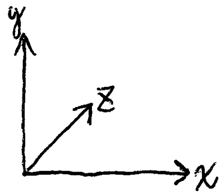
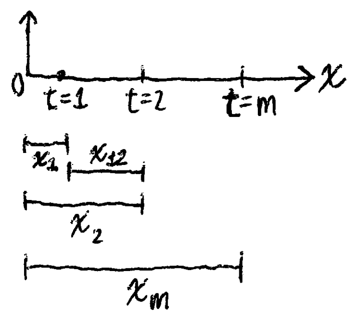
Ch 2 9/8/08

Kinematics - Study of motion w/o forces involved

Kinetics - Study of motion w/ forces involved



Rectilinear Motion



Velocity $V = \frac{dx}{dt}$

Speed is the scalar of the velocity

Acceleration $a = \frac{dv}{dt}$ can be >0, $=0$, or <0

acceleration <0 is called deceleration

$$a = \frac{dv}{dx} \cdot \frac{dx}{dt} = \frac{dv}{dx} \cdot V$$

Consider the following:
- rectilinear motion
- a is constant

$dv = a\,dt$ | $V\,dx = a\,dx$

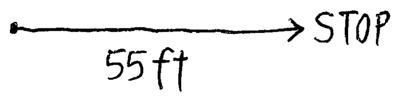
$\int_{V_0}^{V} dv = \int_{t_0}^{t} a\,dt$ | $\int_{V_0}^{V} V\,dx = \int_{x}^{x_0} a\,dx$

$V = V_0 + at$ | $\frac{1}{2}(V^2 - V_0^2) = a(x - x_0)$

$$V = at + V_0$$

$$x = \frac{1}{2}at^2 + V_0 t + x_0$$

Ex. $V = 30\ mi/h$, $t = 0$, $d = 16\ ft/s^2$ or $a = -16\ ft/s^2$



Find:

* Can the vehicle stop legally?
* $a \rightarrow t$
* $v \rightarrow t$
* $v \rightarrow x$

$V = 30\ mi/h = 44\ ft/s^2$

$a = -16\ ft/s^2$

$V = V_0 + at$

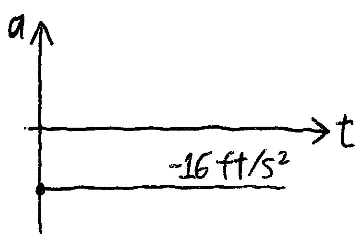
$0 = 44 - 16t \Rightarrow t = 2.75\,s$

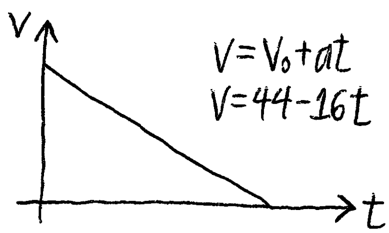
$$x - x_0 = \frac{V^2 - V_0^2}{2a}$$

$$x = \frac{-44^2}{-2 * 16} = 60.5\ ft > 55\ ft$$ Cannot stop legally

$$x = \frac{1}{2}at^2 + V_0 t + x_0$$

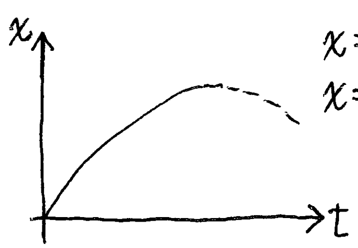
$$x = \frac{1}{2}(-16)(2.75)^2 + 44(2.75) + 0 = -60.5 + 121 = 60.5\ ft$$





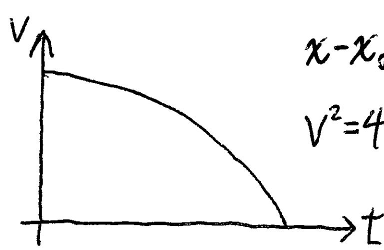
$V = V_0 + at$

$V = 44 - 16t$



$x = \frac{1}{2}at^2 + V_0 t + x_0$

$x = 44t - 8t^2$



$$x - x_0 = \frac{V^2 - V_0^2}{8}$$

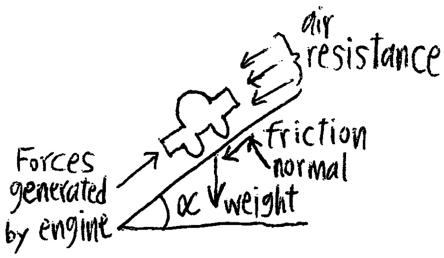
$V^2 = 44^2 - 32x$

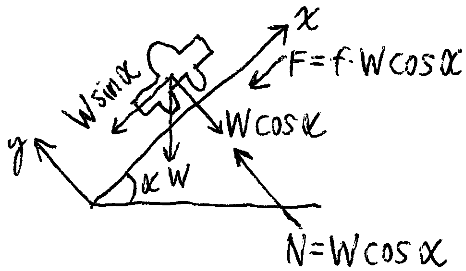
9/10/08

$$V = at + V_0$$

$$x - x_0 = \frac{V^2 - V_0^2}{2a} \qquad x = \frac{1}{2}at^2 + V_0 t + x_0$$

2.2.2 Breaking Distance





$f = 0.6$ dry pavement
$f = 0.3$ wet 〃

$D_b = x \cdot \cos\alpha \qquad \alpha = 0,\ x = D_b$

$$\Sigma F_x = 0:\ N = W\cos\alpha$$

$$\Sigma F_y = 0:\ \frac{W}{g}\cdot a + W\cdot f\cos\alpha + W\sin\alpha = 0 \Rightarrow \frac{V^2 - V_0^2}{2gD_b}\cdot\frac{\cos\alpha}{\cos\alpha} + f\frac{\cos\alpha}{\cos\alpha} + \frac{\sin\alpha}{\cos\alpha} = 0$$

$$x - x_0 = \frac{V^2 - V_0^2}{2a} \Rightarrow \frac{D_b}{\cos\alpha} = \frac{V^2 - V_0^2}{2a} \qquad \frac{V_0^2 - V^2}{2gD_b} = -f - \tan\alpha$$

$$\frac{V^2 - V_0^2}{2gD_b}\cos\alpha + f\cos\alpha + \sin\alpha = 0$$

$$D_b = \frac{V^2 - V_0^2}{2g(f \pm G)} \quad \text{where } G = \tan\alpha$$

Ex 2 in Ch 2

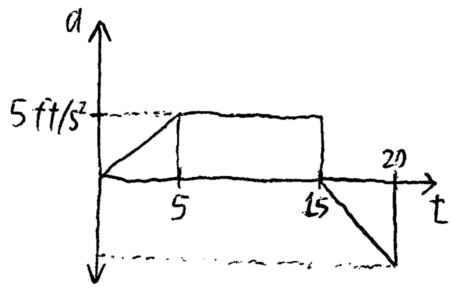
$\tan\alpha = G = 2\%$ $\quad \alpha = 1.15^\circ$

$d = 8\ ft/s^2$ $\quad D_b = x\cos\alpha \cong x$

$$x = \frac{V^2 - V_0^2}{2a} = \frac{V^2 - V_0^2}{2(8)} = \frac{V^2 - V_0^2}{2g(f+G)} \implies 2(8) = 2g(f + 0.02)$$

$$f = 0.23$$

Ex 1 in Ch 2



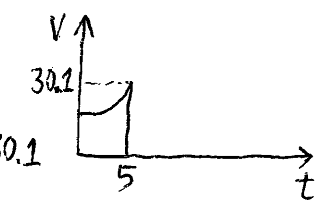
Find:
* $V \to t$
* $D(20)$

$V(0) = 12\ mi/h = 17.6\ ft/s$

I) $0 \le t \le 5$ min

$\frac{dv}{dt} = a = t$ $\quad V = \frac{t^2}{2} + V_0$

$V = t^2/2 + 17.6 = 30.1$



$\frac{dx}{dt} = V$ $\quad x = \frac{t^3}{6} + 17.6t + x_0$

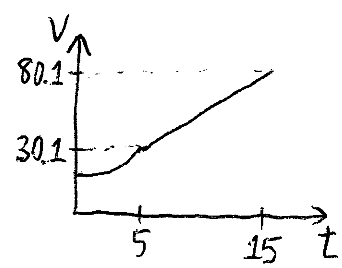
$x = 5^3/6 + 17.6(5) = 108.8\ ft$

II) $5 \le t \le 15$

$0 \le (t-5) \le 10$

$\frac{dv}{dt} = a = 5$ $\quad V = 5(t-5) + V_0$

$V = 5(10) + 30.1 = 80.1$



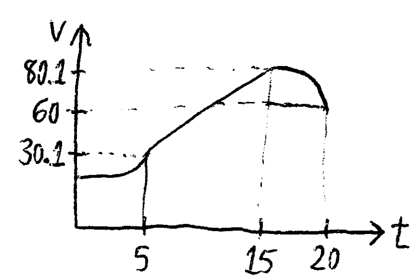
$x = \frac{5(t-5)^2}{2} + 30.1(t-5) + x_0$ $\quad x_0 = 108.8\ ft$

$x = 659.8\ ft$

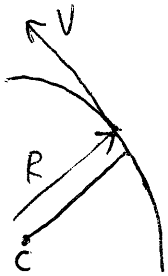
III) $0 \le (t-15) \le 5$

$\frac{dv}{dt} = \frac{-8}{5}(t-15)$ $\quad V = \frac{-8}{5} \cdot \frac{(t-15)^2}{2} + 80.1$

$x = \frac{-8}{5} \cdot \frac{(t-15)^3}{6} + 80.1(t-15) + 659.8$

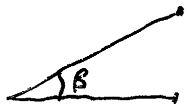


9/12/08



$a_t = \frac{dv}{dt}$ $\quad a_n = \frac{V^2}{R}$

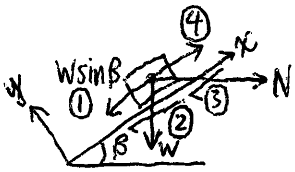
$\Sigma F_t = m\frac{dv}{dt}$ $\quad \Sigma F_n = m\frac{V^2}{R}$



$e = \tan\beta$

↓

rate of superelevation



$\Sigma F_y = W\cos\beta + ma_n \cdot \sin\beta = 0$

$\Sigma F_x = \underset{①}{W\sin\beta} + \underset{②}{f_s \cdot W\cos\beta} + \underset{③}{f_s \cdot \frac{W}{g} \cdot \frac{V^2}{R}} \cdot \sin\beta = \underset{④}{\frac{W}{g}\frac{V^2}{R}\cos\beta}$

$\tan\beta + f_s + \frac{f_s V^2}{gR} \cdot \tan\beta = \frac{V^2}{gR}$

$e + f_s + f_s\frac{V^2}{gR} \cdot e = \frac{V^2}{gR}$ $\quad e + f_s = \frac{V^2}{gR}(1 - ef_s)$

Ex. $W = 2000$ lb $\quad v = 88$ ft/s $\quad F = ?$

$R = 500$ ft $\quad d = 8$ ft/s$^2 = a_t$

$F_t = m \cdot a_t = \frac{2000}{g}(-8) = -497$ lb

$F_n = m \cdot a_n = m \cdot \frac{V^2}{R} = \frac{2000}{32.2}\left(\frac{88^2}{500}\right) = 962$ lb $\quad F = \sqrt{F_t^2 + F_n^2} = 1083$ lb

Ex. $R = 1000$ ft $\quad f = 0.2$

$V = 60$ mi/h $\quad \beta = ?$

$= 88$ ft/s

$\tan\beta = e$ $\quad e = \frac{V^2}{gR} - f_s = \frac{(88)^2}{32.2R} - 0.2 = 0.04$

$\tan\beta = 0.04$ $\quad \beta = 2.3°$

$e = 0$, max $V = ?$

$V = \sqrt{f_s \cdot gR} = \sqrt{0.2 \times 32.2 \times 1000} = 80$ ft/s $\cong 55$ mi/h

HW 1: 2.6, 2.8, 2.11 due 9/22/08

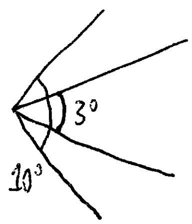
20/20 : normal vision

$H = \frac{1}{3}$ in $d = 20$ ft

20/40

$H = \frac{1}{3}$ in $d = 10$ ft

Vision Region(s)



Ex. 20/20 vision $H = 2$ in $d = 90$ ft

20/50 vision $H = 2$ in $d = ?$

$$x = 90 \text{ ft} \cdot \frac{20}{50} = 36 \text{ ft}$$

20/60 vision $H = ?$ $d = 90$ ft

$$H = 2 \text{ in} \cdot \frac{60}{20} = 6 \text{ in}$$

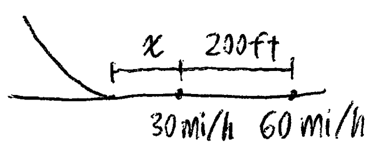
$90 : 6 = 36 : x$ Find H

$$x = \frac{36 \cdot 6}{90} = 2.4 \text{ in}$$

20/40 vision

$d = 50$ ft $H = 1$ in $V_0 = 60$ mi/h $V = 30$ mi/h

for 20/20 $H = 8$ in



$d = 8 \times 50 = 400$ ft (for 20/20)

$d = 200$ ft (for 20/40)

$V_0 = 88$ ft/s $V = 44$ ft/s

δ = perception reaction time

$$x = \frac{V_0^2 - V^2}{2g(f+G)} = \frac{88^2 - 44^2}{2(32.2)(0.3)} + \underset{88 \text{ ft/s}}{V_0} \cdot \underset{1.5}{\delta} = 433 \text{ ft}$$

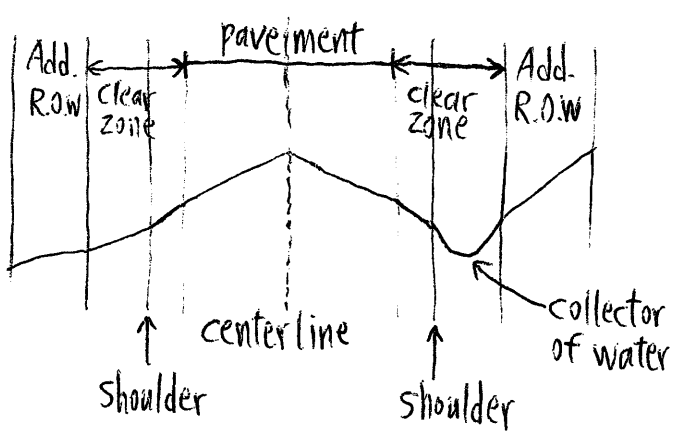
2 ways to classify highways:

1) functionality
2) entity

	Rural	Urban
Principal Arterials	Freeways Others	Interstate Freeways Freeways Others
Minor Arterials (Collectors)	Major Minor Local Roads	Collectors Local Streets

- cross-section
- horizontal alignment
- superelevation
- vertical alignment
- intersections

Cross-Section

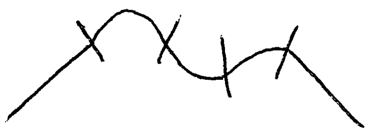


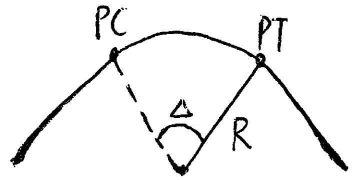
Slope = Normal crown

$\frac{1}{8}$ to $\frac{1}{4}$ in/ft

HW 1 postponed → due Fri 9/26

Horizontal Alignment





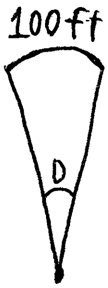
A is located:

14 sta from a ref. point

1400 ft

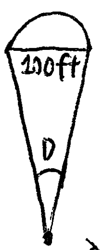
1 sta = 100 ft

$$L = 2\pi R \cdot \frac{\Delta}{360}$$



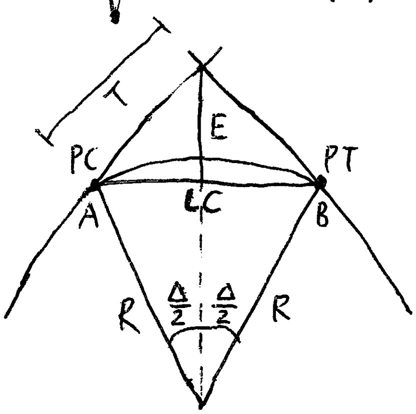
Arc definition

$$\frac{100}{2\pi R} = \frac{D}{360} \Rightarrow D = \frac{5729.58°}{R}$$



Chord definition

$$\sin\left(\frac{D}{L}\right) = \frac{50}{R}$$



M = middle ordinate distance

$$M = R - R\cos\frac{\Delta}{2} = R\left(1 - \cos\frac{\Delta}{2}\right)$$

T = length of tangent

L = length of curvature

$$T = R\tan\frac{\Delta}{2}$$

$$L = 100 \cdot \frac{\Delta}{D}$$

LC = long chord

$$LC = 2R\sin\frac{\Delta}{2}$$

$$e + f_s = \frac{V^2}{gR} \quad \text{OR} \quad e + f_s = \frac{V^2}{15R}$$

$e = 0.12$ ft/ft
$\quad \searrow 0.1$
$\quad \searrow 0.08$
max e

$f_s = 0.17$ 20 mi/h
$\quad\; 0.10$ 70 mi/h
max f_s

$$R_{min} = \frac{V^2}{g(e_{max} + f_s)}$$

$R > R_{min}$

Ex. Calculate D & R_{min}

$\Delta = 100°$
$V = 50$ mi/h
$f_{max} = 0.14$

$$R_{min} = \frac{V^2}{15(e_{max} + f_s)} = \frac{50^2}{15(0.1 + 0.14)} = 695 \text{ ft}$$

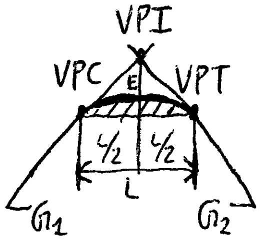
$$D = \frac{5729.58°}{R} = 8.24°$$

Ex. Calculate e

$R = 800$ ft
$V = 50$ mi/h
$f_s = 0.14$

$$e = \frac{V^2}{15R} - f_s = \frac{50^2}{15(800)} - 0.14 = 0.07 \text{ ft/ft}$$

Vertical Alignment



freeways 2%–6%
local streets 6%
railroad max 4%

percent grade $A = G_2 - G_1$ < 0 crest curve, > 0 sag curve

Absolute value of change in grade $k = \frac{L}{|A|}$

$E = \frac{A * L}{800}$ External Distance

offset $\Rightarrow y = 4E\left(\frac{x}{L}\right)^2$

Highest point $X = \frac{L G_1}{G_1 - G_2}$

Elevation of P = Elevation of VPC $+ \frac{G_1 x}{100} + y$

Ex. $L = 600$ ft
$G_1 = 4\%$ $G_2 = -2\%$
25+60.55 sta. <= VPI(x)
VPC=?
Middle of the curve
Curve elevation at 24 and 27 sta.
VPI elev. 648.64 ft

	pt. Sta	x	tan elev.	off-set	curve elev.
VPC	22+60.55	0	636.64	0	636.64
24.00	24	139.45	642.21	-0.97	641.25
VPI	25+60.55	300	648.64	-4.5	644.14
27.00				-9.66	644.56
VPT				-18	642.64
High	26+60.55	400	652.64	-8.0	644.64

$A = G_2 - G_1 = -2 - (4) = -6\%$

$k = \frac{L}{|A|} = \frac{600}{6} = 100$ ft $\quad E = \frac{AL}{800} = \frac{-6 \times 600}{800} = -4.5$ ft

$X = \frac{L G_1}{G_1 - G_2} = \frac{600 \times 4}{4 + 2} = 400$ ft $\quad y = 4E\left(\frac{x}{L}\right)^2 = 4(-4.5)\left(\frac{400}{600}\right)^2 = -8.0$

Tan elev. VPC: $648.64 - 300(.04) = 636.64$

Tan elev. P: $636.64 + 400(.04) = 652.64$

x for 24 Sta: $2400 - 2260.55 = 139.45$

Tan elev. 24 Sta: $636.64 + 139.45 \times .04$

$y(24\text{ Sta}) = 4(-4.5)\left(\frac{139.45}{600}\right)^2$

9/24/08

Exercise 2.20

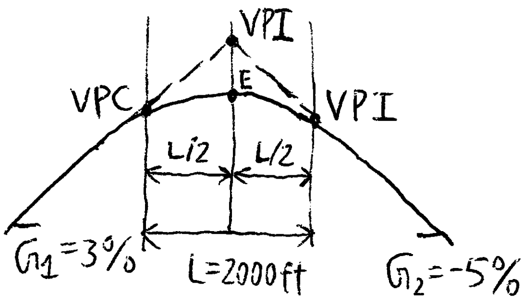
$L = 2000$ ft

$G_1 = 3\%$ $\quad G_2 = -5\%$

VPI intersects at 52+60.55 sta

VPI elevation = 877.62 ft

Find:
* VPC
* VPT
* high point
* 54.00 sta



$A = G_2 - G_1 = -5 - 3 = -8\%$

$K = \frac{L}{|A|} = \frac{2000}{8} = 250 \text{ ft}/^{\circ}$

$E = \frac{AL}{800} = \frac{-8 \times 2000}{800} = -20 \text{ ft}$

		Point	x	Tangent elevation	y	Curve elevation y'
	VPC	42+60.55	0	847.62	0	847.62
high pt.		50+10.55	750	870.12	-11.25	858.87
	VPI	52+60.55	1000	877.62	-20	857.62
54.00		54.00	1139	881.79	-25.95	855.84
	VPT	62+60.55	2000	907.62	-80	827.62

Note:
$y' = T_E - y$

$T_{E(VPC)} = \frac{L}{2} \times G_1 = 1000 \times 3\% = 30 \text{ ft}$

$y_{(VPT)} = 4E\left(\frac{x}{L}\right)^2 = 4 \times (-20)\left(\frac{2000}{2000}\right)^2 = -80 \text{ ft}$

High Point $\rightarrow x = \frac{L G_1}{G_2 - G_1}$

$x = \frac{2000 \times 3}{8} = 750 \text{ ft}$

$T_{E(HP)} = x * G_1 = 750 \times 3\% = 12.5 \text{ ft}$

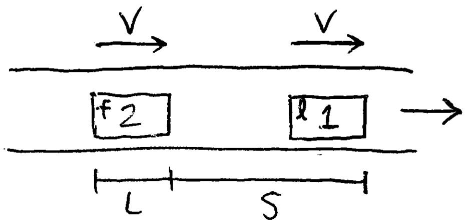
$y_{(HP)} = 4E\left(\frac{x}{L}\right)^2 = 4 \times (-20)\left(\frac{750}{2000}\right)^2 = -11.25 \text{ ft}$

$T_{E(54.00)} = 1139 \times 3\% = 847.62$

$y = 4(-20)\left(\frac{1139}{2000}\right)^2 = -25.95$

9/26/08

Uninterrupted



V_0 = initial speed of vehicle

d_ℓ = deceleration rate of leading vehicle

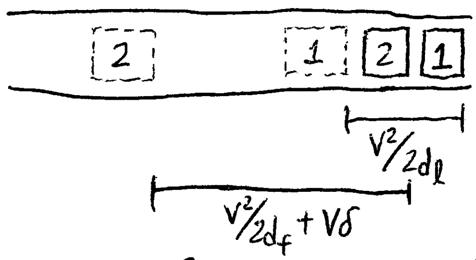
d_f = deceleration rate of following vehicle

δ = perception-reaction time

x_0 = safety margin after stop

L = length of the vehicle

N = number of vehicles in train



$$x_\ell = \frac{V^2}{2d_\ell} \qquad x_f = \frac{V^2}{2d_f} + V\delta \qquad S = x_f - x_\ell + NL + x_0$$

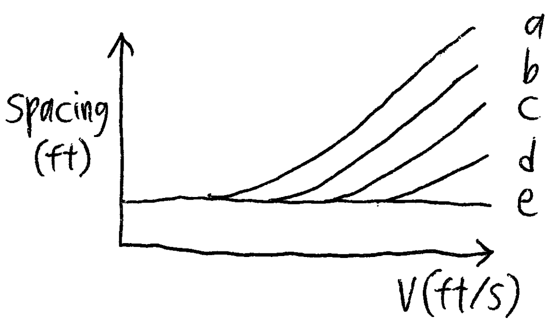
$$x_f = S + x_\ell - NL - x_0 \qquad S = V\cdot\delta + \frac{V^2}{2d_f} - \frac{V^2}{2d_\ell} + NL + x_0$$

d_n = normal deceleration rate

d_e = emergency " "

∞ = instantaneous stop

a best safety cond.
b
c
d
e worst safety cond.



$L = 20\,ft$

$N = 1$

$x_0 = 3\,ft$

$\delta = 1\,s$

$d_n = 8\,ft/s^2$

$d_e = 24\,ft/s^2$

Regime	Decel. leading Veh.	Decel. following Veh.
a	∞	d_n
b	d_e	d_n
c	∞	d_e
d	d_e	d_f
e	no breaking	no breaking

Ex. (Prob 3.1)

$N=1$

b safety regime

$\delta=1.5\ s$

$d_n = 8\ ft/s^2$

$d_e = 32\ ft/s^2$

$L = 40\ ft$

$x_0 = 4\ ft$

Find:

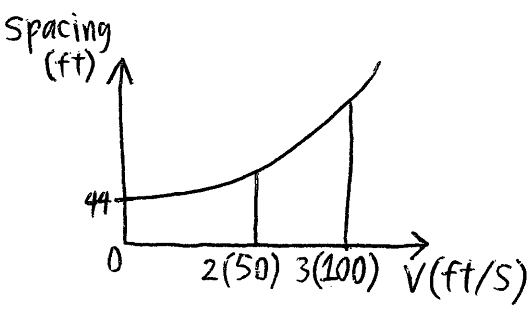
$* \ S \leftrightarrow V$

$d_\ell = d_e$

$d_f = d_n$

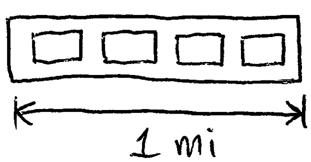
$$S = V\cdot\delta + \frac{V^2}{2d_n} - \frac{V^2}{2d_e} + NL + x_0$$

$$① \quad S = V(1.5) + \frac{V^2}{2(8)} - \frac{V^2}{2(32)} + 1(40) + 4$$

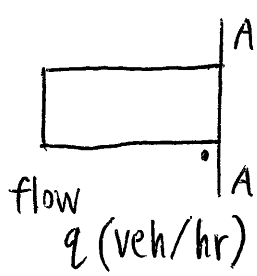


$$② \quad S = 50(1.5) + \frac{50^2}{16} - \frac{50^2}{64} + 44$$

Concentration (K): number of vehicles per roadway length



$$K = \frac{4\text{ veh.}}{1\text{ mi}} = 4\ \text{veh.}/\text{mi} \qquad S = 1/K$$



$h = \frac{1}{q}$ headway

Average Speed

Time Mean Speed

$$\mu_t = \frac{1}{N}\sum_{i=1}^{N} V_i$$

Space Mean Speed

$$t_i = D/V_i$$

$$t_{avg} = \frac{1}{N}\sum_{i=1}^{N}\frac{D}{V_i} \qquad \mu_s = \frac{1}{\frac{1}{N}\sum_{i=1}^{N}\frac{1}{V_i}}$$

9/29/08

HW 2 due 10/8

2.21, 3.9, 3.14, $\underset{?}{\underline{3.17}}$

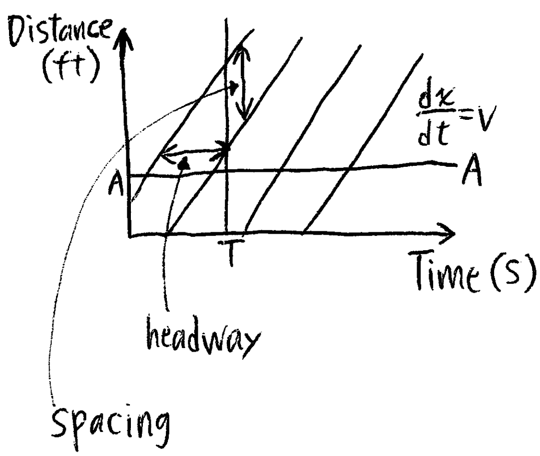
Ex.

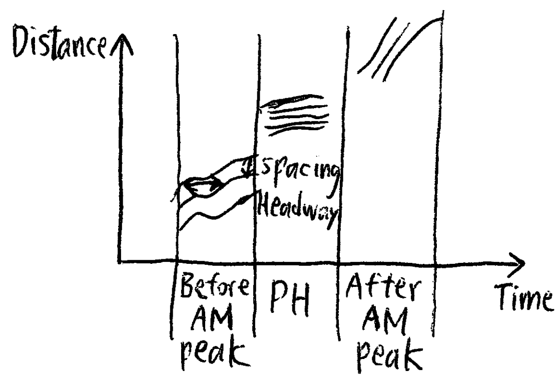
30, 40, 50, 60 ft/s

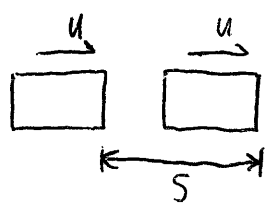
$$\mu_t = \frac{1}{4}\left(\frac{30+40+50+60}{}\right) = 45 \text{ ft/s}$$

$$\mu_s = \frac{1}{\frac{1}{4}\cdot\left(\frac{1}{30}+\frac{1}{40}+\frac{1}{50}+\frac{1}{60}\right)} = 42.1 \text{ ft/s}$$

μ_t & μ_s are different



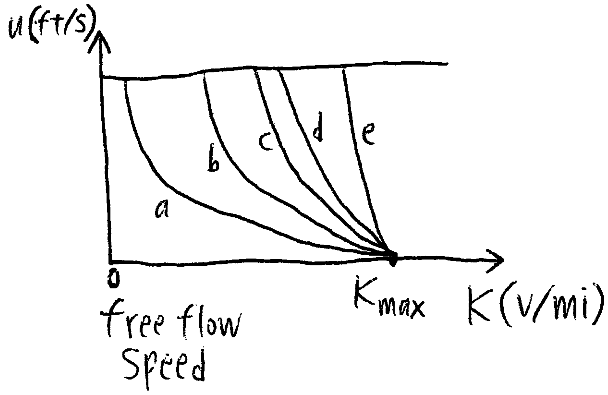




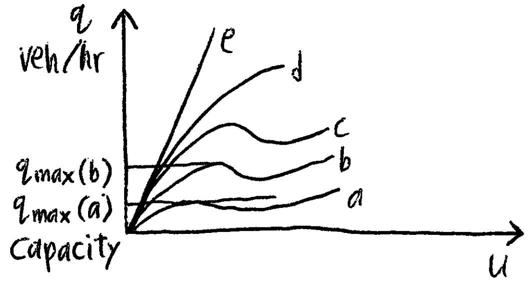
$h=\frac{S}{u}$ $\quad h=\frac{1}{q}$ $\quad K=\frac{1}{S} \Rightarrow S=\frac{1}{K}$

$\frac{1}{q}=\frac{1}{K\cdot u}$ $\quad q=K\cdot u$

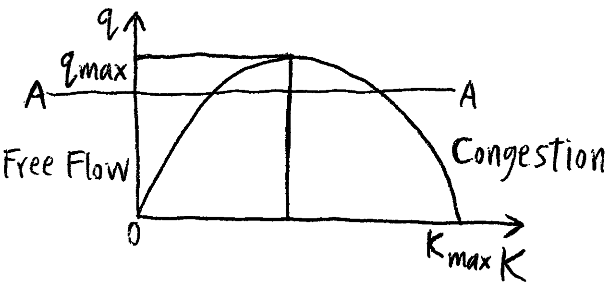
$$S = u\delta + \frac{u^2}{2d_f} - \frac{u^2}{2d_l} + NL + x_0 \qquad K=\frac{1}{S}=\frac{1}{u\delta+\frac{u^2}{2d_f}-\frac{u^2}{2d_l}+NL+x_0}$$

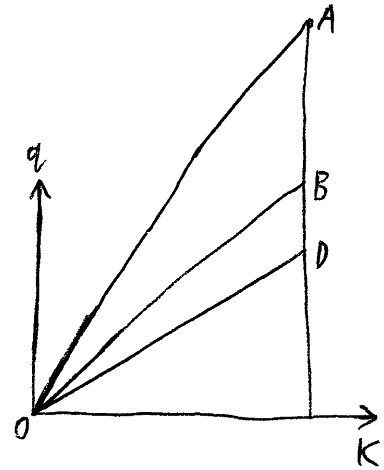


$$q = Ku = \frac{u}{u\delta + \frac{u^2}{2d_f} - \frac{u^2}{2d_\ell} + NL + x_0}$$

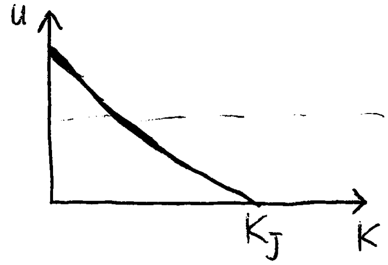


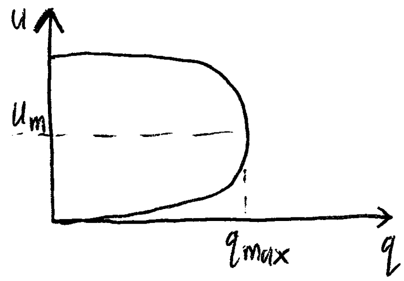
$$q = Ku \Rightarrow q = K \cdot u(K)$$

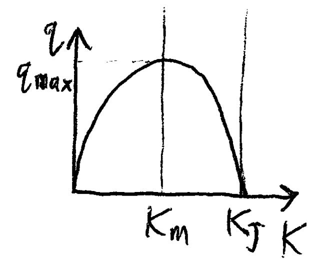




10/1/08





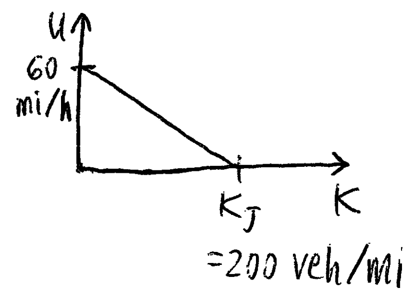


Ex. Exercise 3.4

$$S = \frac{0.30}{(60-u)}$$

Find
* $u-K$
* $u-q$
* $q-K$
* q_{max}

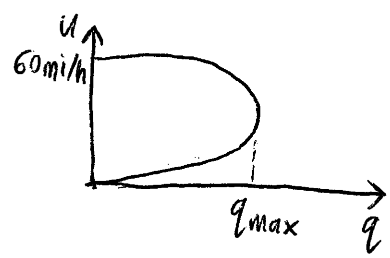
$$\frac{1}{K} = \frac{0.30}{60-u} \Rightarrow K = \frac{60-u}{0.30} = 200 - 3.33u$$



$$u = \frac{q}{K} = \frac{q}{60-u} \cdot 0.30$$

$$0.30q = 60u - u^2$$

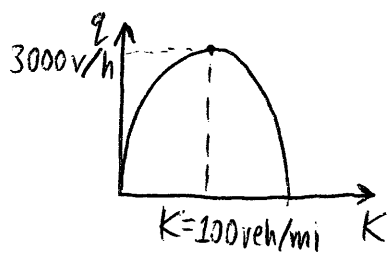
$$q = \frac{60u - u^2}{0.30} = 200u - 3.33u^2$$



$$K = 200 - 3.33\frac{q}{K}$$

$$K^2 = 200K - 3.33q$$

$$q = \frac{200K - K^2}{3.33} = 60K - 0.3K^2$$

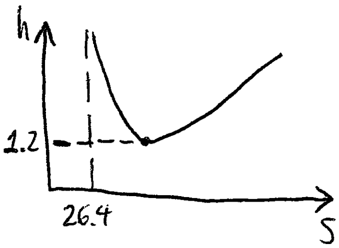


$$q_{max} \Rightarrow \frac{dq}{dK} = 0 \qquad 60 - 0.6K = 0$$

$$K = 100$$

$$q_{max} = 6000 - 3000 = 3000 \text{ veh/hr}$$

Ex.



jam conditions $\quad u=0 \quad K=\frac{60}{0.3}$

[redacted] $\quad S=\frac{1}{K}=\frac{0.3}{60}=0.005 \text{ mi}=26.4 \text{ ft}$

at capacity $\quad h=\frac{1}{q_{max}}=\frac{3600}{3000}=$ [redacted] 1.2

Ex. Exercise 3.8

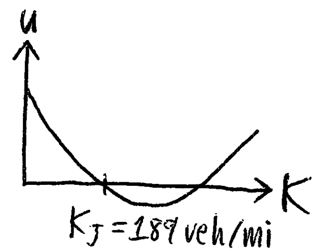
$u+2.6=0.001(K-240)^2$ $\qquad$ Find: $u_{ff}, K_J, q_{max}, u_m$

speed of free flow

$K=0 \Rightarrow u_{ff}=0.001(240)^2-2.6=55 \text{ mi/h}$

$u=0 \Rightarrow (K-240)^2=2.6$

$K_J=189$ or 291 veh/mi



$\frac{dq}{dK}=0 \qquad q=u\cdot K=\left(0.001(K-240)^2-2.6\right)K$

$=0.001K^3-0.48K^2+55K$

$\frac{dq}{dK}=0.003K^2-0.96K+55=0 \qquad K=75$ or 245

[redacted] $K_m=75 \qquad q_{max}=1846$ veh/hr

$u_m=\frac{q_{max}}{K_m}=\frac{1846}{75}=24.6 \text{ mi/h}$

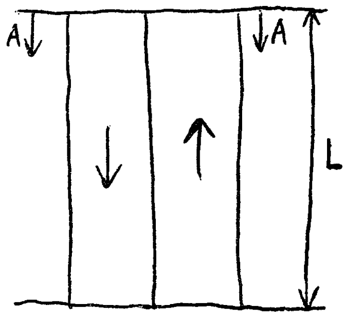
For Exam 1:

1. Rectilinear and Curvilinear Motion
2. Perception Reaction Time & Visual Acuity
3. Horizontal & Vertical Alignment
4. u-K-q
5. The moving observer
6. Shock Waves

10/3/08

The moving observer method

$q = u \cdot K$



1st case

$q = \frac{N_o}{T}$

2nd case

$K = \frac{N_p}{L}$

$N_p = KL = KVT$

$= K \times L = K \times V \times T$

3rd case

M_o: number of vehicles overtake by the observer

M_p: number of vehicles overtaken the observer

$M = M_o - M_p$

$= qT - KVT$

$\frac{M}{T} = q - KV$

$\downarrow \quad T_a \quad M_a$

$\uparrow w \quad T_w \quad M_w$

$q = \frac{M_w + M_a}{T_w + T_a}$

* M_o: car faster than obs.
* M_p: car slower than obs.

Ex. $L = 5$ mi

$\uparrow w$

	V	$M_o - M_p$
1	10	100
2	20	-150

Find:
* q
* K
* u_s
* S
* h

$\frac{M_1}{T_1} = q - KV_1$

$\frac{100}{T_1} = q - 10K$

$\frac{100}{0.5} = q - 10K \qquad \frac{-150}{0.25} = q - 20K$

$200 = q - 10K \qquad -600 = q - 20K$

$-600 = 200 + 10K - 20K$

$K = 80$ veh/mi

$200 = q - 800$

$q = 1000$ veh/hr

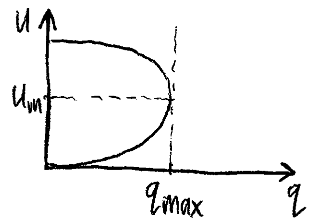
$h = \frac{1}{q} = \frac{1}{1000} = 0.001 \text{ hr} = 3.6 \text{ s}$

$s = \frac{1}{K} = \frac{1}{80} = 0.013 \text{ mi} = 66 \text{ ft}$

$u = \frac{q}{K} = \frac{1000}{80} = 12.5 \text{ mi/hr}$

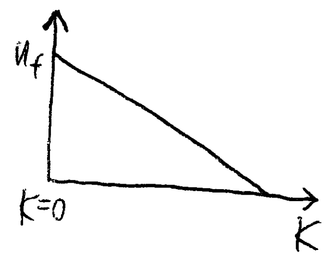
$q = q(u) \quad q = a + bu$

q_{max} & u_m , $K_m = \frac{q_{max}}{u_m}$



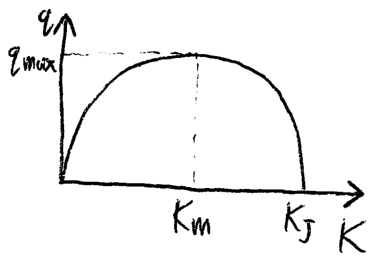
$\frac{dq}{du} = 0 \rightarrow u$

$u_{ff} \quad K=0 \quad u = u(K)$



To get q_{max}, need q-u or q-K

$K_J \quad q=0 \quad q = q(K)$



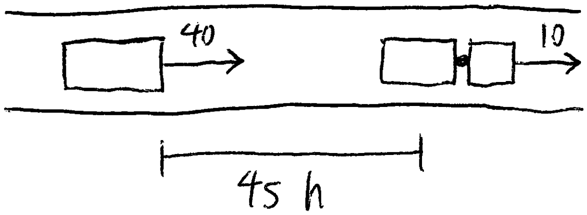
q_{max}?

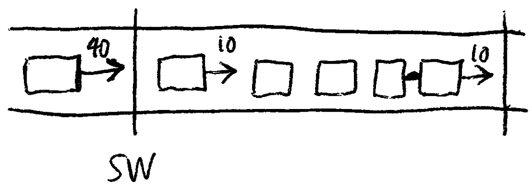
$\frac{dq}{dK} = 0 \rightarrow K_m \rightarrow q_{max} \qquad q=0 \rightarrow K_J$

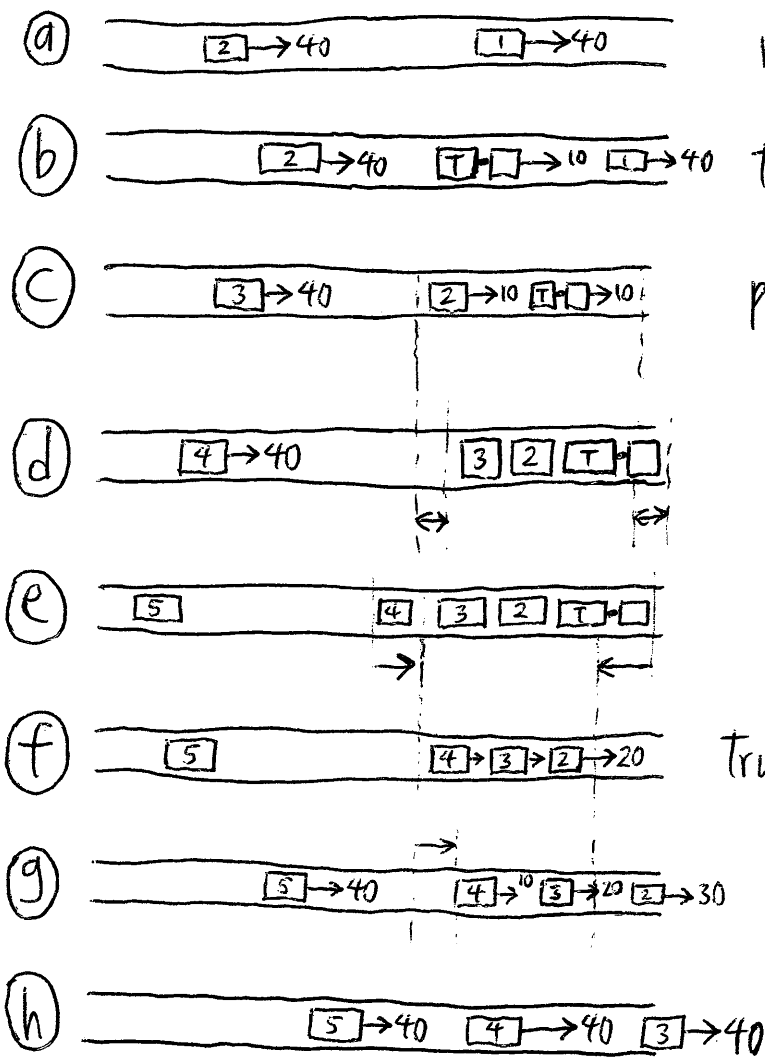
$u_m = \frac{q_{max}}{K_m}$

10/6/08

Shockwaves





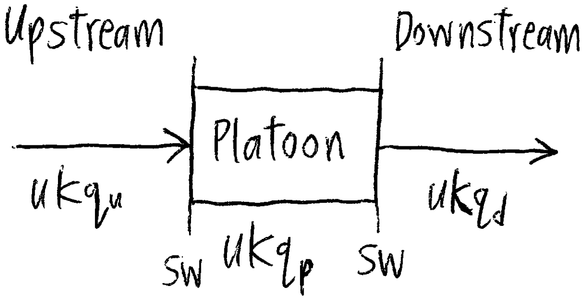


normal flow

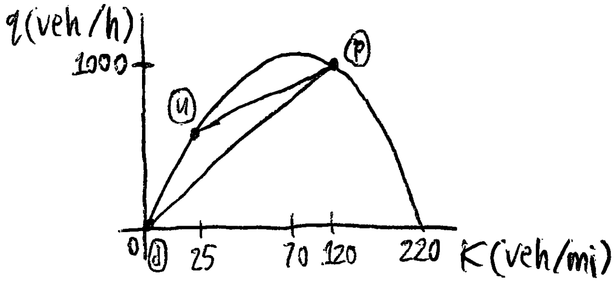
truck enters

platoon begins

truck exits



Graphical



$u_{up} = 40$ mi/h

$q_{up} = 1000$ veh/h

$K_{up} = 25$ veh/mi

$u_p = 10$ mi/h

$q_p = 1200$ veh/h

$K_p = 120$ veh/mi

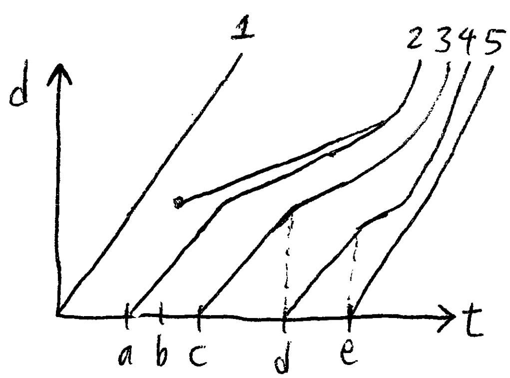
$u_d = 40$ mi/h

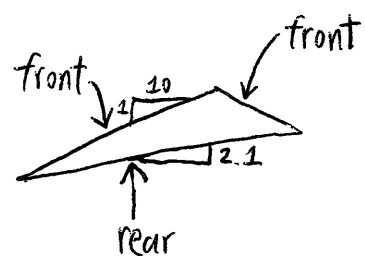
$q_d = 0$ veh/h

$K_d = 0$ veh/mi

$$\frac{\Delta q}{\Delta K} = \frac{1200-1000}{120-25}$$

$$= 2.1 \text{ mi/h}$$

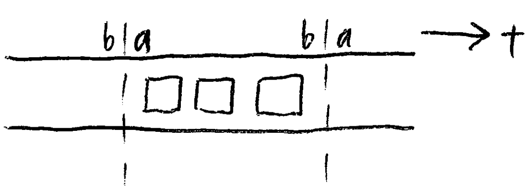




Analytical Method

$$u_{sw} = \frac{q_b - q_a}{K_b - K_a}$$

where b is the conditions upstream of a



$u_{sw} > 0$, shockwave →

< 0, shockwave ←

$= 0$, stationary

① $u_x, u_Y > 0$

$u_Y > u_x$ forward

$u_Y < u_x$ backward

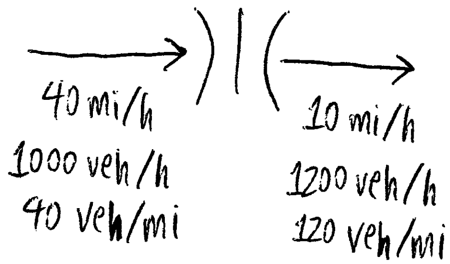
② $u_x > 0$, $u_Y < 0$

③ $u_x, u_Y < 0$

similar to ①

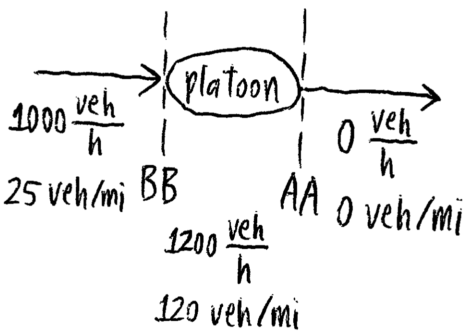
10/8/08

Review

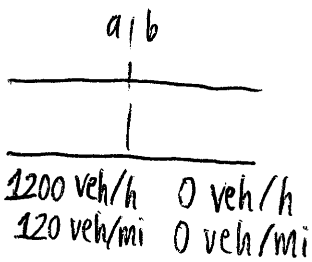


Exam 1 Fri
* 5 or 6 problems
* open book

Example 3.5



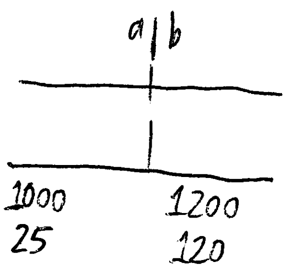
Find:
* $u_{sw,BB}$
* $u_{sw,AA}$
* $u_{sw,AA} - u_{sw,BB}$



$$u_{sw,AA} = \frac{q_b - q_a}{k_b - k_a}$$

$$= \frac{0-1200}{0-120}$$

$$= +10 \text{ mi/h}$$



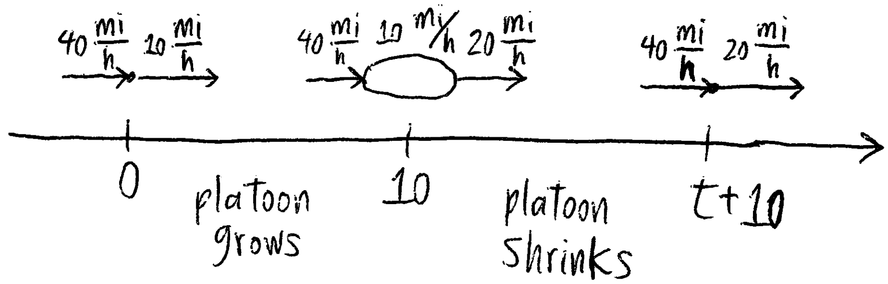
$$u_{sw,BB} = \frac{q_b - q_a}{k_b - k_a}$$

$$= \frac{1200-1000}{120-25}$$

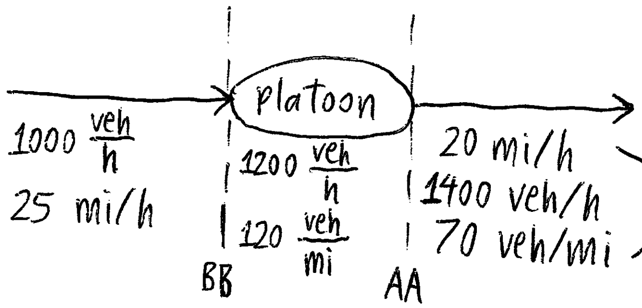
$$= +2.1 \text{ mi/h}$$

$$\Delta u_{sw} = u_{sw,AA} - u_{sw,BB}$$

$$= 10 - 2.1 = 7.9 \text{ mi/h}$$



Example 3.6



$q = uk$
$= 20 \times 70 = 1400$

From 3.5 Δu platoon $= 7.9$ mi/h

$$l = uT = 7.9 \frac{mi}{h} \times \frac{1}{6} h = 1.3 \text{ mi}$$

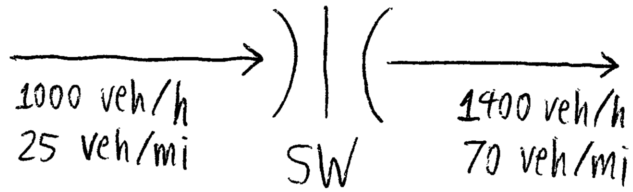
$$u_{sw,BB} = 2.1 \text{ mi/h}$$

$$u_{sw,AA} = \frac{1400-1200}{70-120} = \frac{200}{-50} = -4 \text{ mi/h}$$

$$\Delta u = -4 - 2.1 = -6.1 \text{ mi/h}$$

$$t = \frac{l}{u} = \frac{1.3 \text{ mi}}{-6.1 \text{ mi/h}} = 0.21 \text{ h} = 12 \text{ mins}$$

Example 3.7



$$u_{sw} = \frac{q_b - q_a}{k_b - k_a} = \frac{1400-1000}{70-25}$$
$$= +8.9 \text{ mi/h}$$

Exercise 3.12

Test Run	Test Veh Speed (mi/h)	$M_o - M_p$ Veh
1	10	100
2	20	-150

eq 3.5.4 $\frac{M}{T} = q - kV$

where $M = M_o - M_p$

$T_1 = 0.5$ h $\quad V_1 = 10 \quad M_1 = 100$

$T_2 = 0.25$ h $\quad V_2 = 20 \quad M_2 = -150$

$$\frac{M_1}{T_1} = q - kV_1 \quad (1)$$

$$- \quad \frac{M_2}{T_2} = q - kV_2 \quad (2)$$

$$\frac{M_1}{T_1} - \frac{M_2}{T_2} = (q - kV_1) - (q - kV_2)$$

$$\frac{M_1}{T_1} - \frac{M_2}{T_2} = -kV_1 + kV_2 = k(V_2 - V_1)$$

$$\frac{100}{.5} - \frac{-150}{.25} = k(20-10)$$

$$k = \frac{\frac{100}{.5} + \frac{150}{.25}}{20-10} = 80 \text{ veh/mi}$$

$$\frac{100}{.5} = q - 80(10)$$

$$q = \frac{100}{.5} + 80(10) = 1000 \frac{\text{veh}}{\text{h}}$$

$k = 80$ veh/mi

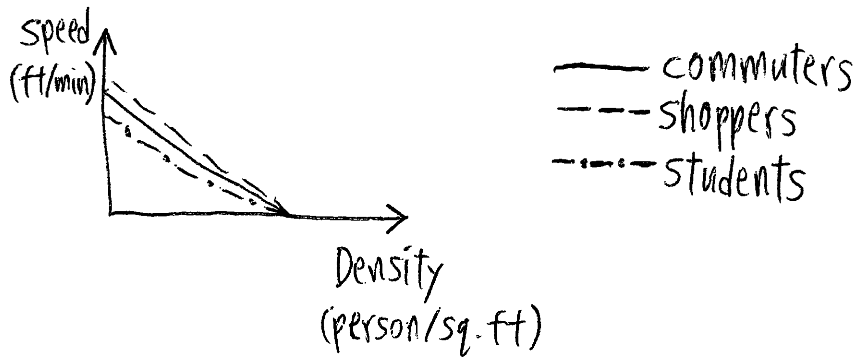
$q = 1000$ veh/h

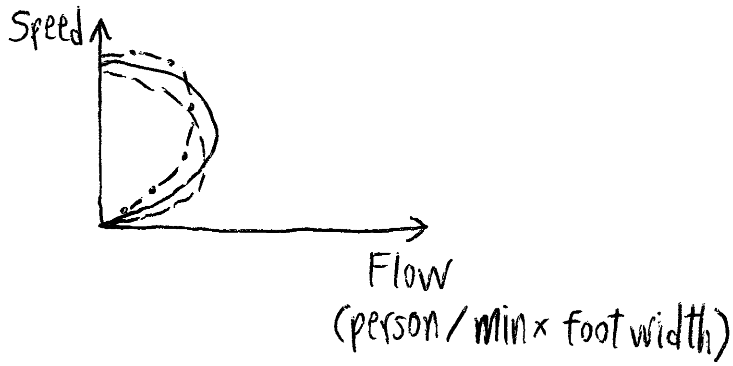
$u = q/k = 12.5$ mi/h

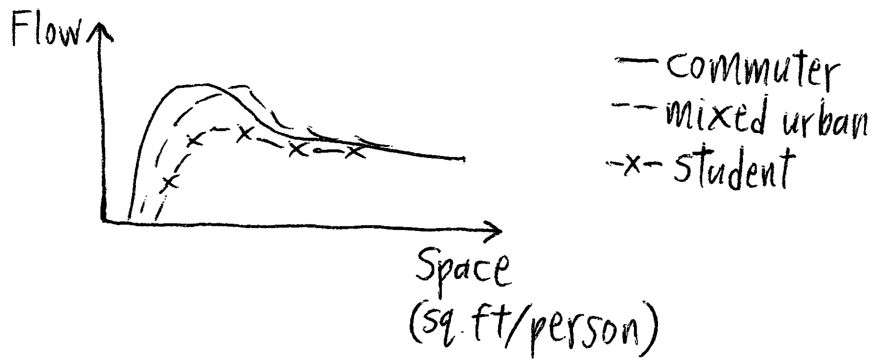
$s = 1/k = 0.013$ mi $= 66$ ft

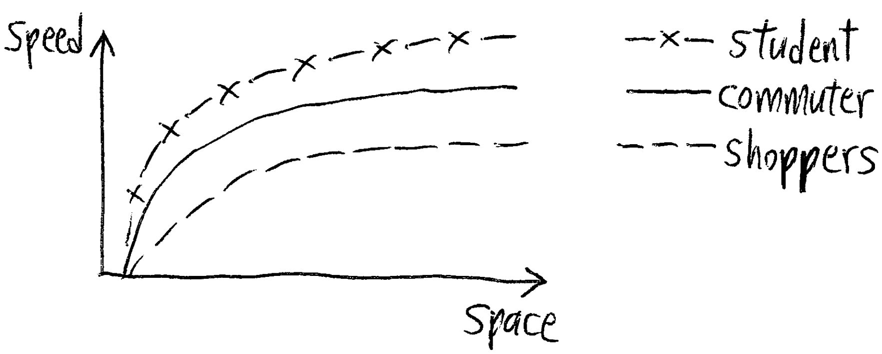
$h = 1/q = 0.001$ h $= 3.6$ s

10/13/08







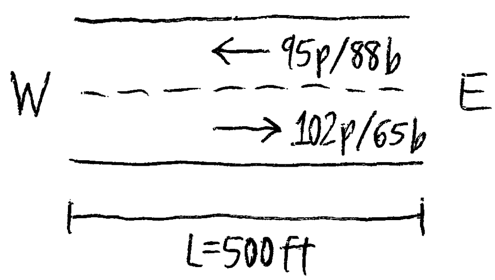


MP: number of events per hour that a bicylist experiences

$$MP_{exclusive} = V_o + 0.118\,V_s$$

$$MP_{shared} = 2.5\,V_{po} + V_{bo} + 3\,V_{ps} + 0.118\,V_{bs}$$

Ex.



Direction	Pedest. Vol	Biker Vol
EB	102	65
WB	95	88

Pedestrians EB

$MP_{EB} = \frac{3600}{95} = 37.9\,s$ LOS C

$3600s = 1\,hr$

Pedestrians WB

$MP_{WB} = \frac{3600}{102} = 35.3\,s$ LOS C

Bikers EB

$MP = V_o + 0.118\,V_s$

$= 88 + 0.118(65) = 95.7$

LOS C

Bikers WB

$MP = V_o + 0.118\,V_s$

$= 65 + 0.118(88) = 75.4$

LOS C

Ped & Bike EB

Ped

$\frac{3600}{95+88} = 19.6\,s$ LOS D

Bike

$MP = 2.5V_{po} + V_{bo} + 3V_{ps} + 0.118V_{bs}$

$= 2.5(95) + 88 + 3(102) + 0.118(65)$

$= 639.2$

Ped & Bike WB

Ped

$\frac{3600}{102+65} = 21.6\,s$ LOS D

Bike

$MP = 2.5V_{po} + V_{bo} + 3V_{ps} + 0.118V_{bs}$

$= 2.5(102) + 65 + 3(95) + 0.118(88)$

$= 615.4$

10/15/08

Transit Systems

q veh/h

$N = qT$ $\quad$ T_{rt}: time to complete trip (roundtrip)

$F = N \cdot \frac{T_{rt}}{T}$ $\quad$ $F = qT \cdot \frac{T_{rt}}{T} = q\,T_{rt}$ $\quad$ T_{rt}: sum of travel time between stops and dwelling time (time at stop)

dwelling time: $d_w = 20 - 90$ s

Ex. 10,000 passengers

2h

$T_{rt} = 30$ min

75 average occupancy

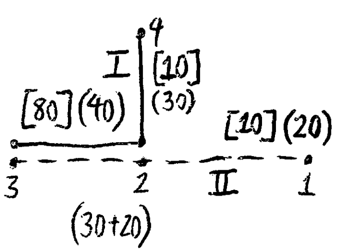
$N = \frac{\#\text{ of passengers}}{\text{capacity of veh}}$

$N = \frac{10000}{75} = 134$ departures in 2 hrs

$q = \frac{134}{2} = 67$ veh/hr

$F = \frac{67}{2} = 34$ veh

Ex.



[ ] outbound mov. w.r.t 3

( ) inbound mov. w.r.t 3

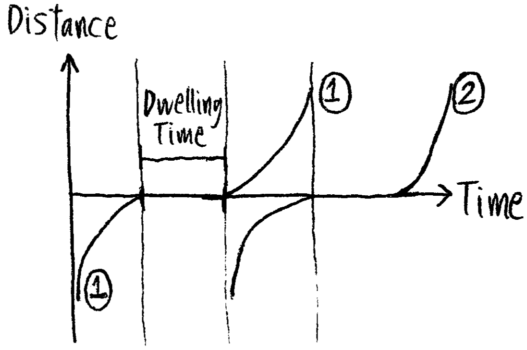
$N_{I} \geq 30$ departures

$N_{II} \geq 20$ departures

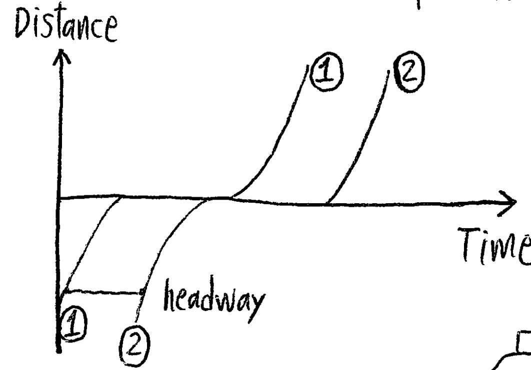
4-2 (I) 30 buses

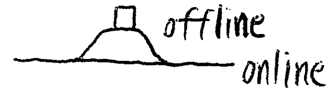
1-2 (II) 20 buses

2-3 add 30 buses



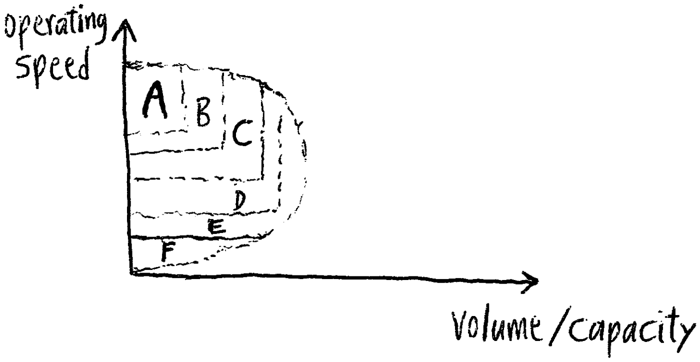
Two Trains on same platform





$$h_{min} = T_{dwell} + \left(\frac{2NL}{a_n}\right)^{1/2} + \delta + \frac{u}{2d_f} - \frac{u}{2d_\ell} + \frac{NL + x_0}{u}$$

10/17/08



$$PHF = \frac{V}{q} = \frac{V}{N_t\left(\frac{60}{t}\right)}$$

PHF=1 uniform demand

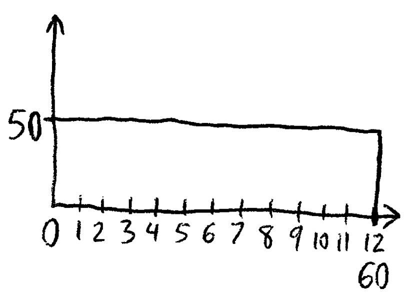
PHF→0 peaked demand

Ex. 50 vehicles

$t = 5$ mins

12 intervals

$$PHF = \frac{V}{q} = \frac{V}{N_t\left(\frac{60}{t}\right)} = \frac{600}{50\left(\frac{60}{5}\right)} = 1$$

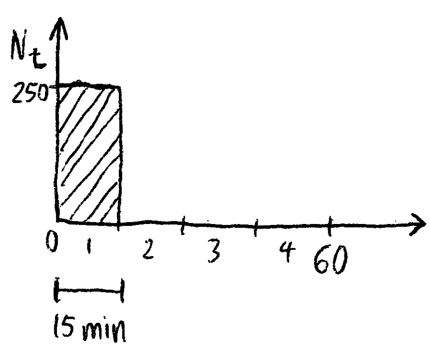


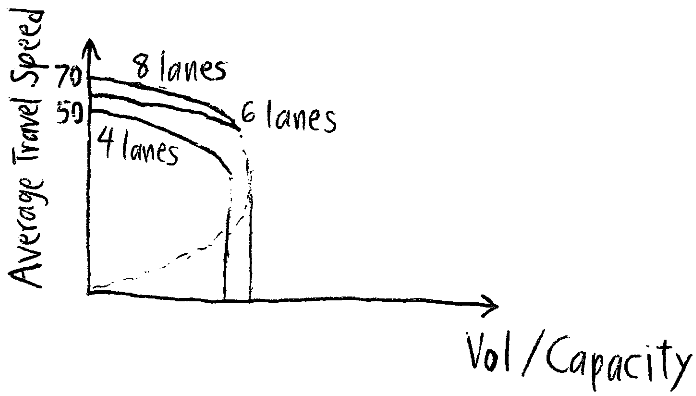
Ex. $N_t = 250$ veh

$t = 15$ mins

$V = 250$ veh

$$PHF = \frac{250}{250\left(\frac{60}{15}\right)} = 0.25$$





C = 2000 veh/h (70 mi/h)
C = 1900 veh/h (60 mi/h)
C = 1800 veh/h (50 mi/h)

$$D = \frac{V_p}{S} = \frac{\text{flow rate (pc/h/ln)}}{\text{average passenger car speed (mi/h)}}$$

$$V_p = \frac{V}{PHF \cdot N \cdot \underbrace{f_{HV}}_{\text{heavy vehicle}} \cdot f_{dp}}$$

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

$$f_{dp} = 0.8 - \underbrace{1.00}_{\text{all commuters}}$$

FFS measured under LOS A

$$FFS = BFFS - f_{LW} - \underbrace{f_{LC}}_{<60} - \underbrace{f_N}_{<5} - f_{INT}$$

$$FFS = BFFS - 1.9(12 - W)^{1.8} - (2.4 - 0.4 \times LC) - (7.5 - 1.5 \times N) + 2.5 - 1.5\ \text{Access}$$

10/20/08

Ex. $N=3$ lanes per direction

$L=\underline{11}$ ft

3 ft lateral distance

1 interchange per mile

$V=3{,}080$ veh/h

$PHF=0.88$

$N_T=154$

Assume all of them are commuters

*Find E_{HV} on pg. 154

Table 4.5.1

$$D=\frac{V_p}{S}$$

$$f_{HV}=\frac{1}{1+P_{HV}(E_{HV}-1)}$$

$$=\frac{1}{1+0.05(1.5-1)}=0.976$$

$$V_p=\frac{V}{PHF\cdot N\cdot f_{HV}\cdot f_{dp}}$$

$$=\frac{3080}{0.88\times3\times0.976\times1}=\underline{1195}\ pc/h$$

$$S\rightarrow FFS=70-1.9(12-W)^{1.8}-(2.4-0.4LC)-(7.5-1.5N)+(2.5-1.5ACC)$$

$$=70-1.9(12-\underline{11})^{1.8}-(2.4-0.4(3))-(7.5-1.5(3))+(2.5-1.5(1))$$

$$=64.9\ mi/h$$

$$D=\frac{1195}{64.9}=18.4\ pc/h/\ell \quad LOS\ C$$

Ex. $\underline{12}$

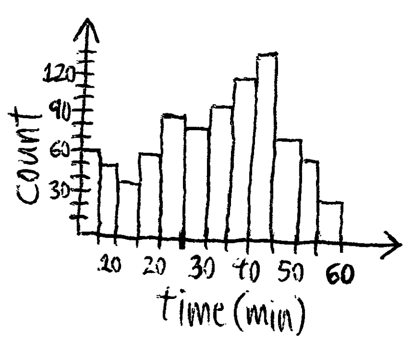
5 min $=t$

60 | 50 | 40 | 60 | 90 | 80 | 100 | 120 | 140 | 75 | 60 | 30

$$PHF=\frac{V}{N_t\left(\frac{60}{t}\right)}=\frac{925}{140\times\left(\frac{60}{5}\right)}=0.55$$

where: $V=$ sum of observed values

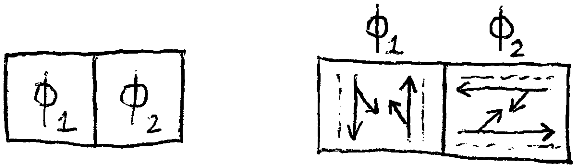
$N_t=$ max of observed values



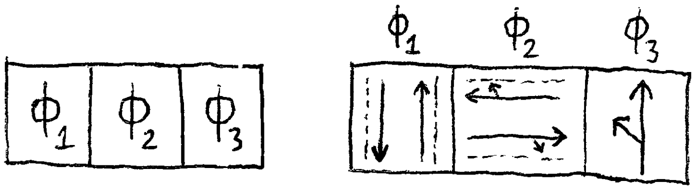
$$F_i=N_i\times\frac{60}{t}$$

$$F_1=60\times\frac{60}{5}=720\ veh/h \qquad F_{12}=30\times\frac{60}{5}=360\ veh/h$$

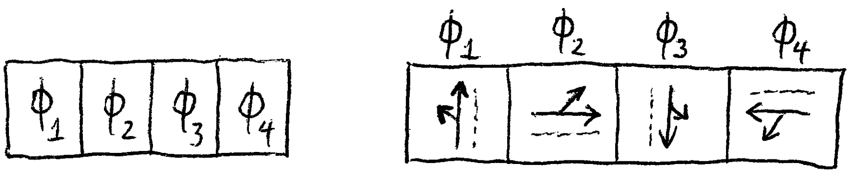
Ex.


ϕ_1 ϕ_2
ϕ_1 ϕ_2

Ex.


ϕ_1 ϕ_2 ϕ_3
ϕ_1 ϕ_2 ϕ_3

Ex.


ϕ_1 ϕ_2 ϕ_3 ϕ_4
ϕ_1 ϕ_2 ϕ_3 ϕ_4

10/22/08

Project Topics

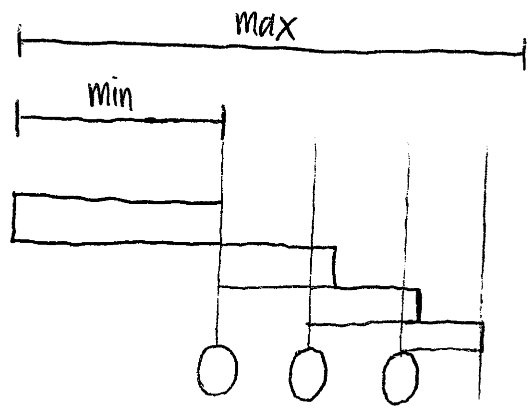
LOS intersection
Cycle Length
Design Survey
Mode Choice Model
Parking
GIS & Land Use

Car Ownership
HOT/HOV Lanes on Beltway

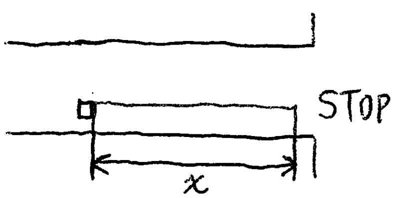
Cycle Length

Green → 30-60 s

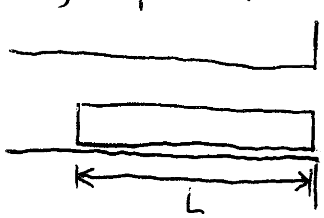
min < Green < max



Short Loop: detects if vehicle passes



Long Loop: detects how many vehicles



$L = 1.47V(G - V_i) - L_v$

L = length of the loop

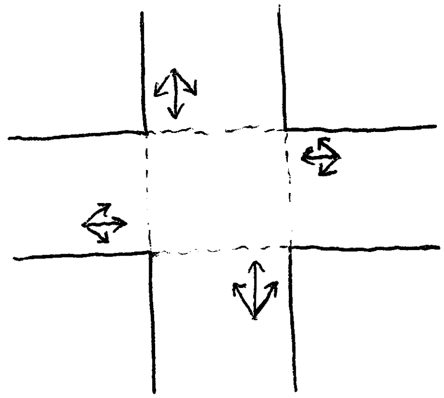
V = approach speed mi/h

G = 2-5 s

V_i = vehicle interval to travel distance L

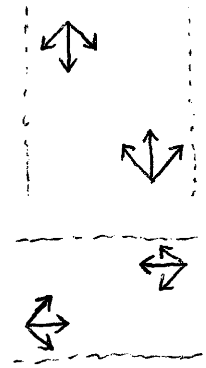
L_v = vehicle length

Minimum Green = 4s + 2n



Φ_A

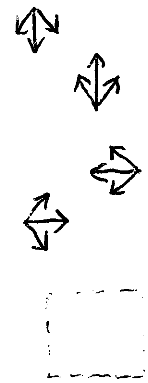
Φ_B



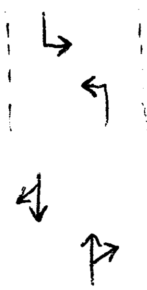
Φ_A

Φ_B

Φ_C



Φ_A Φ_B



Φ_C Φ_D

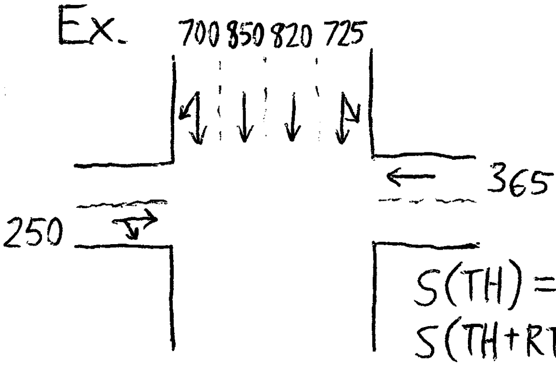
$$C_0 = \frac{1.5L+5}{1-CS}$$

C_0 = optimal cycle length

L = total lost time (3-4s)

CS = flow ratio of critical movement

Ex.

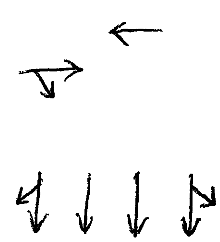


S(TH) = 1800 veh/h

S(TH+RT) = 1600

S(TH+LT) = 1700

Φ_A Φ_B



$$\Phi_A \quad \max\left\{\frac{365}{1800}, \frac{250}{1600}\right\} = \max\{0.147, 0.203\} = 0.203$$

$$\Phi_B \quad \max\left\{\frac{700}{1600}, \frac{850}{1800}, \frac{820}{1800}, \frac{725}{1700}\right\} = 0.464$$

$CS = 0.464 + 0.203 = 0.667$

$L = 4s \times 2 = 8s$

$$C_0 = \frac{1.5L+5}{1-CS} = \frac{1.5(8)+5}{1-0.667} = 51\,s \left\langle \begin{array}{l} 35\,s \\ 65\,s \end{array} \right.$$