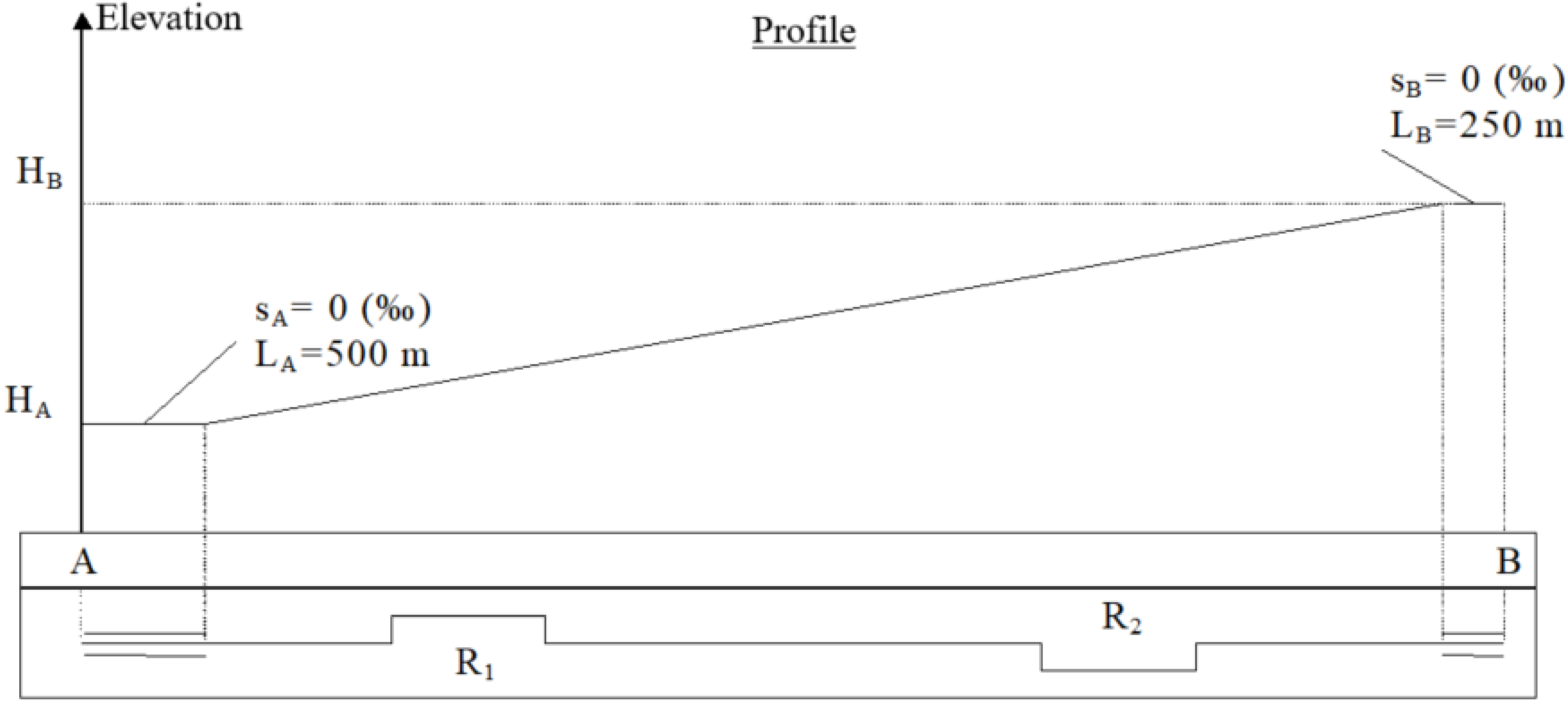
ASSIGNMENT-1 (RAILWAY)

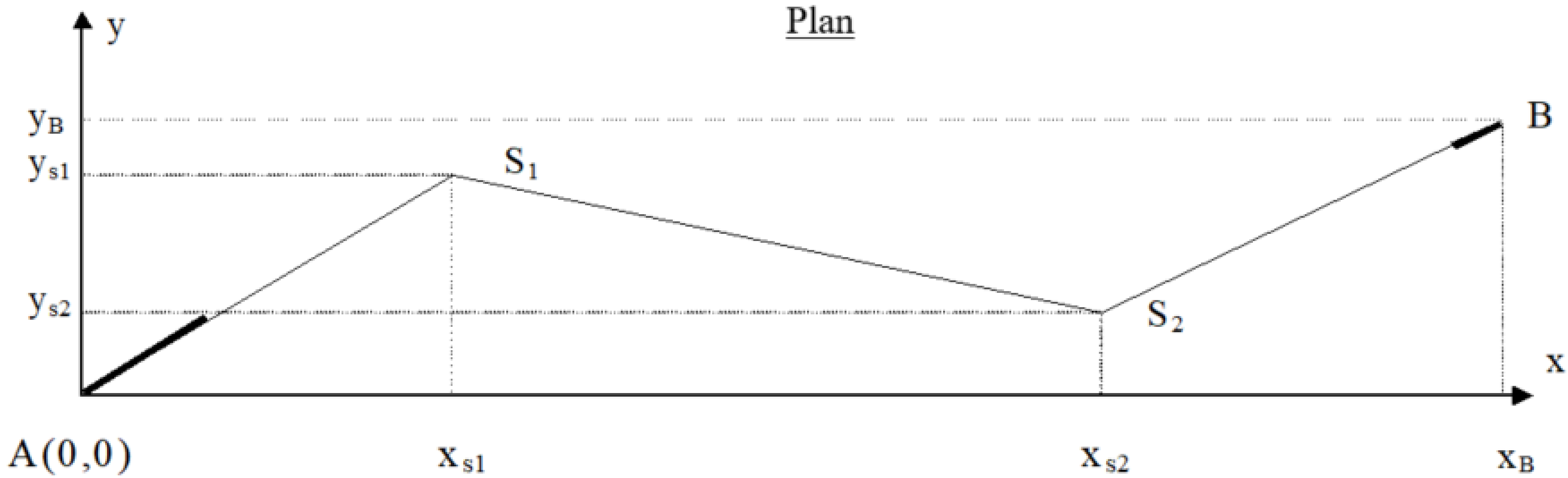
The profile showing the grade (red) line and the plan showing the alignment centerline between station A and station B are given. This railway line will be design based on the "principle of constant resistance".

It is your duty to prepare the design project for upgrading the railway section and to determine the running conditions for the railway vehicles.

NOTES:

- **Use two digits after the decimal point for the results at each calculation steps.**
- **Calculations and drawings must be prepared by hand.**


Elevation
Profile
s_B= 0 (‰)
L_B=250 m
H_B
s_A= 0 (‰)
L_A=500 m
H_A
A
B
R_2
R_1


y
Plan
y_B
y_{s1}
y_{s2}
B
S_1
S_2
x
A(0,0)
x_{s1}
x_{s2}
x_B

Essential measures (parameters) to be used in the design and information associated with railway vehicles to be operated are summarized in the following tables.

ASSIGNMENT NUMBER

(For example, for Assign. No=1234; **d**=1, **c**=2, **b**=3, **a**=4)

d	c	b	a
1	2	3	4

	Unit	Value		Unit	Value
H_A	m	100 + 100***b**	H_B	m	300+110***b**+16***a**
x_A	m	0	x_B	m	30000+2100***d**
y_A	m	0	y_B	m	7500
x_{S1}	m	8000	x_{S2}	m	23000 - 800***b**
y_{S1}	m	3500 + 300***a**	y_{S2}	m	3500 - 300***a**
R_1	m	800 + 50***a**	R_2	m	3500 - 200***a**

	Unit	Value
Design speed	km/h	150 + 5***a**
Transverse (comfort) accel.	m/s^2	(**a** + 16) / 25
Max. superelev.	mm	150
Superelevation (cant) excess (Δd_f)	mm	90
μ_y (rail-wheel)	N/kN	(160 +7500/(V+44))
μ_f (brk.shoe-wheel)	N/kN	12500/(50+V)

	Unit	Value
α/ β/ γ	---	0.7 / 0.9 / 1.0
Curve resistance	N/kN	650 / (R - 55)
Station slope	‰	0
Accel. of gravity	m/s^2	10
Passenger weight	kg	70

	Unit	PASSENGER	FREIGHT
Max. train weight (total)	gross ton	250 + 15***c**	1000 + 20***b**
Max. (regime) velocity	km/h	V_{pr} - 50	70 + 2***b**
Loco. (Powered unit) type	-----	B_o' B_o'	C_o' C_o'
Loco. (Pow. unit) power	kW	1500 + 50***c**	3000 + 50***b**
Loco. (Pow. unit) weight	ton	60 (tare)	120
Loco. (Pow. unit) length	m	24	24
Max. Pow. unit capacity	passenger	40	----
Wagon tare weight	ton	28	12
Max. wagon capacity	passenger-net ton	60	21
Wagon length	m	22	12.5
Coeff. of train mass increa.	----	1.06	1.06
Rolling (run.) resistance	N/kN	1.**b**+ (V^2/4000)	2.**a**+ (V^2/3000)
Traffic amount	pass.-ton/year-direc.	$5*10^6$	$6*10^6$
Average journey length	km	100	300
Total service distance	km	500	500
Max. traffic / Ave. traffic	---	1.2	1.2
Coeff. of train util. rate	---	1.0	0.9
Coeff. of wagon util. rate	---	0.8	0.8

In the tables below the marked numbers are calculated regarding the sample assignment number. All other numbers are valid and same for all assignments.

	Unit	Value		Unit	Value
H_A	m	**700**	H_B	m	**1005**
x_A	m	0	x_B	m	**40000**
y_A	m	0	y_B	m	7500
x_{S1}	m	8000	x_{S2}	m	**18200**
y_{S1}	m	**5600**	y_{S2}	m	**1400**
R_1	m	**1150**	R_2	m	**2100**

	Unit	Value
Design speed	km/h	**185**
Transverse (comfort) accel.	m/s^2	**0.92**
Max. superelev.	mm	150
Superelevation (cant) excess (Δd_f)	mm	90
μ_y (rail-wheel)	N/kN	(160 +7500/(V+44))
μ_f (brk.shoe-wheel)	N/kN	12500/(50+V)

	Unit	Value
$\alpha/\ \beta/\ \gamma$	---	0.7 / 0.9 / 1.0
Curve resistance	N/kN	650 / (R - 55)
Station slope	‰	0
Accel. of gravity	m/s^2	10
Passenger weight	kg	70

	Unit	PASSENGER	FREIGHT
Max. train weight (total)	gross ton	**310**	**1120**
Max. (regime) velocity	km/h	**125**	**72**
Loco. (Powered unit) type	-----	B_o’ B_o’	C_o’ C_o’
Loco. (Pow. unit) power	kW	**1700**	**3300**
Loco. (Pow. unit) weight	ton	60 (tare)	120
Loco. (Pow. unit) length	m	24	24
Max. Pow. unit capacity	passenger	40	----
Wagon tare weight	ton	28	12
Max. wagon capacity	passenger-net ton	60	21
Wagon length	m	22	12.5
Coeff. of train mass increa.	----	1.06	1.06
Rolling (run.) resistance	N/kN	**1.6+ (V^2/4000)**	**2.7 + (V^2/3000)**
Traffic amount	pass.-ton/year-direc.	$5*10^6$	$6*10^6$
Average journey length	km	100	300
Total service distance	km	500	500
Max. traffic / Ave. traffic	---	1.2	1.2
Coeff. of train util. rate	---	1.0	0.9
Coeff. of wagon util. rate	---	0.8	0.8

1st PART

Step 1: Calculating the minimum curve radius based on new design speed (for the sake of application ease, the **minimum curve radius is rounded up to an integer value having 50 or 00 in the last two digits**)

$$R_{\min} = \frac{11{,}8 * V_p^2}{d_{maks} + 153 * \gamma_{maks}} = \frac{11{,}8 * 185^2}{150 + 153 * 0{,}92} = 1388{,}96\,m \Rightarrow R_{\min} = 1400\,m$$

Step 2: Increasing the radius for the curves in need of upgrading and calculating the length of the new alignment

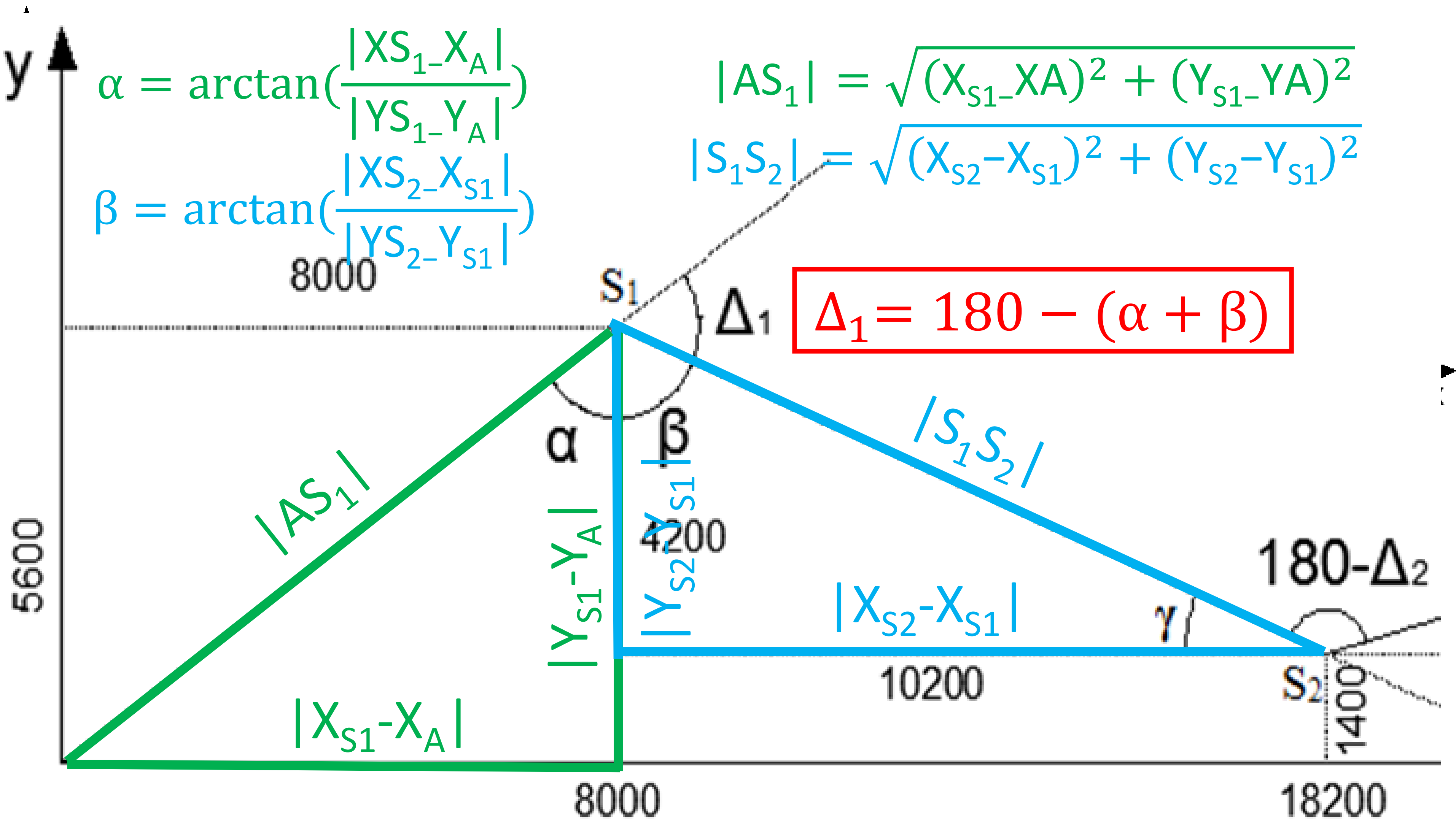
R_1	**1150 m**	R_2	**2100 m**

R_1 was 1150 m, it will be 1400 meters and R_2 remains as 2100 meters. If R_2 was also lower than R_{min} it would also be 1400 meters.

New radius of curves:

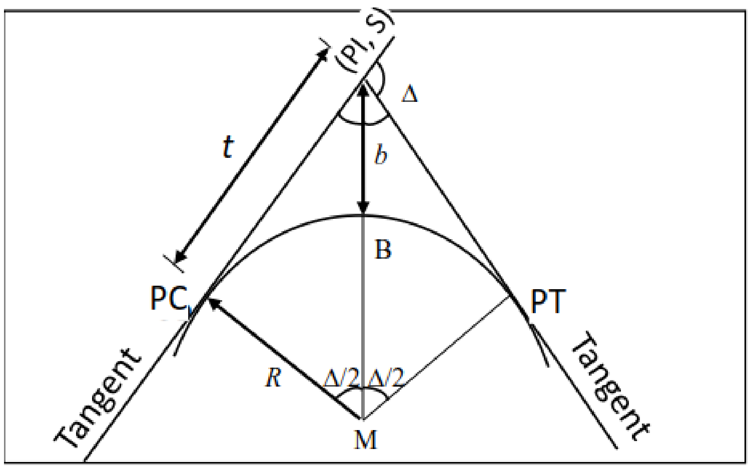
R_1	**1400 m**	R_2	**2100 m**

Calculation of external angles Δ_1 and Δ_2:



The plan above must be drawn by hand with scale (1/100,000). All angles should be shown and <u>all calculations must be presented clearly</u>.

Finding the new road length according to new external angles and radius of the curves:



Length of tangent:

$$t = R * \mathrm{tg}(\frac{\Delta}{2}) \quad (\mathrm{m})$$

Length of curve (arc):

$$D = 2\pi * R * \frac{\Delta}{360} \quad (\mathrm{m})$$

$$\overline{AS_1} = \sqrt{5600^2 + 8000^2} = 9765{,}24m$$

$$\overline{S_1S_2} = \sqrt{4200^2 + 10200^2} = 11030{,}87m$$

$$\overline{S_2B} = \sqrt{6100^2 + 21800^2} = 22637{,}36m$$

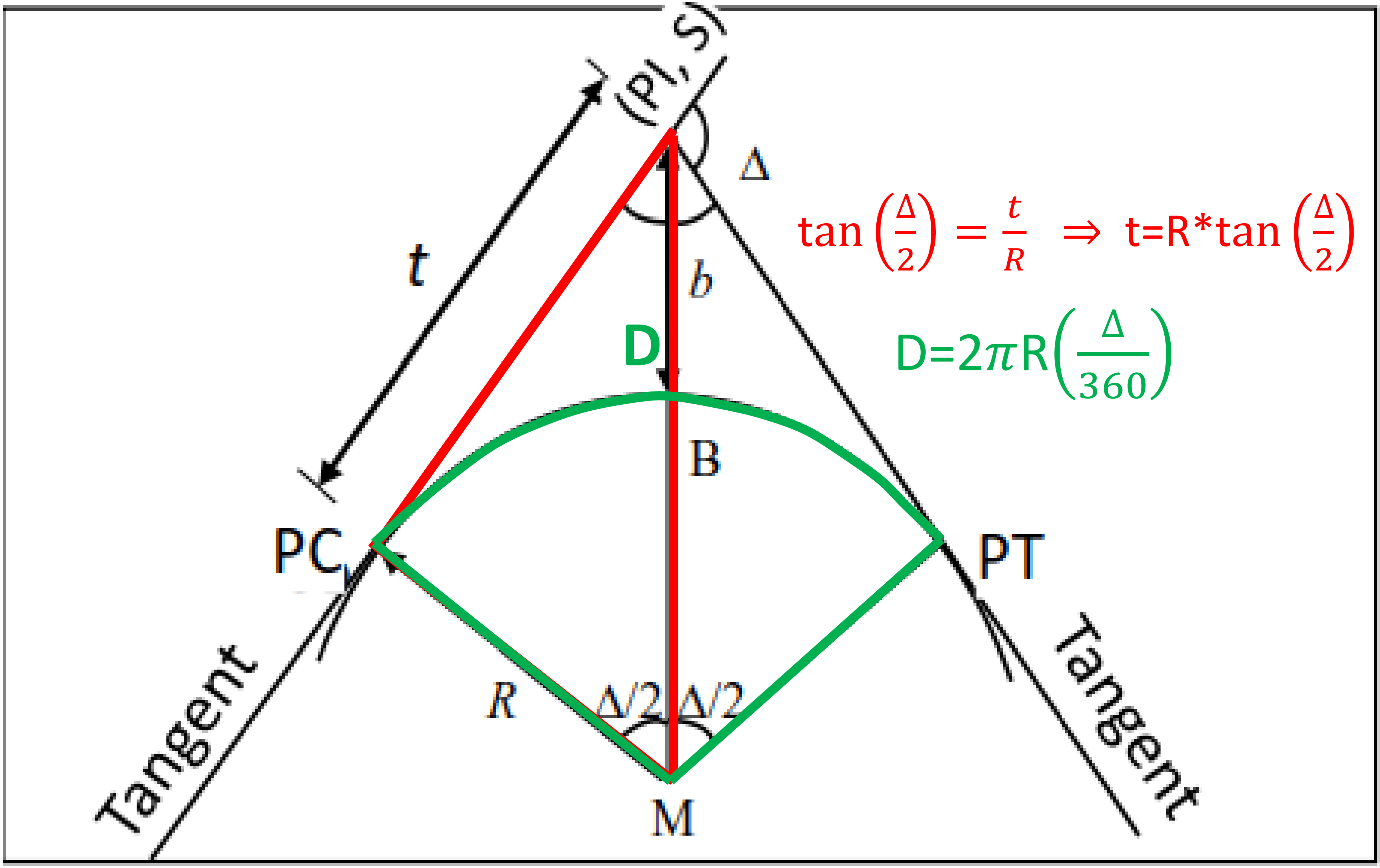
$$t_1 = R_1 * \tan\frac{\Delta_1}{2} = 1400 * \tan\frac{57{,}37}{2} = 766{,}00m$$

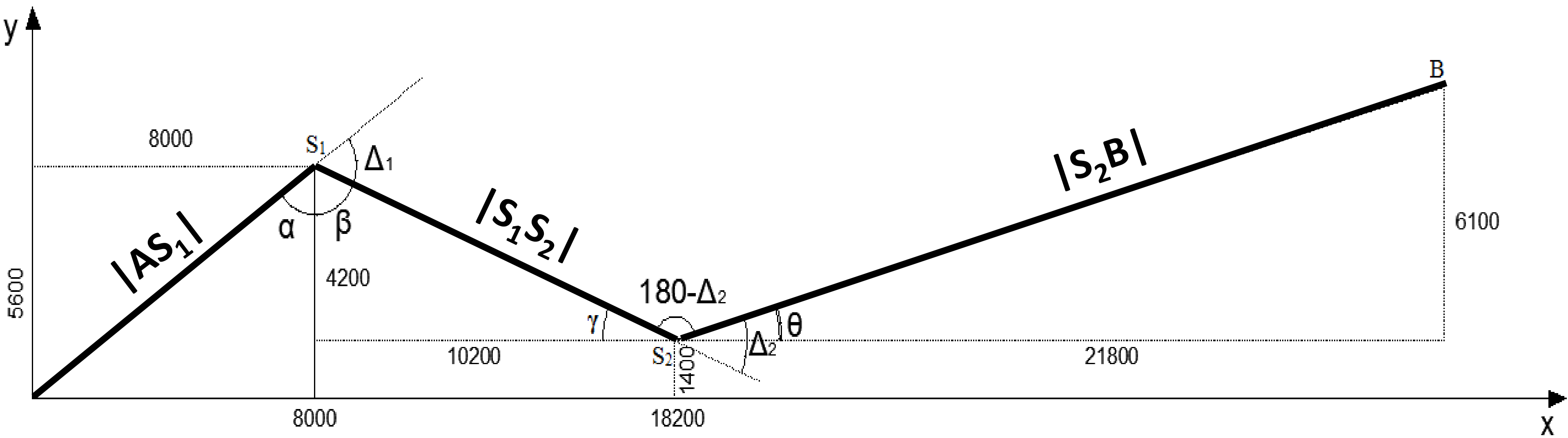
$$t_2 = R_2 * \tan\frac{\Delta_2}{2} = 2100 * \tan\frac{38{,}01}{2} = 723{,}29m$$

$$D_1 = 2 * \pi * R_1 * \frac{\Delta_1}{360} = 2 * \pi * \frac{57{,}37}{360} = 1401{,}81m$$

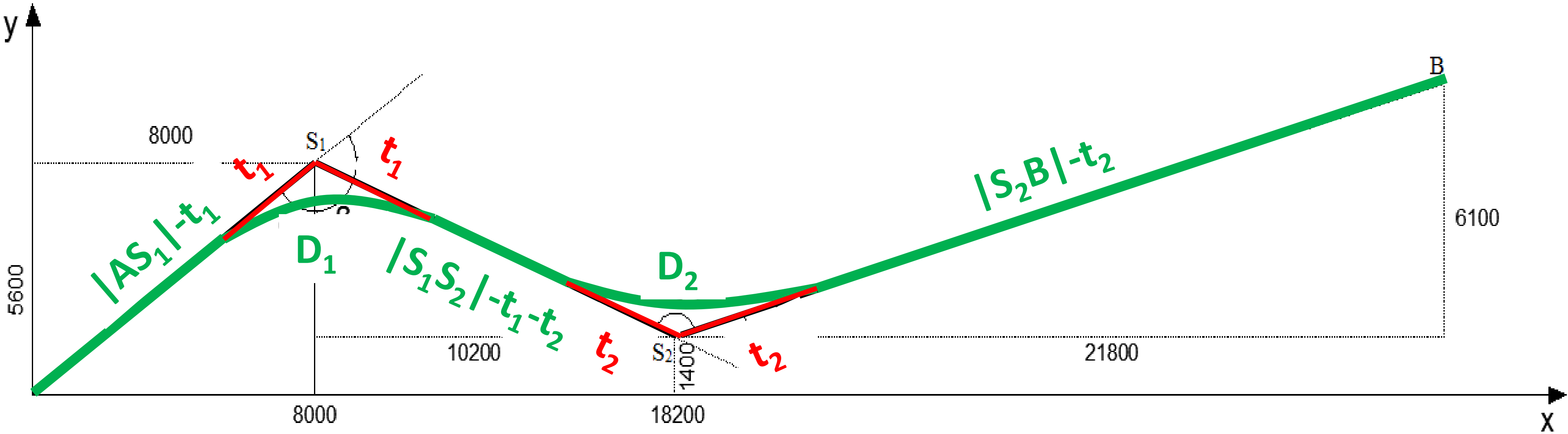
$$D_2 = 2 * \pi * R_2 * \frac{\Delta_2}{360} = 2 * \pi * \frac{38{,}01}{360} = 1393{,}14m$$

Finding the new road length according to new external angles and radius of the curves:





y
x
B
8000
S_1
Δ_1
$|AS_1|$
$|S_1S_2|$
$|S_2B|$
α
β
6100
4200
5600
180-Δ_2
γ
θ
S_2
Δ_2
10200
21800
1400
8000
18200



$$L_{AB} = \overline{AS_1} - t_1 + D_1 + \overline{S_1S_2} - t_1 - t_2 + D_2 + \overline{S_2B} - t_2$$

$$L_{AB} = \overline{AS_1} + \overline{S_1S_2} + \overline{S_2B} - 2t_1 - 2t_2 + D_1 + D_2$$

$$\boxed{L_{AB} = 9765{,}24 + 11030{,}87 + 22637{,}36 - 2*766{,}00 - 2*723{,}29 + 1401{,}81 + 1393{,}14 = 43249{,}84\,m}$$

Step 3: Calculating the new applied gradient, because a 2000-meter long horizontal/level track (which is called "palye" in Turkish) is going to be designed and constructed immediately after the exit of station A (Average gradient and losses of elevation must be computed by including the stations and horizontal track section.)

Calculation of average gradient between points A and B:

$$s_{o,AB} = \frac{H_B - H_A}{(L_{AB}/1000)} = \frac{1005 - 700}{43249{,}84/1000} = ‰7{,}05$$

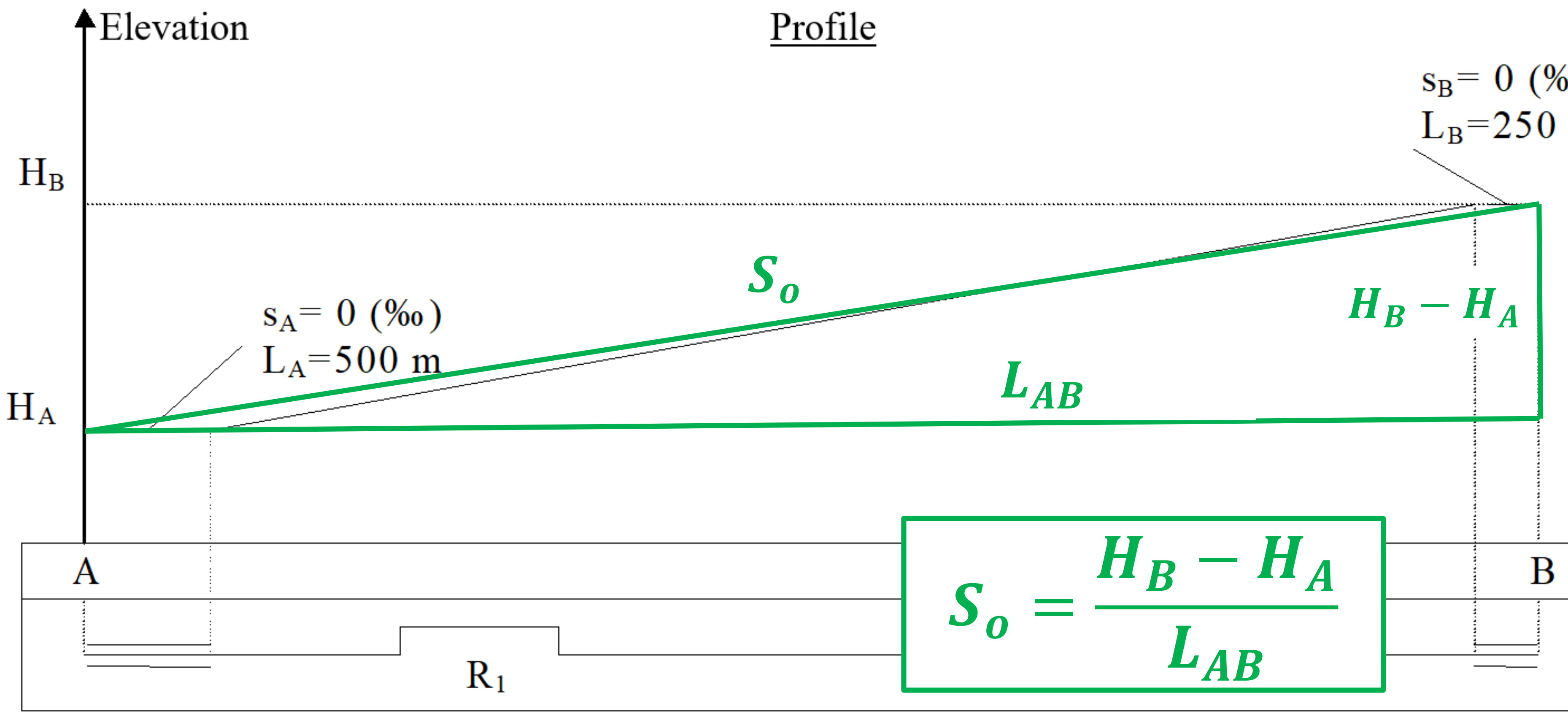
Calculation of applied gradient:

It is required that applied gradient should be calculated by including the stations and the horizontal section (palye). The formula, will be used to calculate the applied gradient:

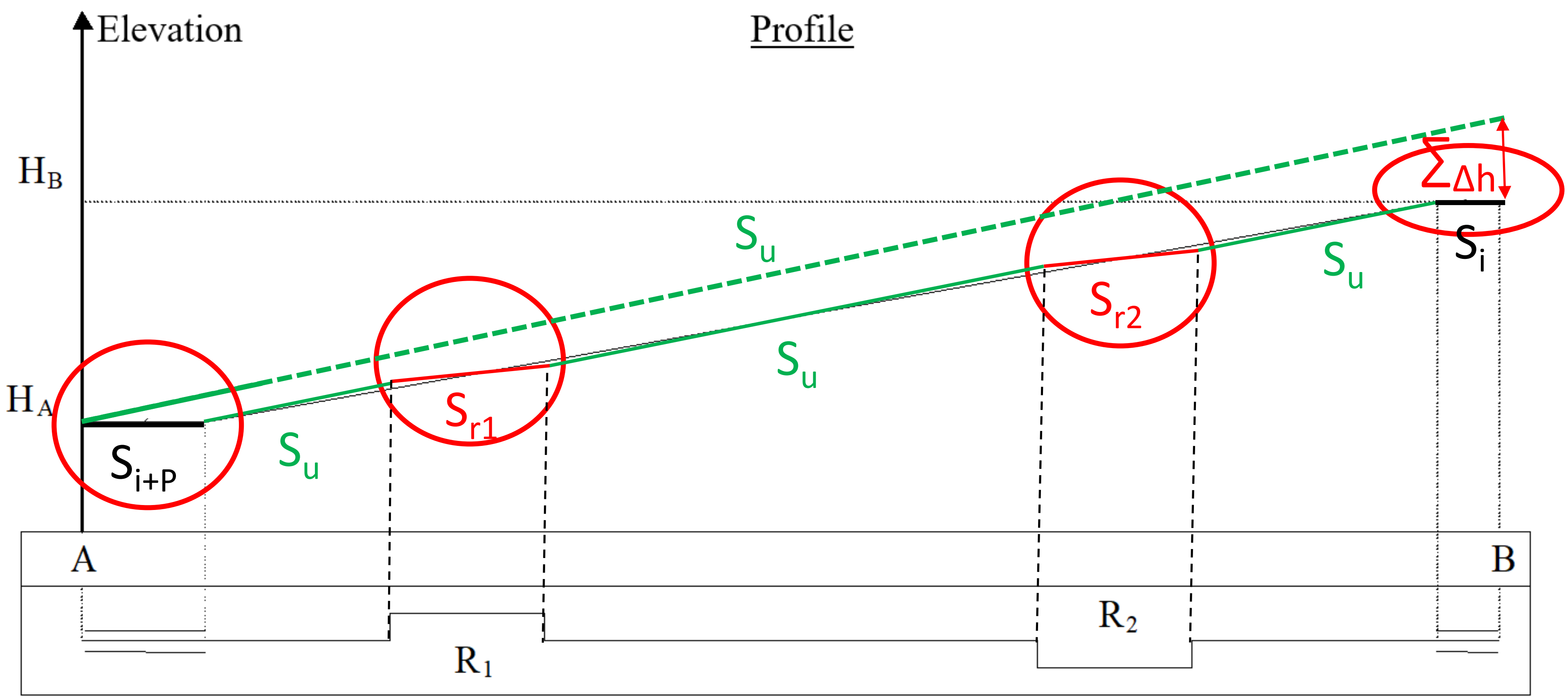
$$s_u = \frac{H_B - H_A + \sum \Delta h}{(L_{AB}/1000)}$$

Step 3: Calculating the new applied gradient, because a 2000-meter long horizontal/level track (which is called "palye" in Turkish) is going to be designed and constructed immediately after the exit of station A (Average gradient and losses of elevation must be computed by including the stations and horizontal track section.)

Calculation of average gradient between points A and B:



$$S_o = \frac{H_B - H_A}{L_{AB}}$$



$$\boxed{\sum_{\Delta h}=h_{iA+P}+h_{iB}+h_{r1}+h_{r2}}$$

The profile above must be drawn by hand with scale (horizontal scale: 1/100,000; vertical scale: 1/10,000) and included the required data on it.

First let’s calculate the elevation losses because of the curves:

$$w_{r_1} = \frac{650}{R_1 - 55} = \frac{650}{1400 - 55} = 0{,}48 N / kN \quad \text{(First curve resistance value)}$$

$$w_{r_2} = \frac{650}{R_2 - 55} = \frac{650}{2100 - 55} = 0{,}32 N / kN \quad \text{(Second curve resistance value)}$$

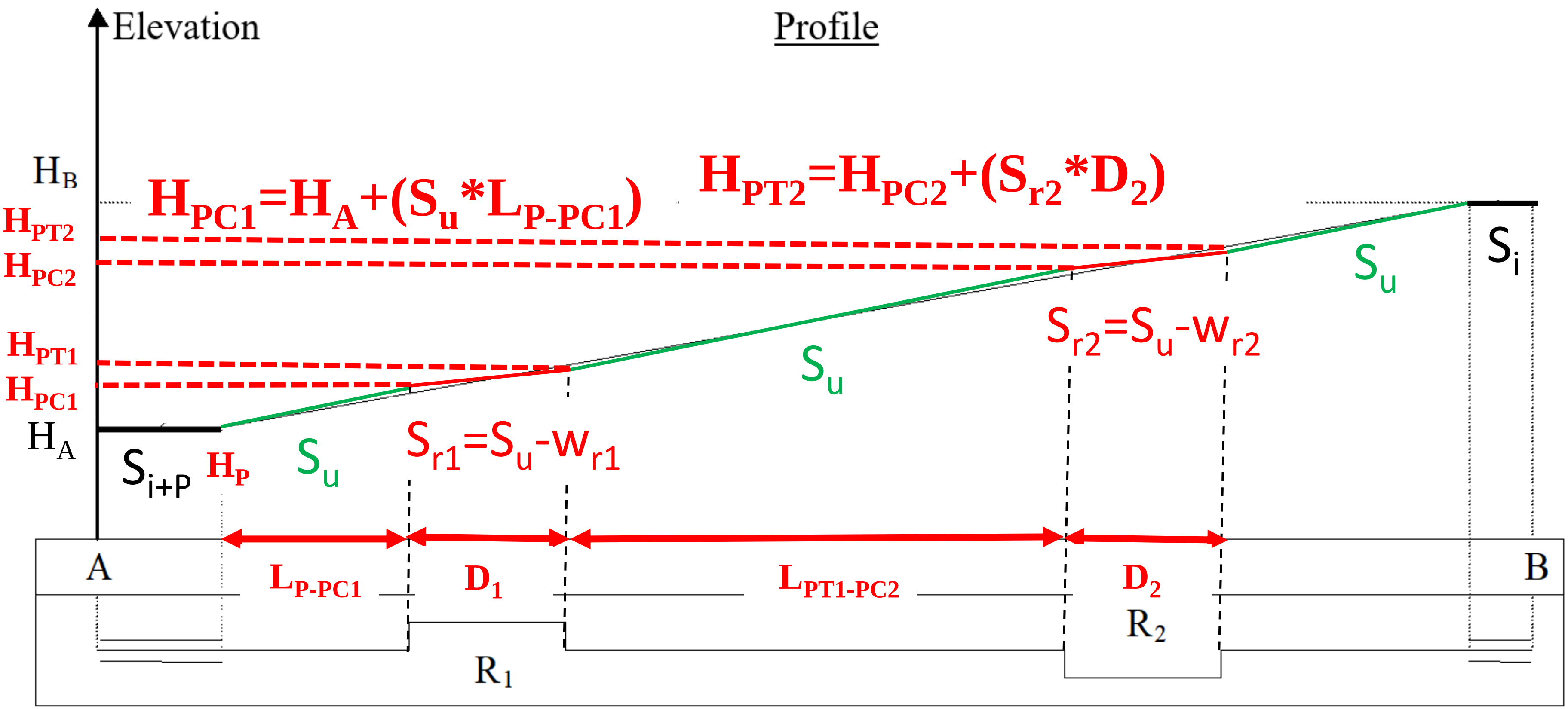
$$\Delta h_{r_1} = w_{r_1} * \frac{D_1}{1000} = 0{,}48 * \frac{1401{,}81}{1000} = 0{,}67 m \quad \text{(Elevation loss because of the first curve)}$$

$$\Delta h_{r_2} = w_{r_2} * \frac{D_2}{1000} = 0{,}32 * \frac{1393{,}14}{1000} = 0{,}45 m \quad \text{(Elevation loss because of the second curve)}$$

$$\Delta h_{i+p} = s_u * \frac{L_A + L_B + L_P}{1000} = s_u * \frac{500 + 250 + 2000}{1000} = 2{,}75 s_u \quad \text{(Elevation loss because of stations and palye)}$$

$$s_u = \frac{H_B - H_A + \sum \Delta h}{(L_{AB} / 1000)} = \frac{1005 - 700 + 0{,}67 + 0{,}45 + 2{,}75 s_u}{(43249{,}84 / 1000)} \Rightarrow \boxed{s_u = ‰7{,}56}$$

Step 4: Calculating the grade (red) levels of the tangent points of horizontal curves on the track designed by using the principle of constant resistance



Calculation of red elevations of the required points:

The length of the section from P to PC_1 (distance between the end of horizontal section and PC_1)

$$\left(\overline{AS_1} - t_1\right) - L_A - L_{Palye} = (9765,24 - 766) - 500 - 2000 = 6499,24m$$

This section has no tunnel or curve. Therefore applied gradient is used here.

$$H_{PC1} = H_A + \frac{L_{P\text{-}PC_1}}{1000} * s_u = 700 + \frac{6499,24}{1000} * 7,56 = \boxed{749,13m}$$

The length of the section from PC_1 to PT_1 is equal to the length of the first curve (1401,81). Since there is a curve on this road section. $s_{r_1} = s_u - w_{r_1}$ = 7,56 - 0,48 = ‰7,08 is used for this section.

$$H_{PT1} = H_{PC1} + \frac{D_1}{1000} * (s_u - w_{r_1}) = 749,13 + \frac{1401,81}{1000} * 7,08 = \boxed{759,05m}$$

The length of the section from PT_1 to PC_2 is $\overline{S_1S_2} - t_1 - t_2 = 9541{,}58m$

This section has no tunnel or curve. Therefore applied gradient is used here.

$$H_{PC2} = H_{PT1} + \frac{L_{PT_1\text{-}PC_2}}{1000} * s_u = 759{,}05 + \frac{9541{,}58}{1000} * 7{,}56 = \boxed{831{,}18m}$$

The length of the section from PC_2 to PT_2 is equal to the length of the second curve (1393,14 m). Since there is a curve on this road section. $s_{r_2} = s_u - w_{r_1} = 7{,}56 - 0{,}32 = ‰7{,}24$ is used for this section.

$$H_{PT2} = H_{PC2} + \frac{D_2}{1000} * (s_u - w_{r_2}) = 831{,}18 + \frac{1393{,}14}{1000} * 7{,}24 = \boxed{841{,}27m}$$

Step 5: Making up passenger and freight (goods) trains based on the maximum train weights given on the Table (determining the number of passenger wagons and freight wagons) (In the beginning, 1 (one) self-powered vehicle and 1 (one) locomotive will be used).

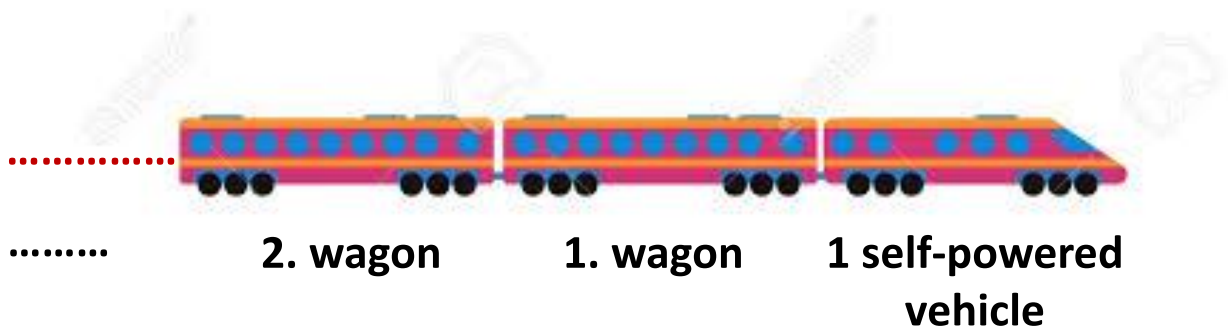
Making up the passenger train:

At the beginning only one self-powered vehicle will be used;

VS: Number of wagons
MKA: Maximum train weight
ODA: Full weight of the self-powered vehicle
VDA: Loaded wagon weight

$$VS = \frac{MKA - ODA}{VDA}$$

MKA = 310 ton (according to assignment number)



ODA = weight of the self-powered veh. (tare) + passenger capacity * av. weight of a person

ODA = 60 + 0,07 * 40 = 62,8 ton

VDA = weight of wagons (tare) + passenger capacity * av. weight of a person

VDA = 28 + 0,07 * 60 = 32,2 ton

$$VS = \frac{310 - 62{,}8}{32{,}2} = 7{,}67 \Rightarrow VS = 7$$

Calculation of the new train weight:

$G_L + G_W$ = ODA + VS*VDA = 62,8 + 32,2*7 = 288,20 ton.

Which is smaller than 310 tons so we are on the safe and acceptable side.

GL = total weight of traction vehicle

GW = total weight of pulled vehicles

Passenger train = 1 self-powered vehicle + 7 wagons

Making up the freight train:

Self-Powered vehicles are not used in freight trains. Self-powered vehicles are only eligible to use for passenger trains. <u>For freight trains locomotive is used.</u> Locomotives do not carry goods and passengers. They have only tractive force. Please do not write self-powered vehicle for freight trains.

Only 1 locomotive will be used at beginning;

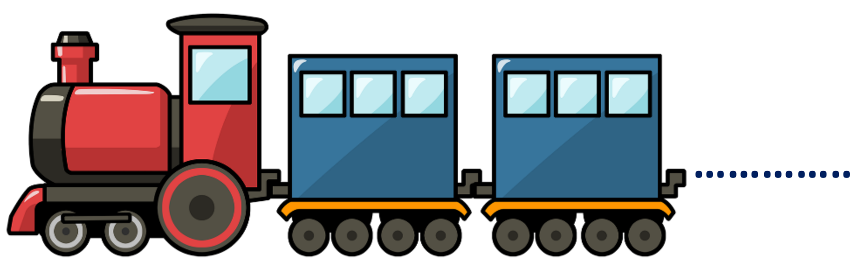
VS: Number of wagons

MKA: Maximum train weight

LA: Locomotive weight

VDA: Loaded wagon weight

$$VS = \frac{MKA - LA}{VDA}$$



1 locomotive 1. wagon 2. wagon ………

LA = 120 ton (constant since locomotive does not carry load or passenger)

VDA = weight of wagons (tare) + load capacity = 12 + 21 = 33 tons

MKA = 1120 ton (according to assignment number)

$$VS = \frac{1120 - 120}{33} = 30{,}30 \Rightarrow VS = 30$$

Calculate the new train weight:

$G_L + G_W = LA + VS*VDA = 120 + 30*33 = 1110$ tons

Which is smaller than 1120 tons so we are on the safe and acceptable side.

Freight train = 1 locomotive + 30 wagons

After that point the procedure is same for both freight and passenger trains therefore calculations will be only performed for passenger trains. Yet for your assignment you have to perform both and show in detail.

Step 6: Calculating the maximum longitudinal gradients for fully loaded passenger and freight trains enabling to run at the regime (maximum) speeds and the maximum longitudinal gradients for them to start with acceleration of 0.25 m/s^2 when they stop on a gradient

Maximum gradient for running at regime speed in the uphill direction: (on a straight and open air section)

Stages (regimes)	Forces acting upon the train	Acceleration or deceleration rate	Equation of motion in the stage
regime (constant speed)	$z - w$	$\frac{dv}{dt} = 0$	$z = w$

$$z_{motor} = \frac{3600 * N}{V_r * g * (G_L + G_W)} = a + \frac{V_r^2}{b} + s_{maks,rejim}$$

$$\frac{3600 * 1700}{125 * 10 * 288,2} = 1,6 + \frac{125^2}{4000} + s_{maks,rejim}$$

s_{max}(regime) = ‰11.80

Calculation of maximum gradient on which it is possible to start moving with a 0.25 m/s² acceleration value (on a straight and open air section)

When a train re-starts its motion from rest, an **acceleration resistance (w_d)** acts on the train depending on the acceleration rate applied:

Stages (regimes)	Forces acting upon the train	Acceleration or deceleration rate	Equation of motion in the stage
acceleration (speed up)	$z - w$	$\frac{dv}{dt} > 0$	$z - w = \frac{1}{\rho}\frac{dv}{dt}$

$$z_{aderans} = \frac{\mu_y * G_a * g}{g * (G_L + G_W)} = a + \frac{V^2}{b} + w_d + s_{maks,kalkis}$$

(coefficient of train mass increase is given as 1,06 in tables)

$$w_d = \frac{1}{\rho} * \frac{dV}{dt} = \frac{1000}{g} * (1 + \xi) * \frac{dV}{dt} = 106 * 0,25 = 26,5 N/kN$$

$$\mu_y = 160 + \frac{7500}{V + 44}$$

(from the table at beginning)

$$\frac{(160 + \frac{7500}{0 + 44}) * 62,8 * g}{g * 288,2} = 1,6 + \frac{0^2}{4000} + 26,5 + s_{maks,kalkis}$$

s_{max}(start) = ‰43.90

Step 7: Comparing the gradients found in step 3 and step 6, and if it is needed, increasing the number of self-powered vehicles for passenger train and increasing the number of locomotives for freight train; determining again the number of passenger wagons and freight wagons with respect to the maximum weight of trains; calculating and comparing again the maximum gradients allowed for tractive conditions

s_{max}(regime) = ‰11.8 > s_u condition satisfied.

s_{max}(start) = ‰43.90 > s_u condition satisfied.

If one of them is not satisfied turn back to step 5 and use 2 self-powered train cars and re-arrange the wagons and re-calculate s_{max}(regime) and s_{max}(start). If this happens at your assignment use 2 vehicles and explain why you have used them. If you do not perform the calculations again your results will not be graded.

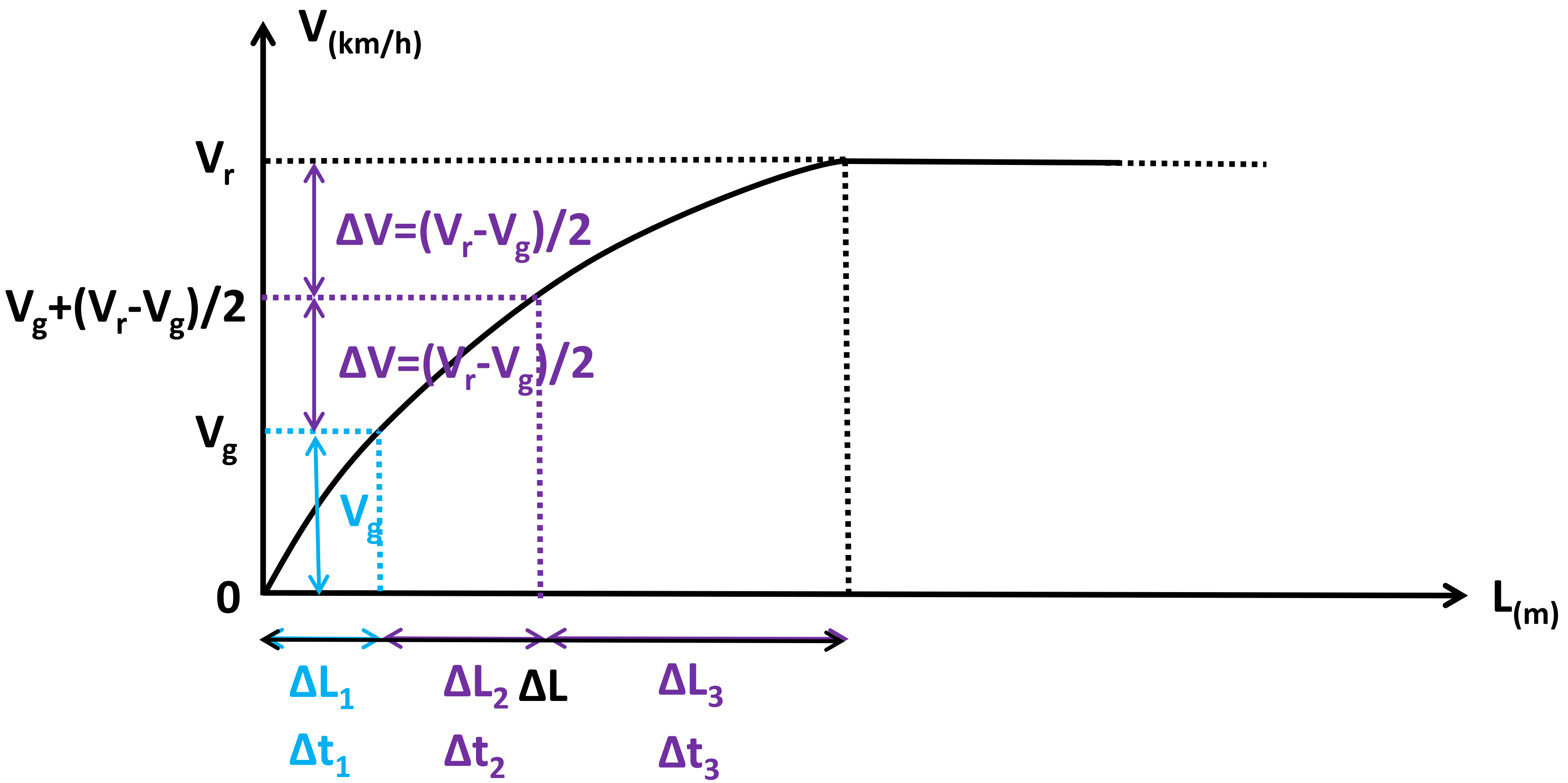
Step 8: Calculating and checking the acceleration distances for fully loaded passenger and freight trains. The computations for acceleration will be performed in **3 speed intervals: one interval up to transition (critical) speed and two equal intervals between critical and regime speeds.** (It is required that fully loaded passenger and freight trains starting their motion at point A be to reach their regime speed within the horizontal/level track-palye section. To make it, the number of self-powered vehicles and/or locomotives will be increased, if needed, and new (adjusted) acceleration distances will be computed. However, **if a new train was made to maintain the requirement for the length of horizontal/level track-palye, the gradient calculation in step 6 will not be repeated; the gradients found in step 6 will be written on the control sheet.**)

Acceleration calculations should be performed for both freight and passenger trains and presented in your assignment. You can use the table format used in your lecture notes. Show one of the calculations for adhesion section and motor power section. <u>If you provide the table and do not show the calculations your results will not be graded.</u>

Calculation of transition speed:

Transition speed is the speed when the traction due to adhesion equals to traction of motor power.

$$\frac{3600 * N}{V_g} = \mu * G_a * g \qquad \frac{3600 * 1700}{V_g} = \left(160 + \frac{7500}{V_g + 44}\right) * 62{,}8 * 10 \qquad \boxed{V_g = 38.91 \text{ km/h}}$$



Acceleration calculations will be performed as, 1 speed interval from start to transition speed and 2 speed intervals from transition speed to regime speed.

Tractive forces will be calculated for adhesion formula until the critical (transition) speed, after that point they will be calculated from the power formula.

	A	B	C	D	E	F	G	H	I	J
1	**Speed interval**	**ΔV (km / h)**	**V_{ort} (km/h)**	**Z (N)**	**z (N / kN)**	**w_0 (N / kN)**	**s (‰)**	**$w_0 \pm$ s (N / kN)**	**Δt (s)**	**ΔL (m)**
2	0 – 38,91	38,91	19,46	174699,98	60,62	1,69	0	1,69	19,44	105,08
3	38,91 – 81,96	43,05	60,44	101257,45	35,13	2,51	0	2,51	38,86	652,42
4	81,96 – 125	43,04	103,48	59141,86	20,52	4,28	0	4,28	78,04	2243,22
								Σ	136,34	**3000,72**

Row 2 Column D → $Z = \mu * G_a * g = \left(160 + \frac{7500}{V_{ort} + 44}\right) * G_a * g = \left(160 + \frac{7500}{19,46 + 44}\right) * 62,8 * 10 = 174699,98$ N

Row 3 Column D → $Z \frac{= 3600 * N}{V_{ort}} = \frac{3600 * 1700}{60,44} = 101257,45$ N

Row 2 Column E → $z = \frac{Z}{g * (G_L + G_W)} = \frac{174699,98}{10 * 288,2} = 60,62$ N/kN

Row 2 Column F → $w_0 = 1,6 + \frac{V_{ort}^2}{4000} = 1,6 + \frac{19,46^2}{4000} = 1,69$ N/kN

Row 2 Column I → $\Delta t = \frac{1}{\rho} * \frac{\Delta V}{3,6 * (z - (w_0 + s))} = 106 * \frac{38,91}{3,6 * (60,62 - 1,69)} = 19,44$ sn

Row 2 Column J → $\Delta l = \frac{V_{ort}}{3,6} * \Delta t = \frac{19,46}{3,6} * 19,44 = 105,08$ m

Tractive forces will be calculated for adhesion formula until the critical (transition) speed, after that point they will be calculated from the power formula.

	A	B	C	D	E	F	G	H	I	J
1	**Speed interval**	**ΔV (km / h)**	**V_{ort} (km/h)**	**Z (N)**	**z (N / kN)**	**w_0 (N / kN)**	**s (‰)**	**$w_0 \pm s$ (N / kN)**	**Δt (s)**	**ΔL (m)**
2	0 – 38,91	38,91	19,46	174699,98	60,62	1,69	0	1,69	19,44	105,08
3	38,91 – 81,96	43,05	60,44	101257,45	35,13	2,51	0	2,51	38,86	652,42
4	81,96 – 125	43,04	103,48	59141,86	20,52	4,28	0	4,28	78,04	2243,22

G_a **(adhesion weight)** $= \textit{total weight of selfpowered vehicle} * \dfrac{\textit{number of driving axles}}{\textit{number of total axles}}$

self-powered vehicle axle type = Bo' Bo' ➔ (2+2 drive axles)

G_a= 62.8*(4/4)=62.8 ton

Row 2 Column F → $w_0 = 1{,}6 + \dfrac{V_{ort}^2}{4000} = 1{,}6 + \dfrac{19{,}46^2}{4000} = 1{,}69$ N/kN

Row 2 Column I → $\Delta t = \dfrac{1}{\rho} * \dfrac{\Delta V}{3{,}6 * (z - (w_0 + s))} = 106 * \dfrac{38{,}91}{3{,}6 * (60{,}62 - 1{,}69)} = 19{,}44$ sn

Row 2 Column J → $\Delta l = \dfrac{V_{ort}}{3{,}6} * \Delta t = \dfrac{19{,}46}{3{,}6} * 19{,}44 = 105{,}08$ m

Total acceleration length becomes 3000.72 m. Train can not reach the regime speed in horizontal section (station + horizontal track = 500 + 2000 =2500m).

Therefore additional self-powered vehicle is needed. Calculations will be repeated yet if you are adding one more self-powered vehicle because of not reaching the regime speed in horizontal section **you do not need to perform gradient calculations at step 6.**

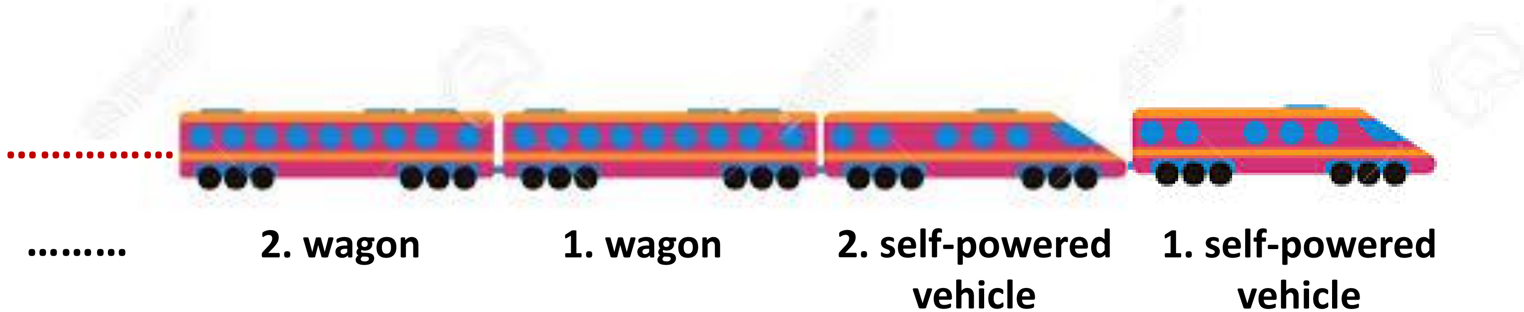
After adding second self-powered vehicle you have to be in the train weight limits. So you have to calculate number of wagons again.

$$VS = \frac{MKA - 2 * ODA}{VDA} = \frac{310 - 2 * 62{,}8}{32{,}2} = 5{,}73 \Rightarrow 5$$

Calculation of the new train weight:

$$G_L + G_W = 2 * 62.8 + 32.2 * 5 = 286.60 \text{ ton} < 310 \text{ ton}$$

Passenger train = 2 self-powered vehicle + 5 wagons



Transition speed does not change with the number of self-powered vehicle. Since there are two self-powered vehicle adhesion weight and self-powered vehicle power is doubled.

	A	B	C	D	E	F	G	H	I	J
1	**Speed interval**	**ΔV (km / h)**	**V_{ort} (km/h)**	**Z (N)**	**z (N/kN)**	**w_0 (N / kN)**	**s (‰)**	**$w_0 \pm s$ (N / kN)**	**Δt (s)**	**ΔL (m)**
2	0 - 38,91	38,91	19,46	349399,96	121,91	1,69	0	1,69	9,53	51,51
3	38,91 - 81,96	43,05	60,44	202514,89	70,66	2,51	0	2,51	18,6	312,27
4	81,96 - 125	43,04	103,48	118283,73	41,27	4,28	0	4,28	34,26	984,78
								Σ	62,39	1348,56

Row 2 Column D → $Z = \mu * G_a * g = \left(160 + \frac{7500}{V_{ort} + 44}\right) * G_a * g = \left(160 + \frac{7500}{19{,}46 + 44}\right) * 2 * 62{,}8 * 10 = 349399{,}96 \text{ N}$

Row 3 Column D → $Z \frac{= 3600 * N}{V_{ort}} = \frac{3600 * 2 * 1700}{60{,}44} = 202514{,}89 \text{ N}$

Row 2 Column E → $z = \frac{Z}{g * (G_L + G_W)} = \frac{349399{,}96}{10 * 286{,}6} = 121{,}91 \text{ N/kN}$

Row 2 Column F → $w_0 = 1{,}69$ N/kN (resistance will not change)

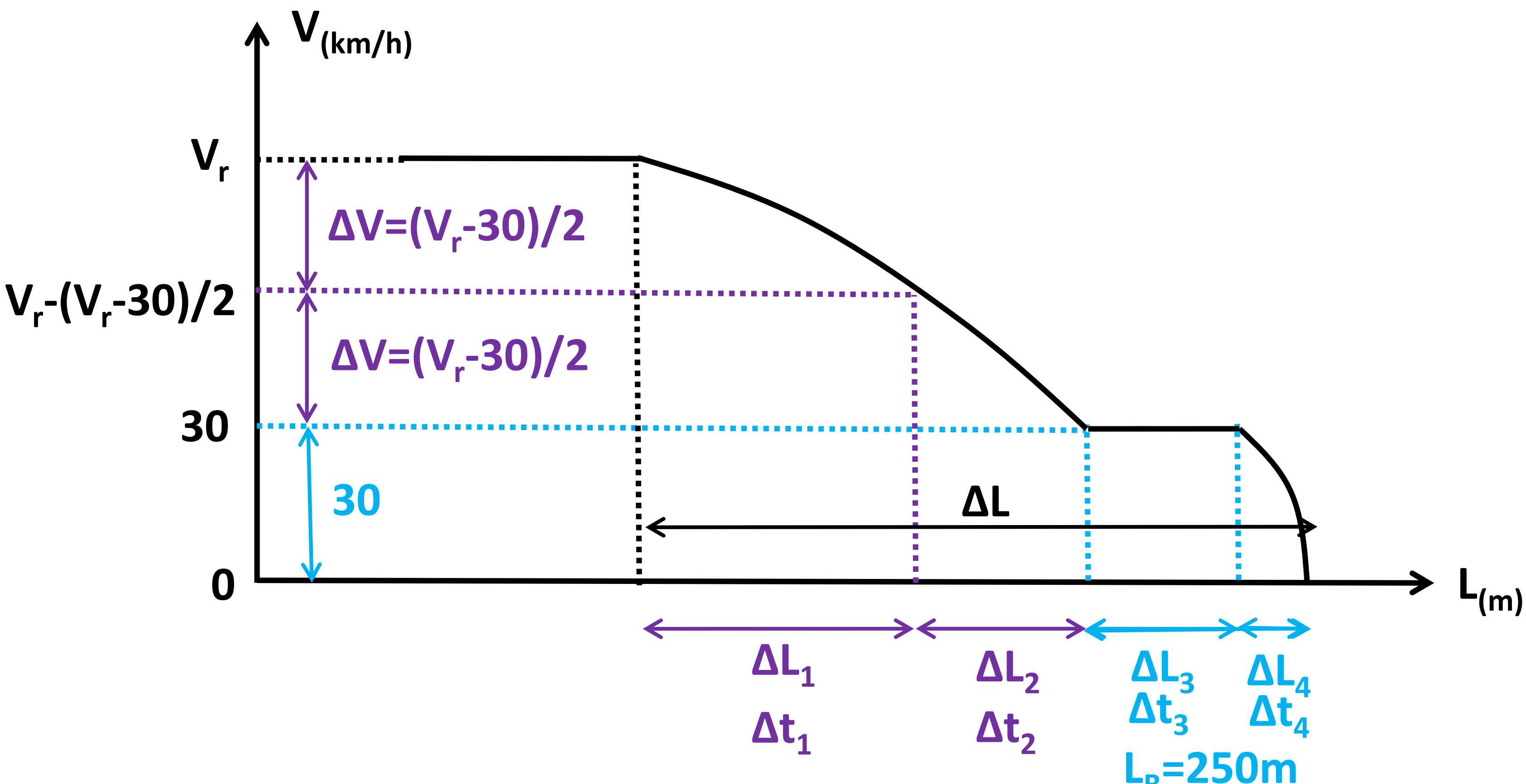
Row 2 Column I → $\Delta t = \frac{1}{\rho} * \frac{\Delta V}{3{,}6 * (z - (w_0 + s))} = 106 * \frac{38{,}91}{3{,}6 * (121{,}91 - 1{,}69)} = 9{,}53$ sn

Row 2 Column J → $\Delta l = \frac{V_{ort}}{3{,}6} * \Delta t = \frac{19{,}46}{3{,}6} * 9{,}53 = 51{,}51$ m

Important note: If you add second self-powered vehicle or locomotive you have to show both calculations (with single locomotive and double locomotive) also show acceleration tables in your homework.

2nd PART

Step 9: Calculating the total running times of passenger and freight trains (in A → B direction). (**There will be two equal speed intervals for braking before station B; a speed limit of 30 km/h is used in station B; this 30 km/h constant speed run in station is considered to be in the braking stage; full stop occurs at point B.**)



The movement inside the B station with constant speed 30 km/h should be included to braking time and distance calculations. Actually braking distance is equal to sum of distance that taken by train until its speed drops to 30 km/h and length of station B (250m).

	A	B	C	D	E	F	G	H	I
1	**Speed interval**	**ΔV (km / h)**	**V_{ort} (km/h)**	**w_f (N/kN)**	**w_0 (N / kN)**	**s (‰)**	**$w_0 \pm s$ (N / kN)**	**Δt (s)**	**ΔL (m)**
2	125 – 77,5	47,5	101,25	52,07	4,16	7,56	11,72	21,93	616,78
3	77,5 – 30	47,5	53,75	75,9	2,32	7,56	9,88	16,3	243,37
4	30 – 30	0	30	0	Not necessary.	0	Not necessary.	26,4	220,04
5	30 – 0	30	15	121,15	1,66	0	1,66	7,19	29,96
							Σ	71,82	1110,15

Row 2 Column D → $w_f = \dfrac{\alpha * \beta}{\gamma} \mu_f = \dfrac{\alpha * \beta}{\gamma} * \dfrac{12500}{50 + V_{ort}} = \dfrac{0,7 * 0,9}{1,0} * \dfrac{12500}{50 + 101,25} = 52,07$ N/kN

Row 2 Column E → $w_0 = 1,6 + \dfrac{V_{ort}^2}{4000} = 1,6 + \dfrac{101,25^2}{4000} = 4,16$ N/kN

Row 2 Column F → it is equal to the applied gradient since train did not reach the station yet.

Row 2 Column H → $\Delta t = \dfrac{1}{\rho} * \dfrac{\Delta V}{3,6 * \left(w_f + (w_0 + s)\right)} = 106 * \dfrac{47,5}{3,6 * (52,07 + 11,72)} = 21,93$ sn

Row 2 Column I → $\Delta l = \dfrac{V_{ort}}{3,6} * \Delta t = \dfrac{101,25}{3,6} * 21,93 = 616,78$

Row 4: This row belongs to constant speed period, therefore no need to calculate for acceleration and resistance. In order to determine the constant speed 30 km/h running time, first the distance which will be travelled by 30 km/h should be known. This distance is found by subtracting the braking distance from 30 to 0 km, from the length of the station B (250m) (which is calculated at row 5 column I = 29.96 m).

	A	B	C	D	E	F	G	H	I
1	**Speed interval**	**ΔV (km / h)**	**V_{ort} (km/h)**	**w_f (N/kN)**	**w_0 (N / kN)**	**s (‰)**	**$w_0 \pm s$ (N / kN)**	**Δt (s)**	**ΔL (m)**
2	125 – 77,5	47,5	101,25	52,07	4,16	7,56	11,72	21,93	616,78
3	77,5 – 30	47,5	53,75	75,9	2,32	7,56	9,88	16,3	243,37
4	30 – 30	0	30	0	Not necessary.	0	Not necessary.	26,4	220,04
5	30 – 0	30	15	121,15	1,66	0	1,66	7,19	29,96
							Σ	71,82	1110,15

Row 2 Column D → $w_f = \frac{\alpha * \beta}{\gamma}\mu_f = \frac{\alpha * \beta}{\gamma} * \frac{12500}{50 + V_{ort}} = \frac{0,7 * 0,9}{1,0} * \frac{12500}{50 + 101,25} = 52,07$ N/kN

Row	**Stages (regimes)**	**Forces acting upon the train**	**Acceleration or deceleration rate**	**Equation of motion in the stage**
Row	deceleration (braking)	$-w - w_f$ $(z = 0)$	$\frac{dv}{dt} < 0$	$-w - w_f = -\frac{1}{\rho}\frac{dv}{dt}$

Row 2 Column H → $\Delta t = \frac{1}{\rho} * \frac{\Delta V}{3,6 * \left(w_f + (w_0 + s)\right)} = 106 * \frac{47,5}{3,6 * (52,07 + 11,72)} = 21,93$ sn

Row 2 Column I → $\Delta l = \frac{V_{ort}}{3,6} * \Delta t = \frac{101,25}{3,6} * 21,93 = 616,78$

Row 4: This row belongs to constant speed period, therefore no need to calculate for acceleration and resistance. In order to determine the constant speed 30 km/h running time, first the distance which will be travelled by 30 km/h should be known. This distance is found by subtracting the braking distance from 30 to 0 km, from the length of the station B (250m) (which is calculated at row 5 column I = 29.96 m).

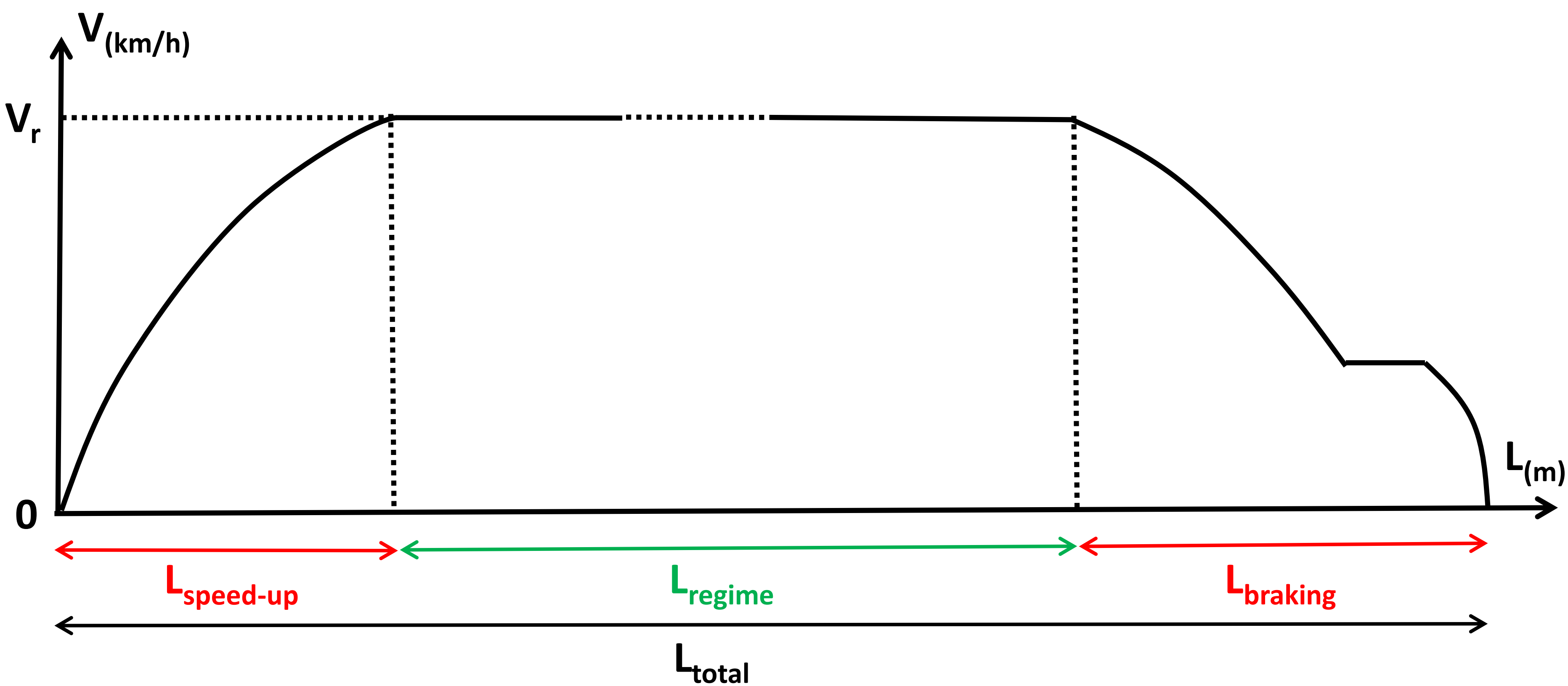
Regime length = total length – (braking and acceleration length)

Regime length = 43249.84 – (1110.15 + 1348.56) = $\boxed{40791.13 \text{ m}}$

Regime time = $\dfrac{L_{rejim}}{(V_{rejim}/3{,}6)} = \dfrac{40791{,}13}{(125/3{,}6)} = \boxed{1174{,}78 \text{ s}}$

Total running time = regime time + braking time + acceleration time

Total running time = 1174.78 + 71.82 + 62.39 = $\boxed{1308.99 \text{ s}}$



Step 10: Calculating the number of passenger and freight trains (services) for traffic demand. (The decimal train numbers calculated will be rounded up to the next integer number.)

Calculating the Number of Train Services Required for Traffic Demand

The number of train types required for passenger and freight traffic demand can be calculated using the equations below. On the left-hand-side of these equations are the amount of **traffic forecasted to be travelled/carried in one day in one direction** (pass-km or ton-km), while on the right-hand-side are the amount of **traffic to be able to be shipped by trains in one day in one direction** (pass-km or ton-km). Hence, **traffic demand** on the left-hand-side is satisfied (met) by the **capacity supply** on the right-hand-side of the equations. **The number of trains (passenger and freight) calculated using these equations has to be rounded up to the nearest integer number (to prevent and unsatisfied demand).**

For passenger traffic: $$\frac{1}{2}\frac{T_v}{365}k_1\lambda_v = N_v a_v k_2 k_3 L_v$$ **(pass-km/day-dir)**

For freight traffic: $$\frac{T_m}{365}k_1\lambda_m = N_m a_m k_2 k_3 L_m$$ **(ton-km/day-dir)**

Where,

T_v:	Number of passengers per year in two directions (passenger/year) (Passenger traffic is usually in two directions; i.e., an outgoing passenger usually returns back to his/her origin.)
T_m:	Number of tons per year in one directions (ton/year-dir) (Freight traffic is usually in single direction. For example, incoming raw material to a factory does not return back to its production location or a product produced in a factory and shipped to the market does not return back to the factory.)
λ_v:	An average travel distance of a passenger (km)
λ_m:	An average shipping distance of one ton freight (goods) (km)
N_v:	The number of passenger trains required to operate per day in one direction (train/day-dir)
N_m:	The number of freight trains required to operate per day in one direction (train/day-dir)
a_v:	Capacity of a passenger train (pass/train)
a_m:	Capacity of a freight train (ton/train)
L_v:	Total length of journey of a passenger train between end terminals (km)
L_m:	Total length of travel of a freight train between end terminals (km)
k_1:	Maximum traffic coefficient: (maximum daily passenger or freight / average daily passenger or freight) ≥ 1,00
k_2:	Wagon utilization coefficient: (average # of pass or tons of freight in trains / pass or ton capacity of trains) ≤ 1,00
k_3:	Train utilization coefficient: (# of (full) wagon in service in trains / # of total wagons in trains) ≤ 1,00

For passenger traffic:

$$\frac{1}{2} * \frac{2*5*10^6}{365} * 1,2 * 100 = N_v * 380 * 0,8 * 1 * 500 \quad N_v = 10,81 \approx \boxed{11} \text{ (train/day-dir)}$$

For freight traffic:

$$\frac{6*10^6}{365} * 1,2 * 300 = N_m * 546 * 0,8 * 0,9 * 500 \quad N_m = 30,11 \approx \boxed{31} \text{ (train/day-dir)}$$

Where,

	Unit	PASSENGER	FREIGHT
Traffic amount	pass.-ton/year-direc.	$5*10^6$	$6*10^6$
Average journey length (λ)	km	100	300
Total service distance (L)	km	500	500
Max. traffic / Ave. Traffic (k_1)	---	1.2	1.2
Coeff. of train util. Rate (k_3)	---	1.0	0.9
Coeff. of wagon util. Rate (k_2)	---	0.8	0.8

a_v (*capacity of passenger train*) = **40*2 + 60*5 =380 pass/train**

a_m (*capacity of freight train*) = **21*26 =546 ton/train**

For passenger traffic:

$$\frac{1}{2}*\frac{2*5*10^6}{365}*1,2*100 = N_v*380*0,8*1*500 \quad N_v = 10,81 \approx \boxed{11} \text{ (train/day-dir)}$$

For freight traffic:

$$\frac{6*10^6}{365}*1,2*300 = N_m*546*0,8*0,9*500 \quad N_m = 30,11 \approx \boxed{31} \text{ (train/day-dir)}$$

Step 11: Calculating the superelevation for curves with radius R1 and R2 based on the even wearing requirement and examining if these superelevations are appropriate for the passenger and freight trains.

Calculating the superelevation based on the even wearing requirement:

Average speed based on even wearing requirement (for the inner and outer rails) :

$$V_o^2 = \frac{\sum n_i G_i V_i^3}{\sum n_i G_i V_i} \quad (\text{km/h})^2$$

Where, n_i: the number of passing of type *i* trains from the curve in a day (train/day)
V_i: the running speed of type *i* trains on the curve (km/h)
G_i: the weight of type *i* trains (G_L+G_W) (ton/train)

	n_i	V_i	G_i	V_i^3	n_i* G_i* V_i^3	n_i* G_i* V_i
Passenger	11	125	286,60	1.953.125	6.157.421.875	394.075
Freight	31	72	1098	373.248	12.704.615.424	2.450.736
				$\sum$	**18.862.037.299**	**2.844.811**

$$V_0^2 = \frac{18.862.037.299}{2.844.811} = 6630{,}33 \rightarrow V_0 = 81{,}43 \text{ km/h}$$

$$d_u = \frac{11,8 V_o^2}{R} \quad \text{(mm)}$$

$$d_1 = \frac{11,8 * 6630,33}{R_1} = \frac{11,8 * 6630,33}{1400} = \boxed{55,88}\ mm$$

$$d_2 = \frac{11,8 * 6630,33}{R_2} = \frac{11,8 * 6630,33}{2100} = \boxed{37,25}\ mm$$

Max-Min Superelevation:

$$d_{\min(yolcu)} = \frac{11,8 V^2_{maks(yolcu)}}{R} - 153\gamma_{maks} \quad \text{(mm)} \qquad d_{maks(yük)} = \frac{11,8 V^2_{\min(yük)}}{R} + \Delta d_f \quad \text{(mm)}$$

$$d_{1\min} = \frac{11,8 * 125^2}{R_1} - 153 * 0,92 = \frac{11,8 * 15625}{1400} - 153 * 0,92 = -9,06\ mm$$

$$d_{2\min} = \frac{11,8 * 125^2}{R_2} - 153 * 0,92 = \frac{11,8 * 15625}{2100} - 153 * 0,92 = -52,96\ mm$$

$$d_{1\max} = \frac{11,8 * 72^2}{R_1} + 90 = \frac{11,8 * 5184}{1400} + 90 = 133,69\ mm$$

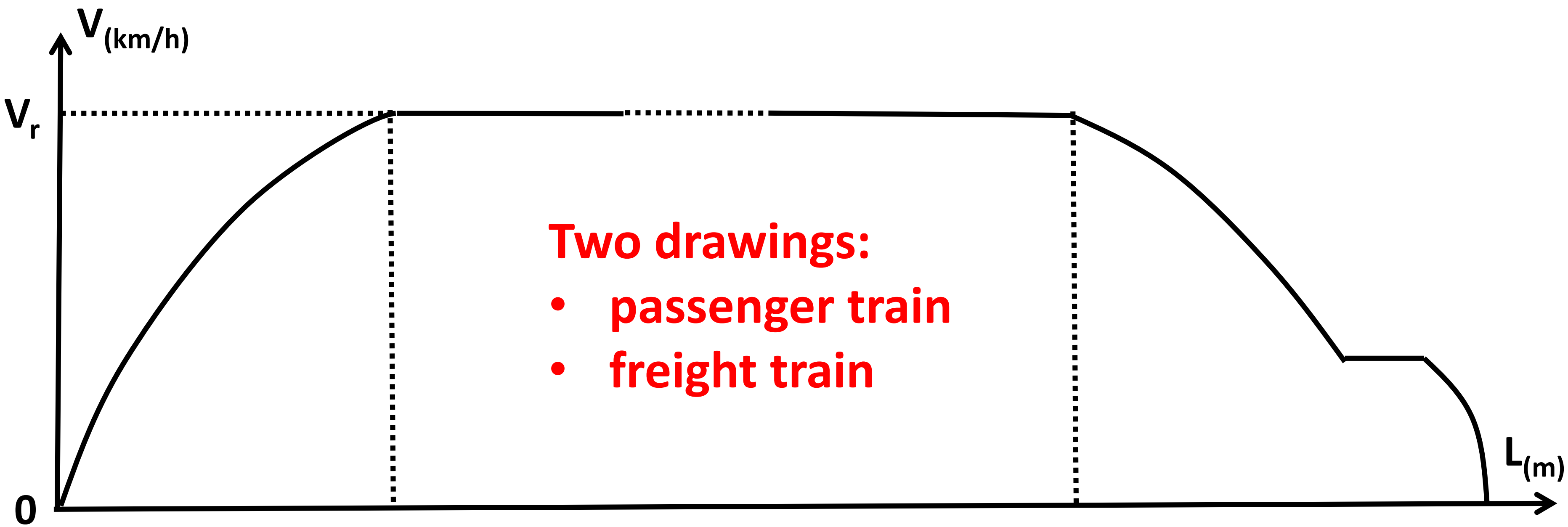
$$d_{2\max} = \frac{11,8 * 72^2}{R_2} + 90 = \frac{11,8 * 5184}{2100} + 90 = 119,13\ mm$$

For first curve ➔ $-9,06 < 55,88 < 133,69$

For second curve ➔ $-52,96 < 37,25 < 119,13$

Superelevation values (d_1, d_2) are appropriate.

You must draw the running (speed-distance) graphics showing the stages of train movement. The horizontal axis is drawn parallel to the longer side of A4 paper (horizontal scale: free to choose; because the constant speed stage is too long, it may be drawn as dashed line; vertical scale: 1 cm = 30 km/h).



<u>DRAWINGS GIVEN IN THE ASSIGNMENT FILE WITH RESPECT TO THE PARTS</u>

D1. Drawing the new plan and showing the required data on it (scale: 1/100,000).

D2. Drawing the new profile and showing the required data on it (horizontal scale: 1/100,000; vertical scale: 1/10,000).

D3. Drawing the running (speed-distance) graphics showing the stages of train movement. The horizontal axis is drawn parallel to the longer side of A4 paper (horizontal scale: free to choose; because the constant speed stage is too long, it may be drawn as dashed line; vertical scale: 1 cm = 30 km/h).

Calculations and drawings in the assignment file must be prepared by hand (tables of running times may be given as computer printout as long as their calculation details are shown). You may use graph papers or plain papers for drawings.