

Given that

$\eta = 0.8$ (efficiency of transmission).

$\gamma_W = 0.4m$ (Radius of wheel).

Torque Vs rpm characteristic of diesel engine.

Vehicle speed @ maximum engine rotation speed.

Power corresponding to the maximum rotation speed of the engine.

$$C(n) = k \rightarrow C(1846) = 1333 \text{ N.m}.$$

$$N(n) = c(n).n$$

$$N(1846) = 1333 \times 1846$$

$$N = 2461 \text{ [kN.m rpm]}$$

Transmission ratio γ for 5th gear transmission.

$$V = 2\pi/60 \times \frac{n_m}{\gamma} \times \gamma_\omega.$$

$$\frac{130}{3.6} = \frac{2\pi}{60} \times \frac{1846}{\gamma} \times 0.4$$

$$\gamma = \frac{2\pi \times 1846 \times 0.4}{60 \times \frac{130}{3.6}}$$

$$\gamma = 2.14$$

Torque Vs. Speed Rotation of Diesel Motor		Vehicle Speed at Maximum Motor Rotation Speed		
N_e [rpm]	**Torque C [N-m]**	**Gear**	**V [km/hr]**	**n [rpm]**
923	1396	**V**	130	1846
1150	1472	**IV**	103	1846
1392	1523	**III**	61	1846
1633	1434	**III**	38	1846
1846	1333	**I**	22	1846

Tractive force @ maxi - rotation speed for each gear.

$$T = \frac{C.\gamma}{\gamma_w} \times \eta.$$

γ for each gear has to be found for its corresponding speed

1st gear, $V_1 = \frac{2\pi n_m}{60\gamma_1} \times \gamma_w$

$$\frac{22}{3.6} = \frac{2\pi \times 1846}{60 \times \gamma_1} \times 0.4$$

$$\gamma_1 = 12.65$$

2nd gear, $V_2 = \frac{2\pi n_m}{60\gamma_2} \times \gamma_w$

$$\gamma_2 = 7.32$$

$$\gamma_3 = 4.56$$

$$\gamma_4 = 2.7$$

$$\gamma_5 = 2.14$$

$$T_1 = \frac{C.\gamma_1}{\gamma_w} \times \eta$$

$$T_1 = \frac{1333 \times 12.65}{0.4} \times 0.8 = 33.725 kN.$$

$$T_2 = 19.515 kN$$

$$T_3 = 12.157 kN$$

$$T_4 = 7.198 kN$$

$$T_5 = 5.705 kN.$$

S.no	Gear	V [km/hr]	V [m/s]	n [rpm]	Radius of Wheel, r_w [m]	Torque, C [N-m]	η	Transmission Ratio, γ	Traction Force, T [KN]
1	I	22	6.11	1846	0.4	1333	0.8	12.66	33.75
2	II	38	10.56	1846	0.4	1333	0.8	7.33	19.54
3	III	61	16.94	1846	0.4	1333	0.8	4.57	12.17
4	IV	103	28.61	1846	0.4	1333	0.8	2.70	7.21
5	V	130	36.11	1846	0.4	1333	0.8	2.14	5.71