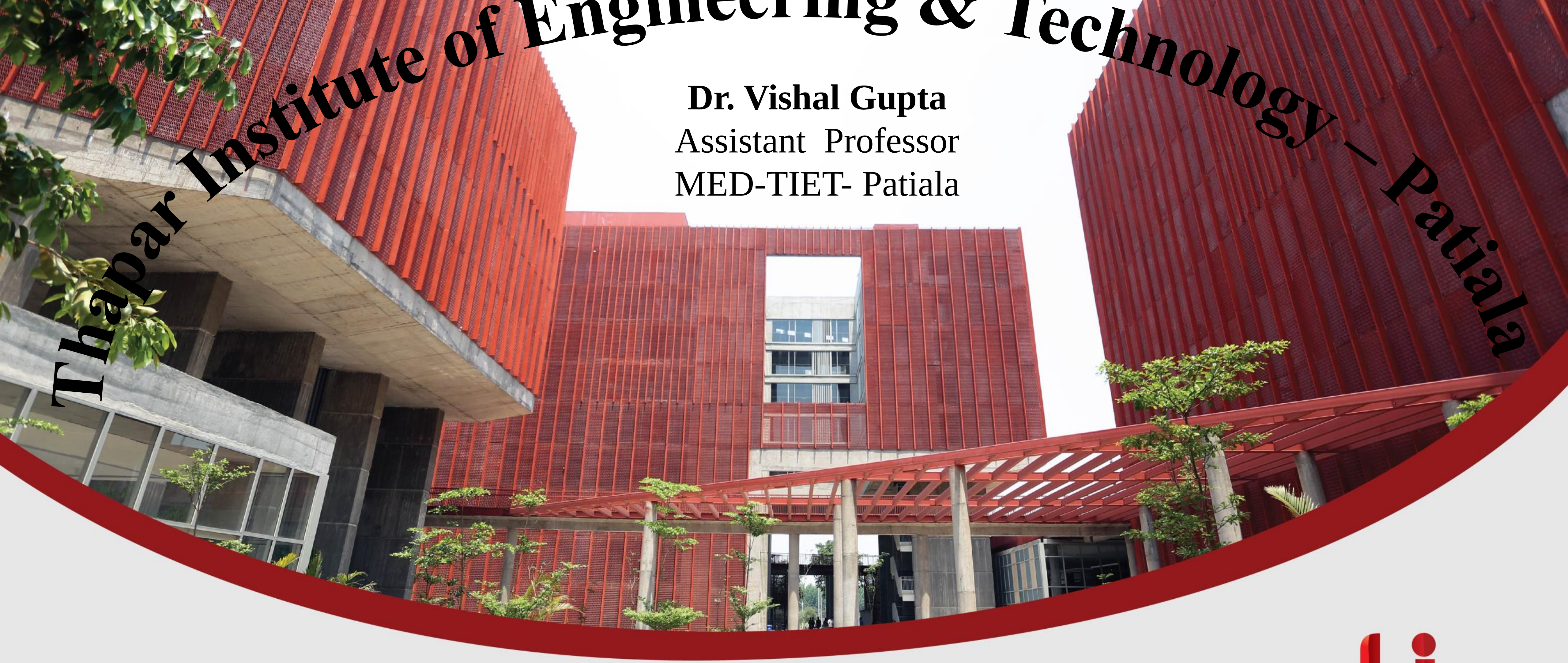
Thapar Institute of Engineering & Technology – Patiala



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THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Overview of the course

Mechanical Engineering Department

Course coordinator
Dr. Vishal Gupta
Assistant Professor
Mechanical Engineering Department

Course Co-coordinator
Dr. Sachin Singh
Assistant Professor
Mechanical Engineering Department

Electronics and Communication Engineering Department

Course Coordinator
Dr. Poonam Verma
Assistant Professor
Electronics and Communication Engineering Department

ENGINEERING DESIGN PROJECT-I
UTA016

Lecture - 2

Instructional objective

- Study of the dynamics for the Mangonal
- No DRAG Condition (Part 1)
- With DRAG

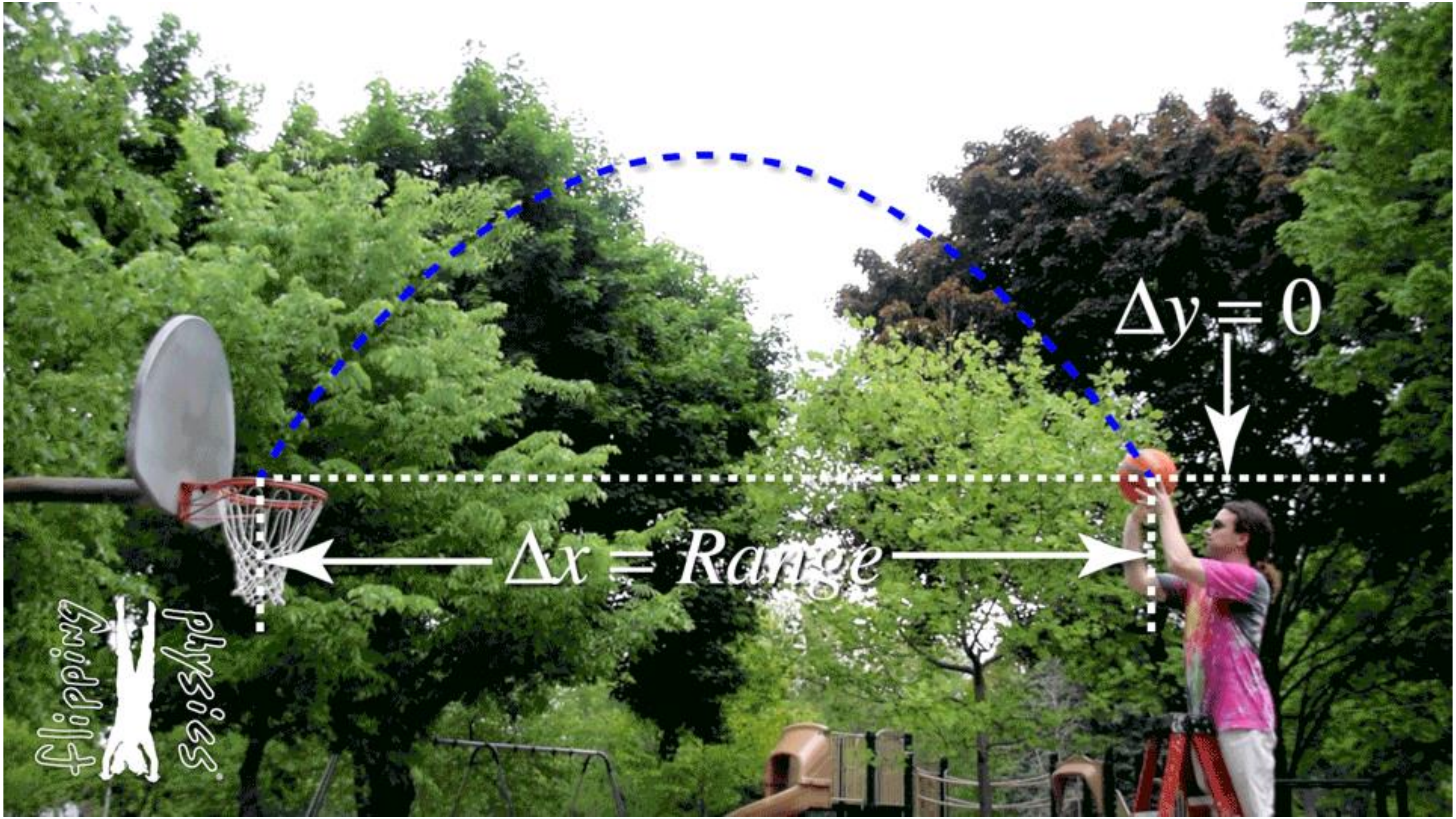
No DRAG Condition

Objective

A Smaller version!

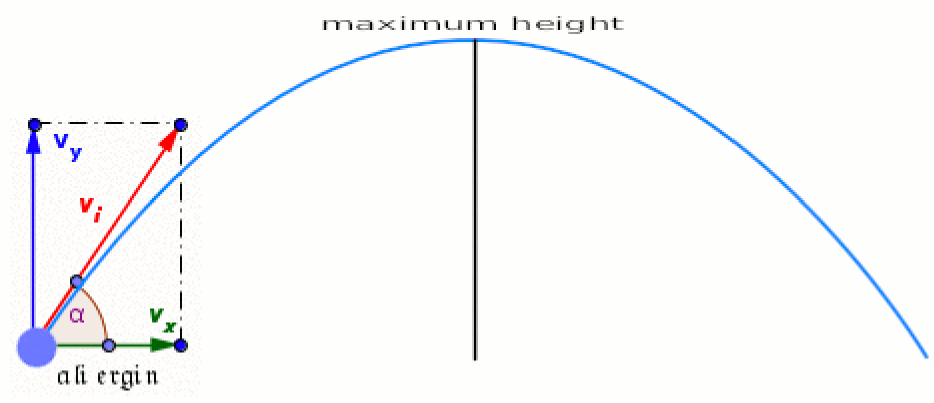
A larger version!

Challenges in Modelling



Challenges in Modelling

- For a given "size", can we maximise the distance?
- What are the key parameters that control the distance?
- Can we formulate a model that will help us design our Mangonel?



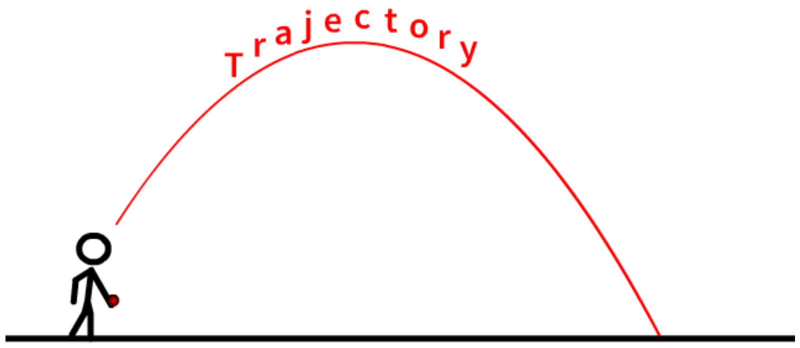
$$D = \frac{v^2 \sin 2\theta}{g}$$

Horizontal Distance of travel = D

Launch Velocity = v

Angle of launch = θ

Acceleration due to gravity = g



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Equation of Motion

Speed=distance/time

Acceleration=velocity/time

$v=u+at$

$s=ut+1/2at^2$

$v^2=u^2+2as$

u=initial velocity

v=final velocity

t=time duration

a=acceleration

s=distance travelled

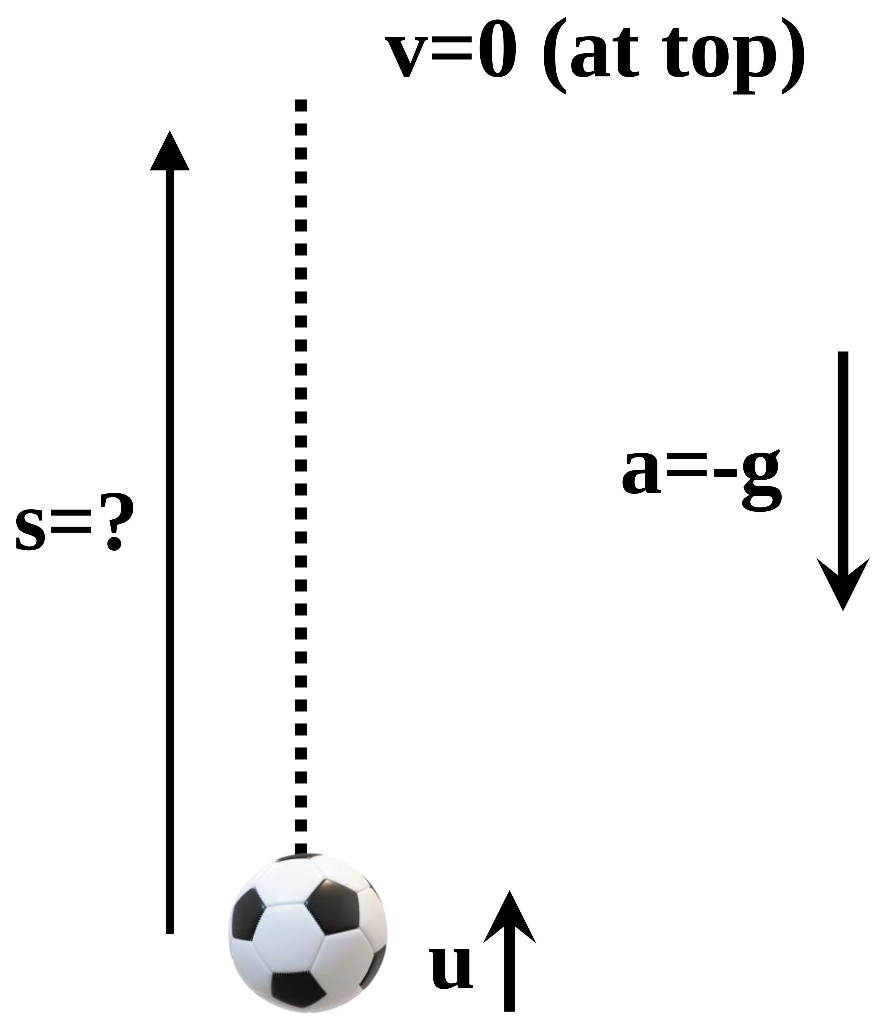
One Dimensional Motion

Example 1: (1-D)

Use equation:

$v^2=u^2+2as$

$s=u^2/2g$



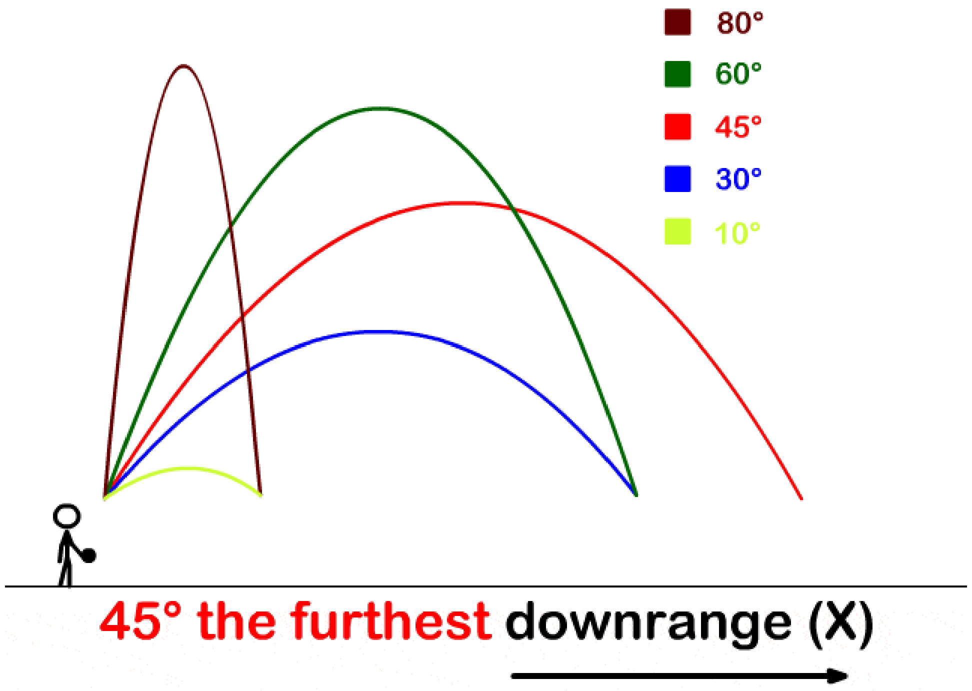
Two Dimensional Motion : Dynamics

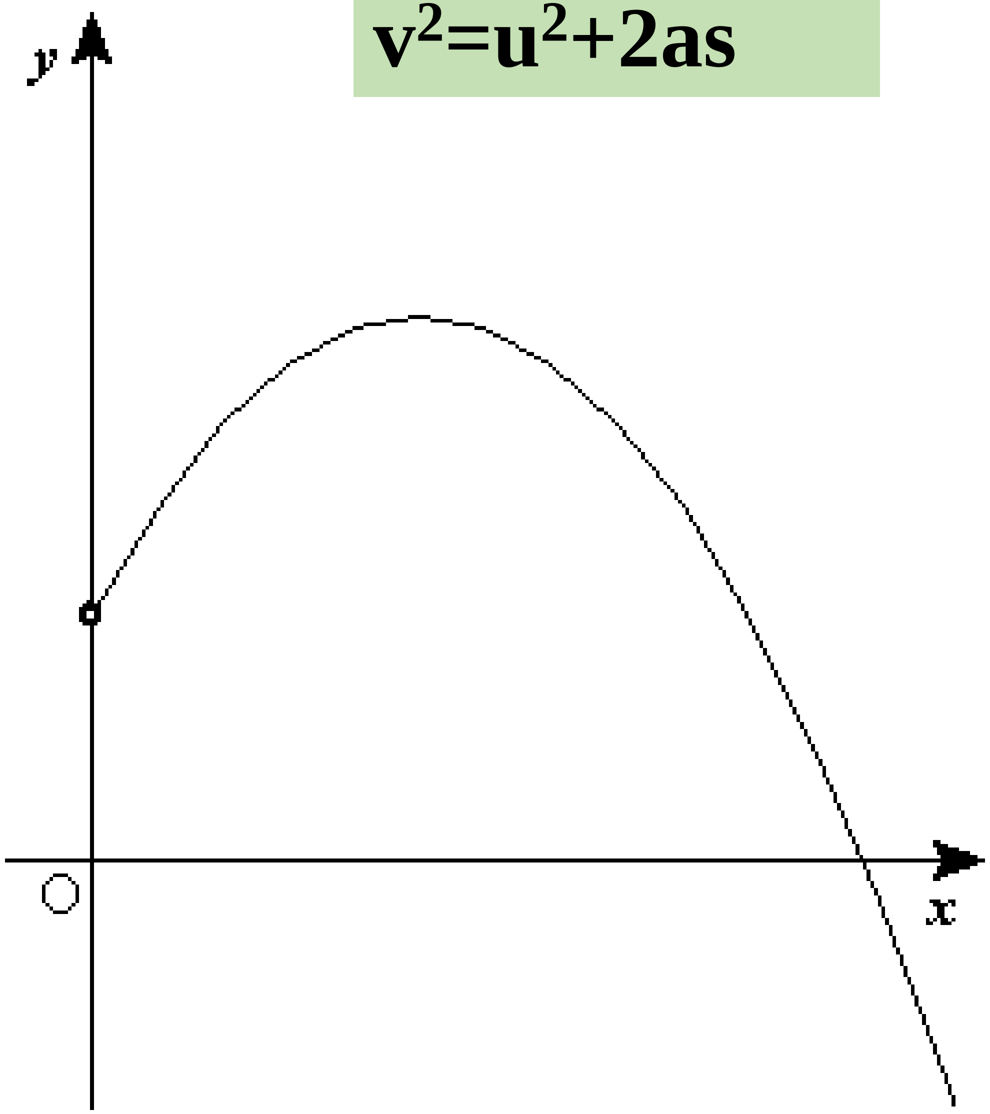
$v=u+at$

$s=ut+1/2at^2$

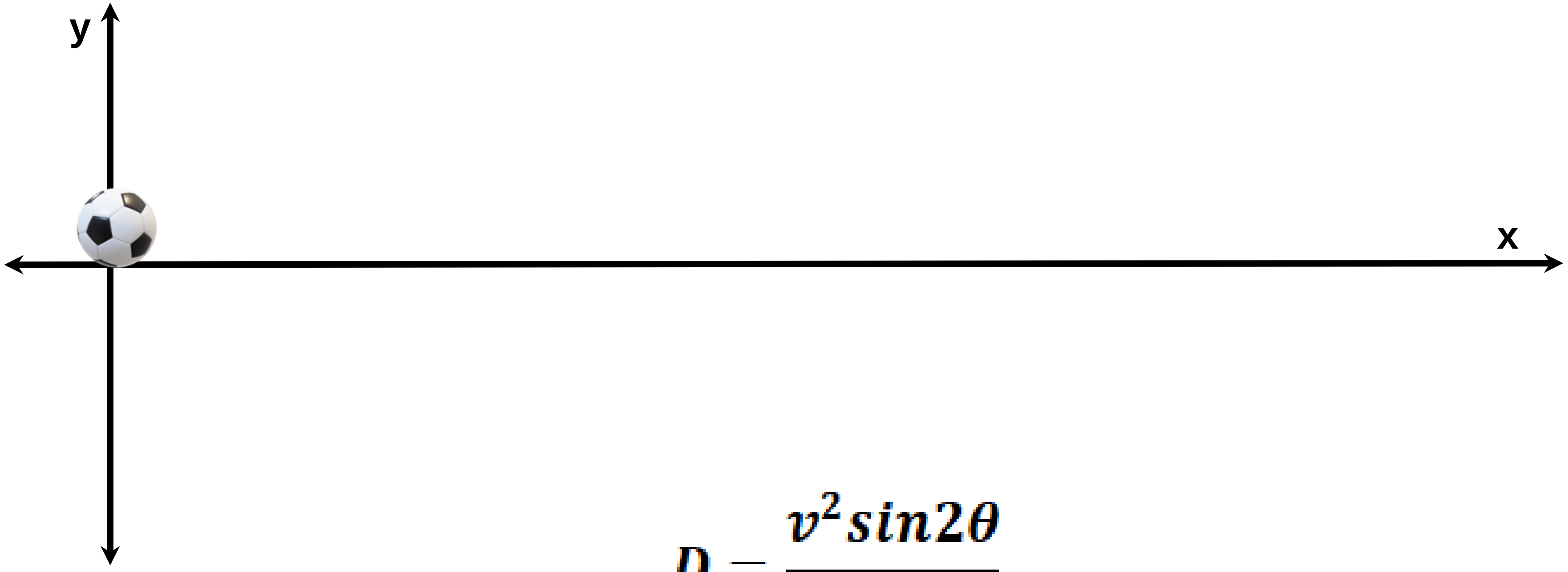
$v^2=u^2+2as$

- Can we use the three equations to model the trajectory of the missile?
- Can we predict the distance?



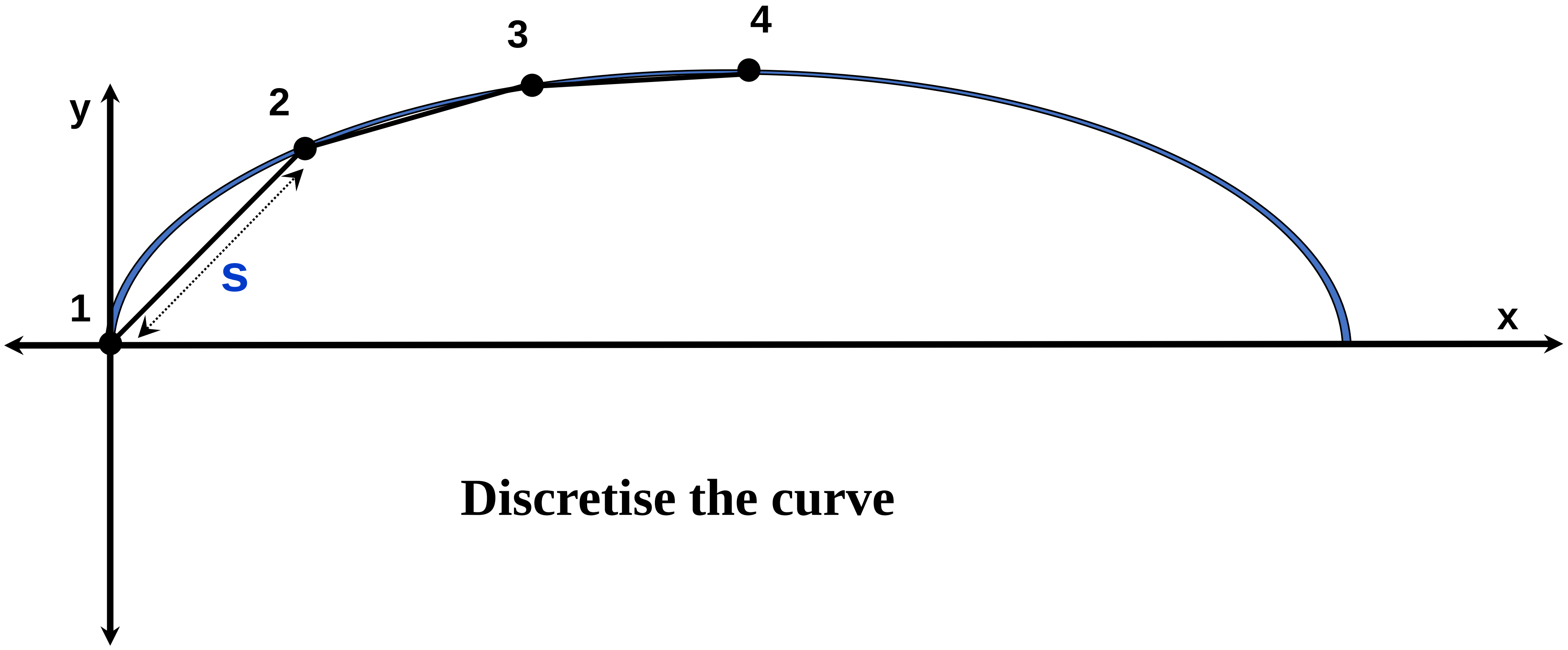


Dynamics



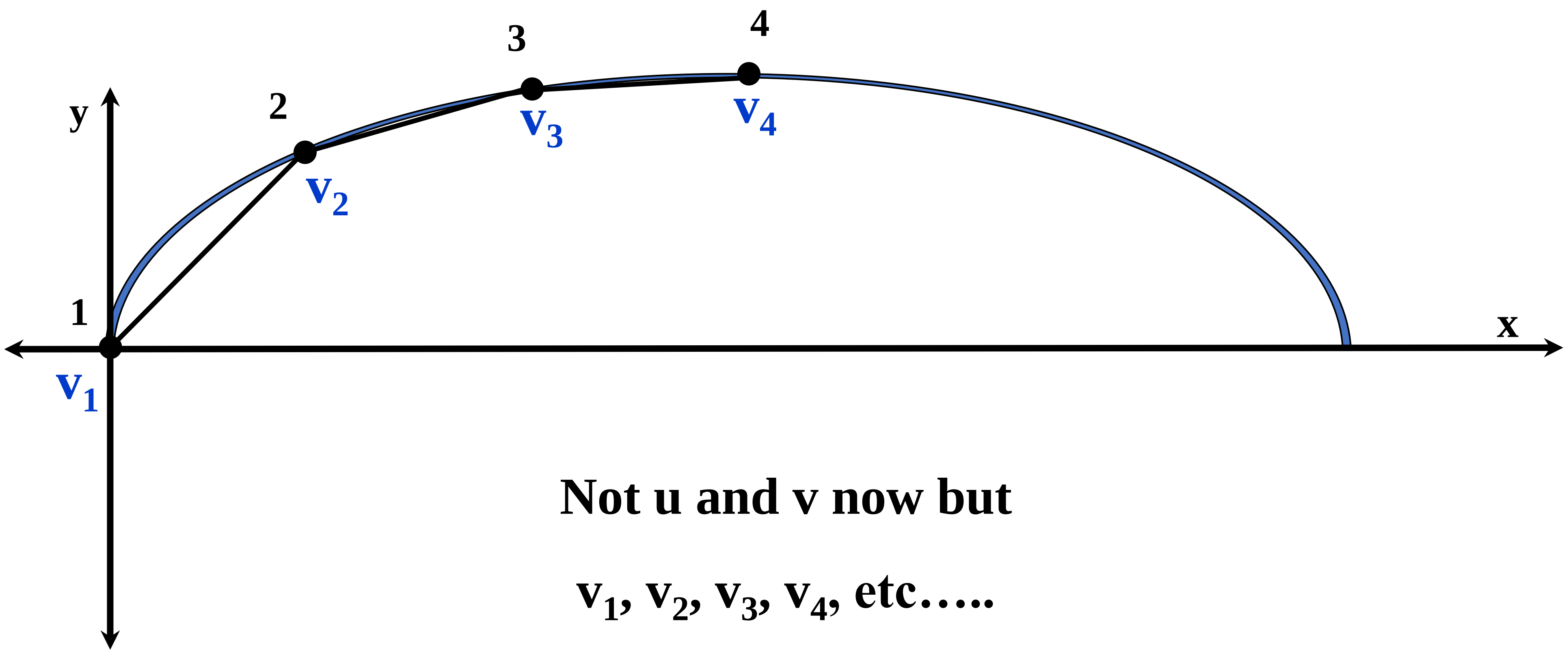
$$D = \frac{v^2 sin2\theta}{g}$$

Dynamics



Discretise the curve

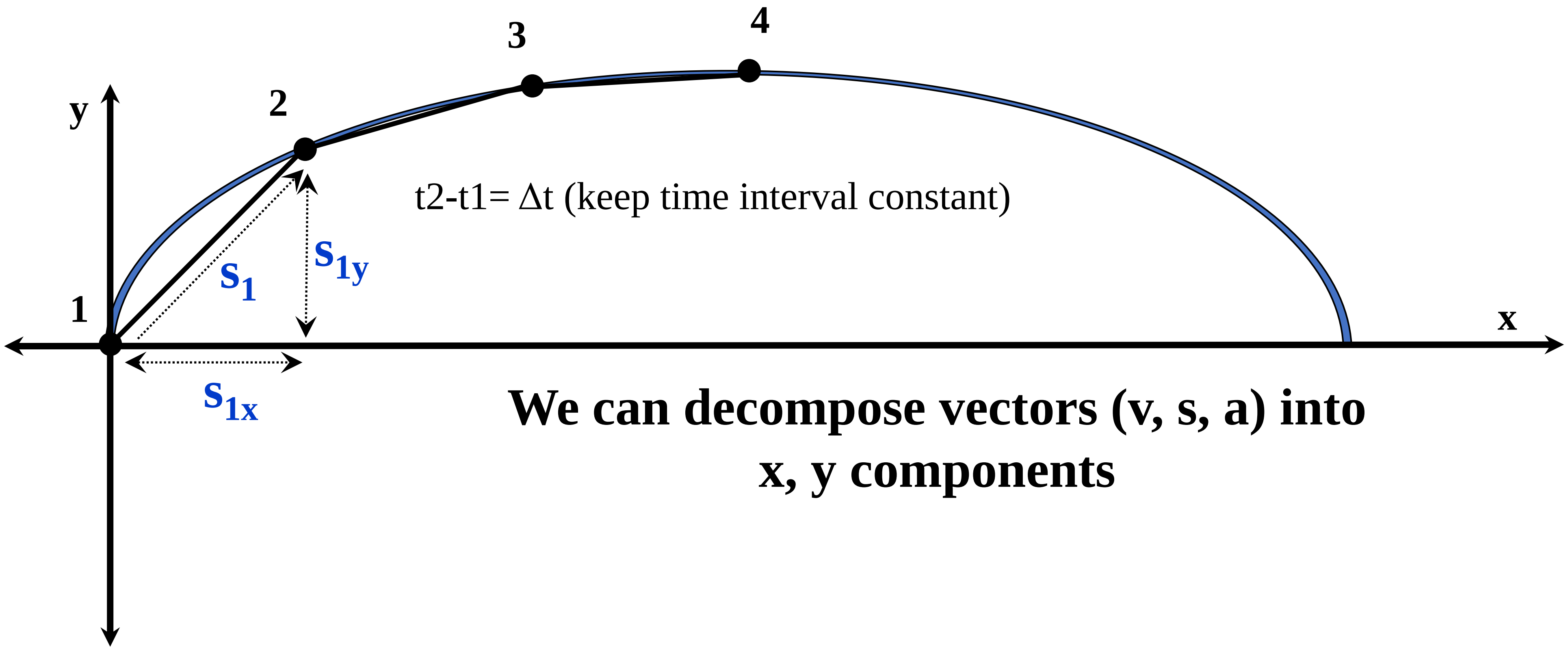
Dynamics



Not u and v now but

v_1, v_2, v_3, v_4, etc…..

Dynamics



We can decompose vectors (v, s, a) into x, y components

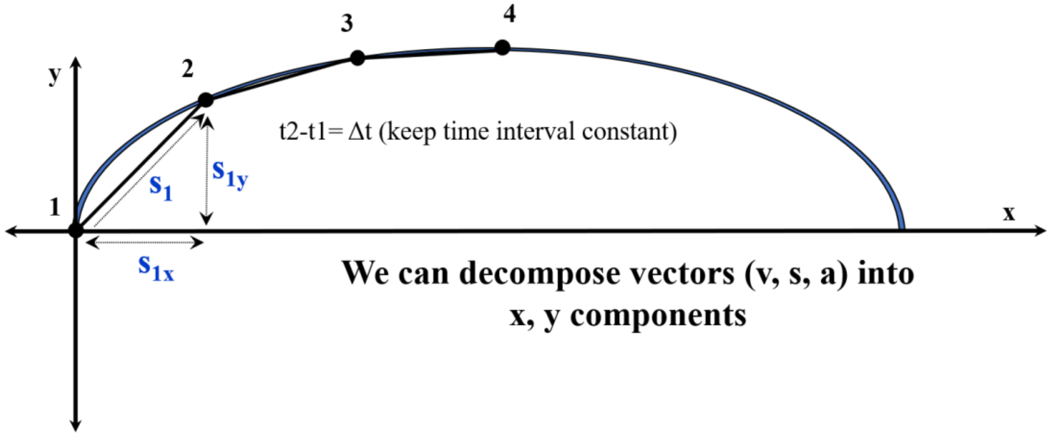
v=u+at becomes:

- $\mathbf{V_{x2} = v_{x1} + a_{x1}\Delta t}$
- $\mathbf{V_{y2} = v_{y1} + a_{y1}\Delta t}$

$S = ut + 1/2at^2$ becomes:

- $\Delta s_x = v_{x1}\Delta t + 1/2a_{x1}\Delta t^2$
- $\Delta s_y = v_{y1}\Delta t + 1/2a_{y1}\Delta t^2$

Dynamics



v=u+at becomes:

- $v_{x2}=v_{x1}+a_{x1}\Delta t$
- $v_{y2}=v_{y1}+a_{y1}\Delta t$

$s=ut+1/2at^2$ becomes:

- $\Delta s_x=v_{x1}\Delta t+1/2a_{x1}\Delta t^2$
- $\Delta s_y=v_{y1}\Delta t+1/2a_{y1}\Delta t^2$

Acceleration is constant (for no drag of lift – we'll return to this point later)

ax=0!

ay=-g

t2-t1= Δt (keep time interval constant)

Dynamics – Assignment1

Use Excel to study trajectory of missile

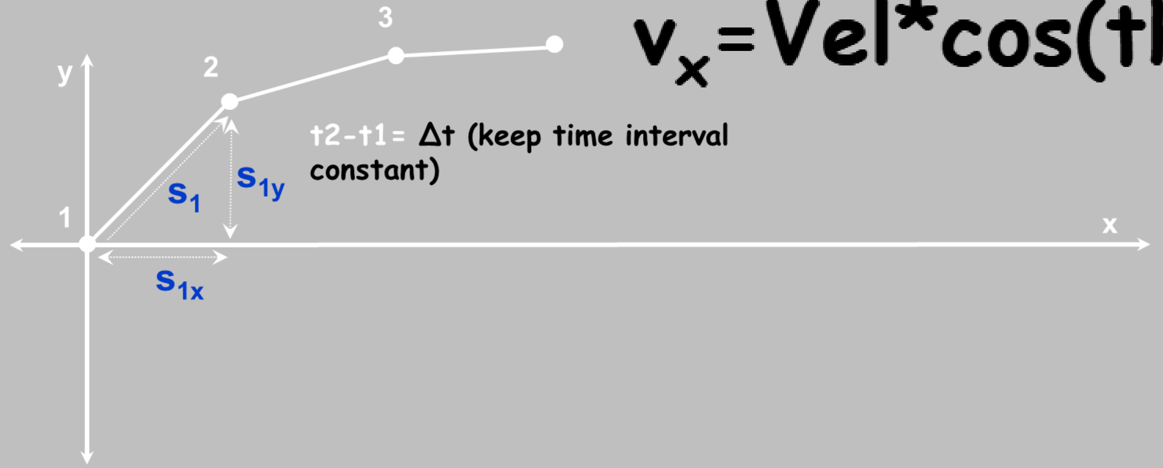
Initial Conditions

Input Data	
Vel	10.00
delt t	0.01
theta (degrees)	30.00
theta (radians)	0.52

Position	t	x	y	vx	vy	ax	ay
1.00	0.00	0.00	0.00	8.66	5.00	0.00	-9.81

$$v_x = Vel * \cos(theta)$$

$$v_y = Vel * \sin(theta)$$

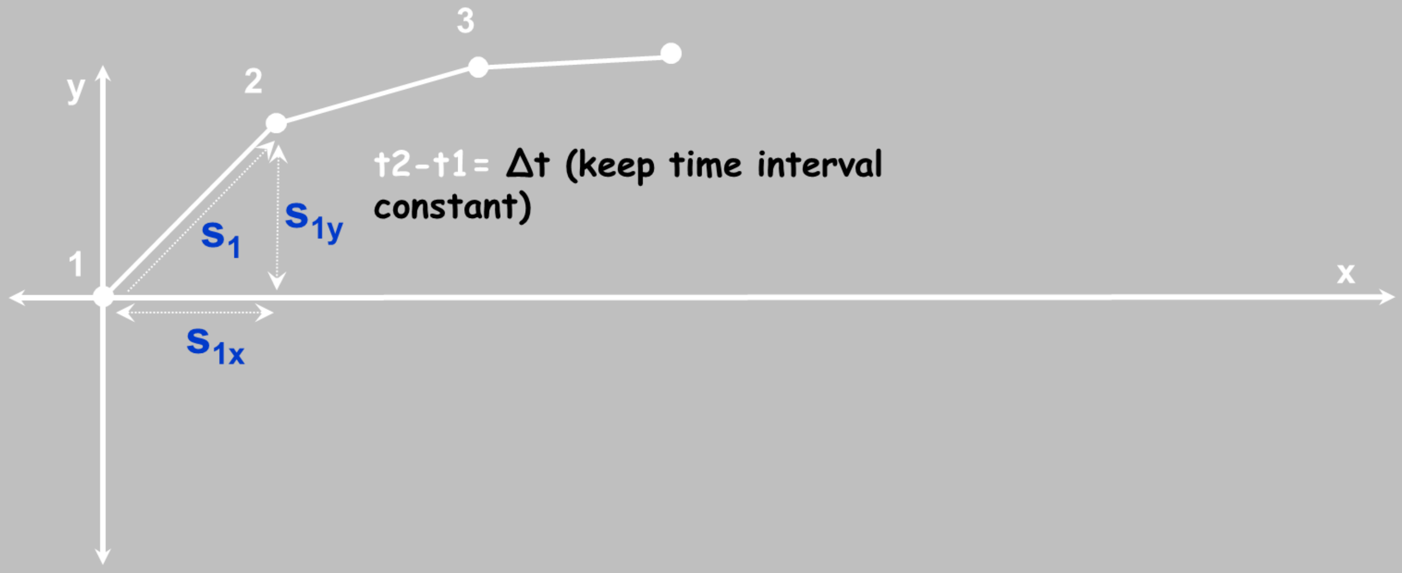


Conti…

Input Data	
Vel	10.00
delt t	0.01
theta (degrees)	30.00
theta (radians)	0.52

Position	t	x	y	vx	vy	ax	ay
1.00	0.00	0.00	0.00	8.66	5.00	0.00	-9.81
2.00	0.01	0.09	0.05	8.66	4.90	0.00	-9.81

$$t2 = t1 + \Delta t$$

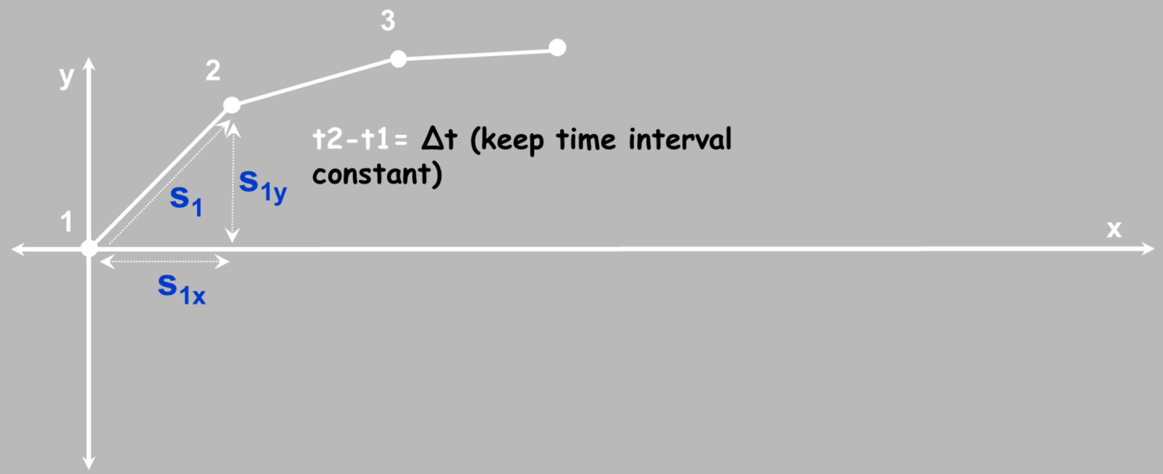


Conti…

Input Data	
Vel	10.00
delt t	0.01
theta (degrees)	30.00
theta (radians)	0.52

Position	t	x	y	vx	vy	ax	ay
1.00	0.00	0.00	0.00	8.66	5.00	0.00	-9.81
2.00	0.01	0.09	0.05	8.66	4.90	0.00	-9.81

$$x_2 = x_1 + v_{x1}\Delta t + 1/2 a_{x1}\Delta t^2$$

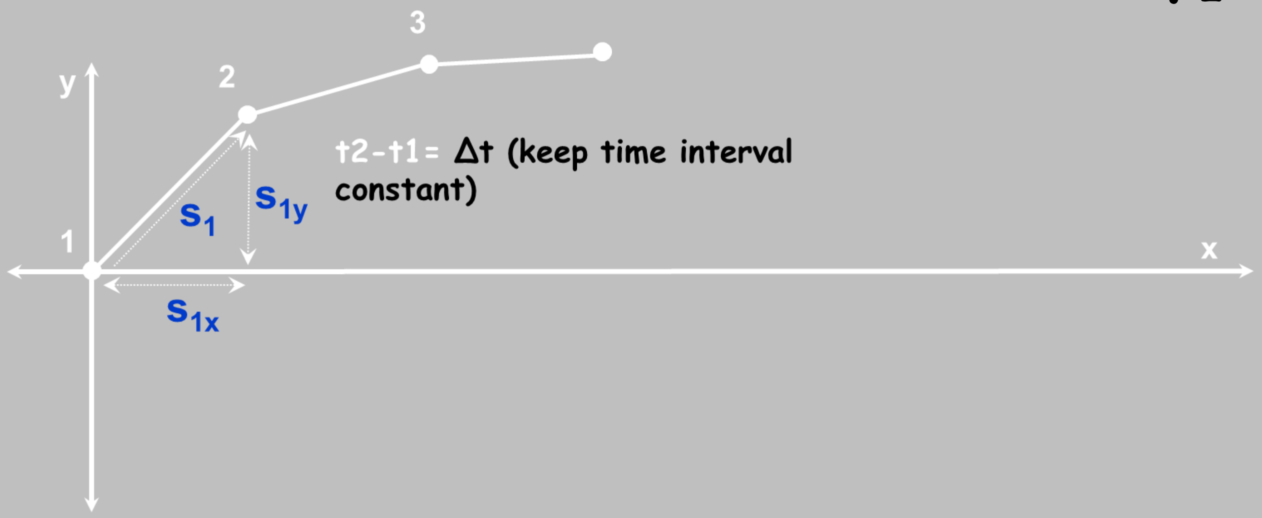


Conti…

Input Data	
Vel	10.00
delt t	0.01
theta (degrees)	30.00
theta (radians)	0.52

Position	t	x	y	vx	vy	ax	ay
1.00	0.00	0.00	0.00	8.66	5.00	0.00	-9.81
2.00	0.01	0.09	0.05	8.66	4.90	0.00	-9.81

$$y_2 = y_1 + v_{y1}\Delta t + 1/2 a_{y1}\Delta t^2$$



t2-t1= Δt (keep time interval constant)

Conti…

Input Data	
Vel	10.00
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theta (degrees)	30.00
theta (radians)	0.52

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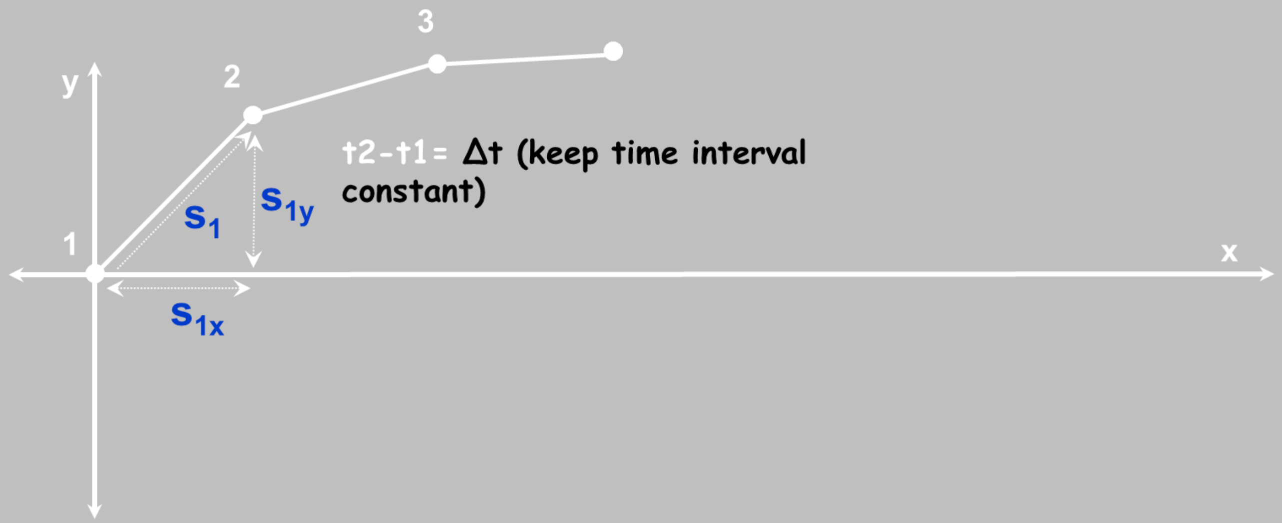
2.00	0.01	0.09	0.05	8.66	4.90	0.00	-9.81

$$v_{x2} = v_{x1} + a_{x1}\Delta t$$



t2-t1 = Δt (keep time interval constant)

Conti…

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Position	t	x	y	vx	vy	ax	ay
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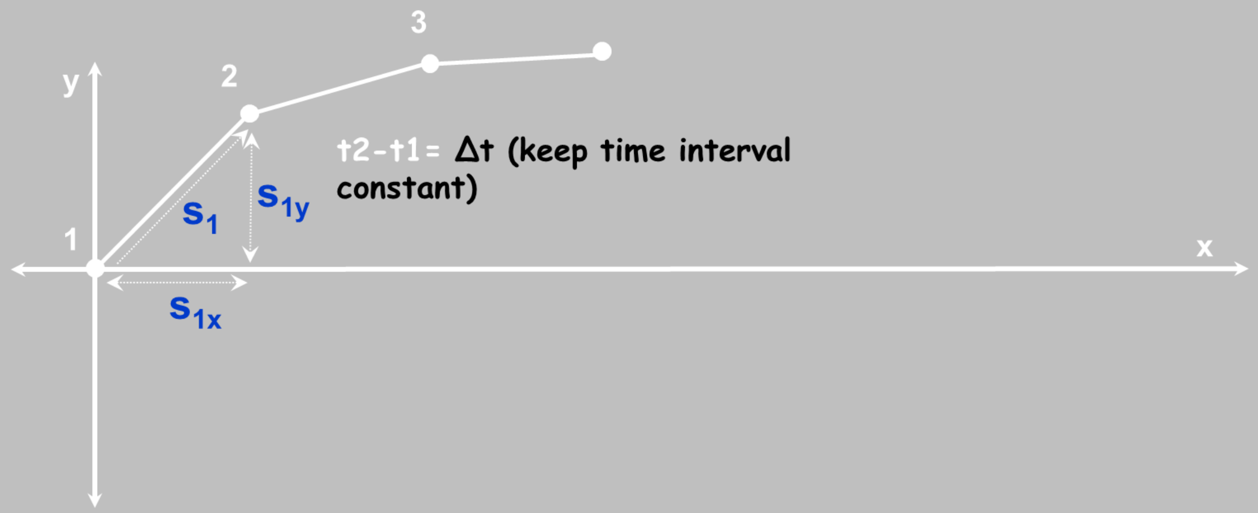
2.00	0.01	0.09	0.05	8.66	4.90	0.00	-9.81

$$v_{y2}=v_{y1}+a_{y1}\Delta t$$



Conti…

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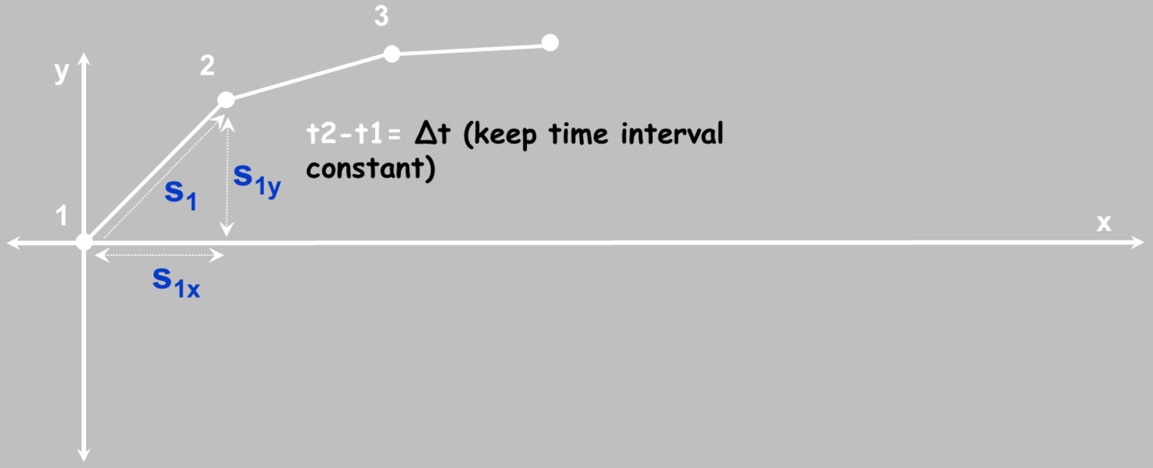
theta (degrees)	30.00
theta (radians)	0.52

Position	t	x	y	vx	vy	ax	ay
1.00	0.00	0.00	0.00	8.66	5.00	0.00	-9.81
2.00	0.01	0.09	0.05	8.66	4.90	0.00	-9.81

Const=0!



Conti…

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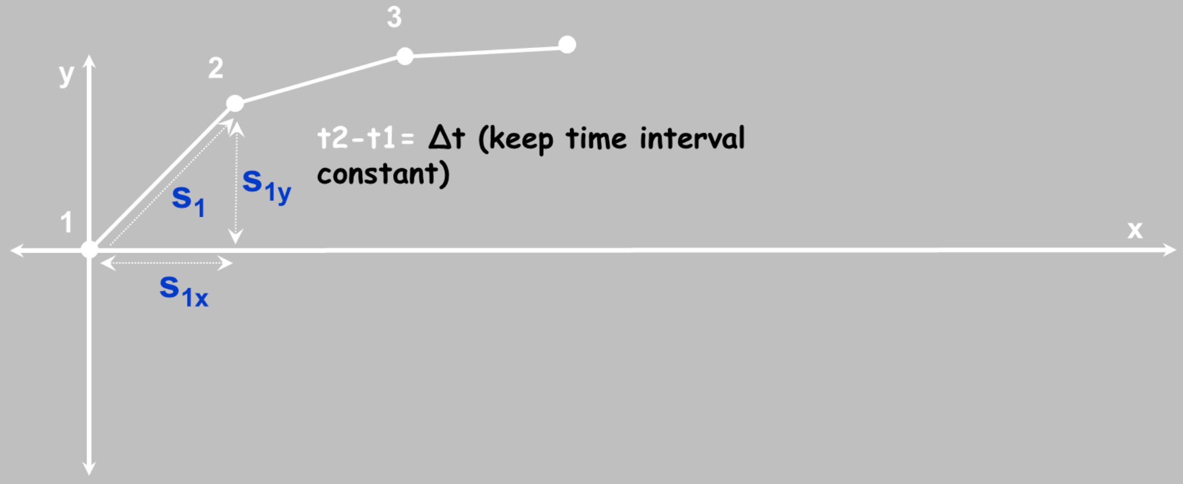
theta (radians)	0.52

Position	t	x	y	vx	vy	ax	ay
1.00	0.00	0.00	0.00	8.66	5.00	0.00	-9.81
2.00	0.01	0.09	0.05	8.66	4.90	0.00	-9.81

Const=-g



Conti…

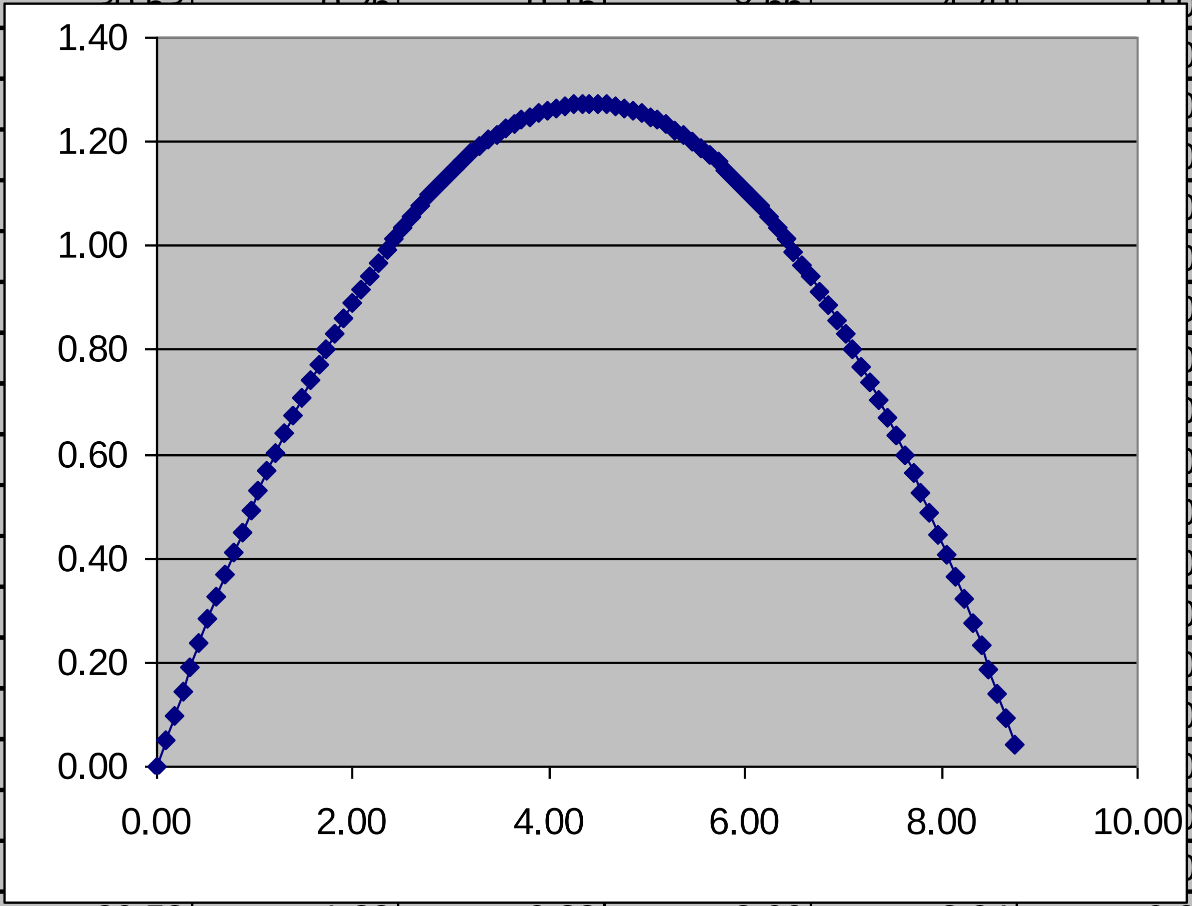
Input Data	
Vel	10.00
delt t	0.01
theta (degrees)	30.00
theta (radians)	0.52

Position	t	x	y	vx	vy	ax	ay
1.00	0.00	0.00	0.00	8.66	5.00	0.00	-9.81
2.00	0.01	0.09	0.05	8.66	4.90	0.00	-9.81
3.00	0.02	0.17	0.10	8.66	4.80	0.00	-9.81
4.00	0.03	0.26	0.15	8.66	4.70	0.00	-9.81
5.00	0.04	0.35	0.19	8.66	4.61	0.00	-9.81
6.00	0.05	0.43	0.24	8.66	4.51	0.00	-9.81
7.00	0.06	0.52	0.28	8.66	4.41	0.00	-9.81
8.00	0.07	0.61	0.33	8.66	4.31	0.00	-9.81
9.00	0.08	0.69	0.37	8.66	4.21	0.00	-9.81
10.00	0.09	0.78	0.41	8.66	4.11	0.00	-9.81
11.00	0.10	0.87	0.45	8.66	4.02	0.00	-9.81
12.00	0.11	0.95	0.49	8.66	3.92	0.00	-9.81
13.00	0.12	1.04	0.53	8.66	3.82	0.00	-9.81
14.00	0.13	1.13	0.57	8.66	3.72	0.00	-9.81
15.00	0.14	1.21	0.60	8.66	3.62	0.00	-9.81
16.00	0.15	1.30	0.64	8.66	3.53	0.00	-9.81
17.00	0.16	1.39	0.67	8.66	3.43	0.00	-9.81
18.00	0.17	1.47	0.71	8.66	3.33	0.00	-9.81
19.00	0.18	1.56	0.74	8.66	3.23	0.00	-9.81

Copy formula down

Input Data	
Vel	10.00
delt t	0.01
theta (degrees)	30.00
theta (radians)	0.52

Position	t	x	y	vx	vy	ax	ay
1.00	0.00	0.00	0.00	8.66	5.00	0.00	-9.81
2.00	0.01	0.09	0.05	8.66	4.90	0.00	-9.81
3.00	30.01	0.17	0.10	8.66	4.80	0.00	-9.81
4.00	30.53	0.26	0.15	8.66	4.70	0.00	-9.81
5.00							-9.81
6.00							-9.81
7.00							-9.81
8.00							-9.81
9.00							-9.81
10.00							-9.81
11.00							-9.81
12.00							-9.81
13.00							-9.81
14.00							-9.81
15.00							-9.81
16.00							-9.81
17.00							-9.81
18.00							-9.81
19.00							-9.81
20.00							-9.81
21.00							-9.81
22.00	30.53	1.82	0.83	8.66	2.94	0.00	-9.81



Plot x versus y using chart wizard

Assignment1

Mangonel Dynamics Design Tool using Excel

Work in groups and/or individually in computer rooms today and during week to

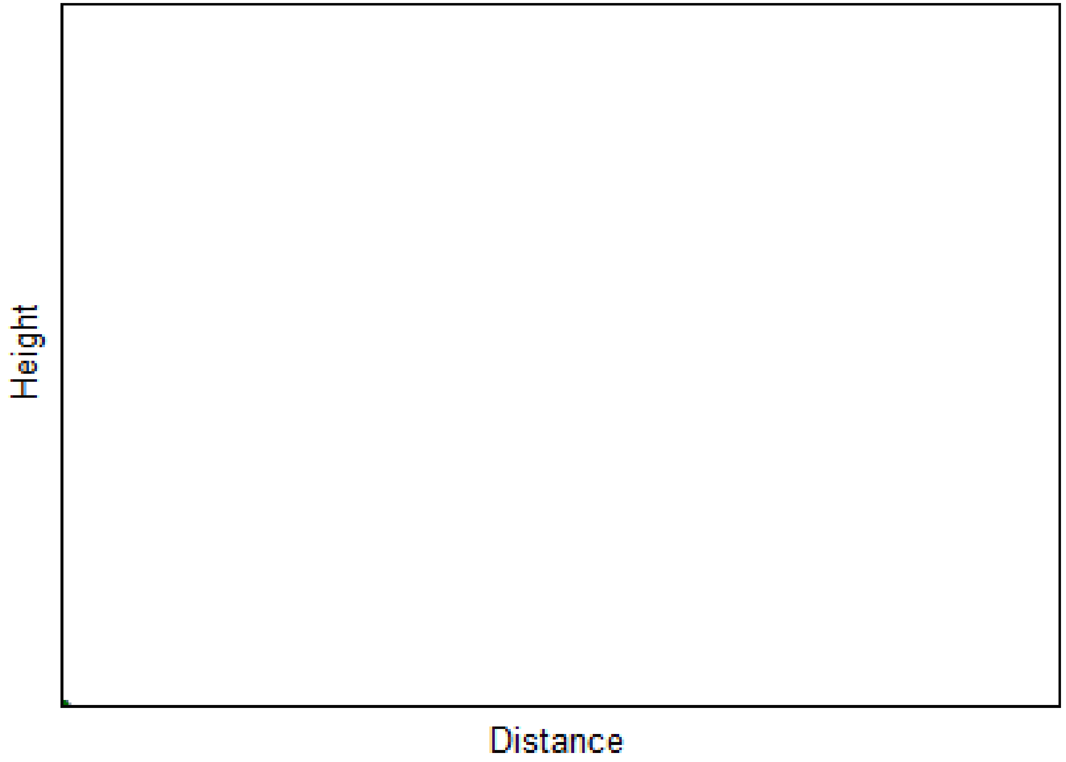
1. Create excel spreadsheet as demonstrated
2. Plot x versus y
3. Study effect of changing velocity
4. Study effect of changing angle

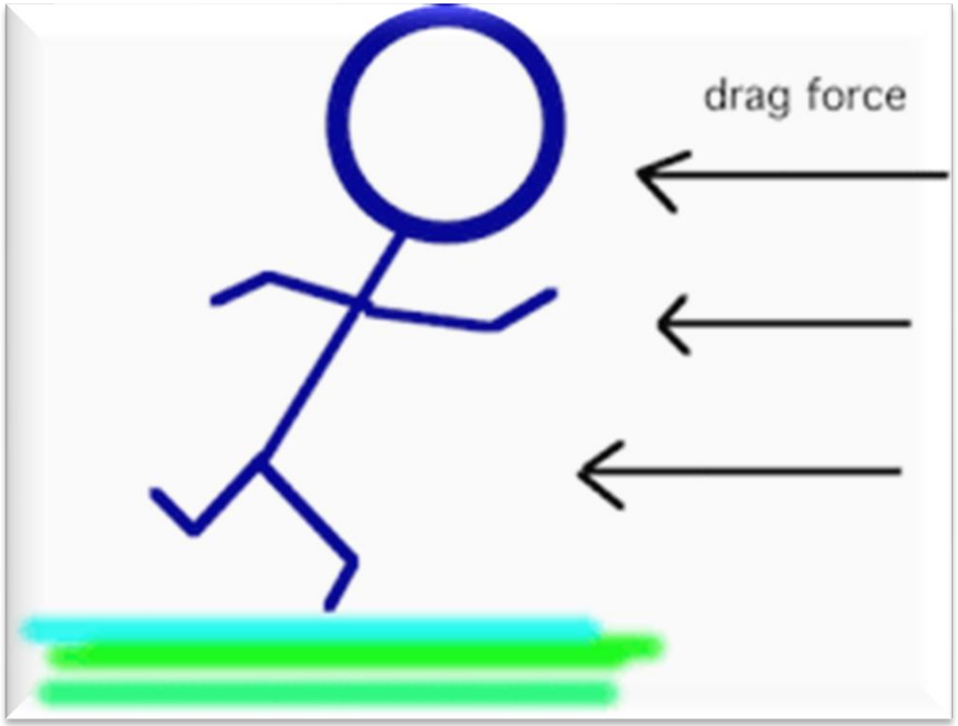
An assignment will be set based on this work. Assignment to be submitted individually – no copying!

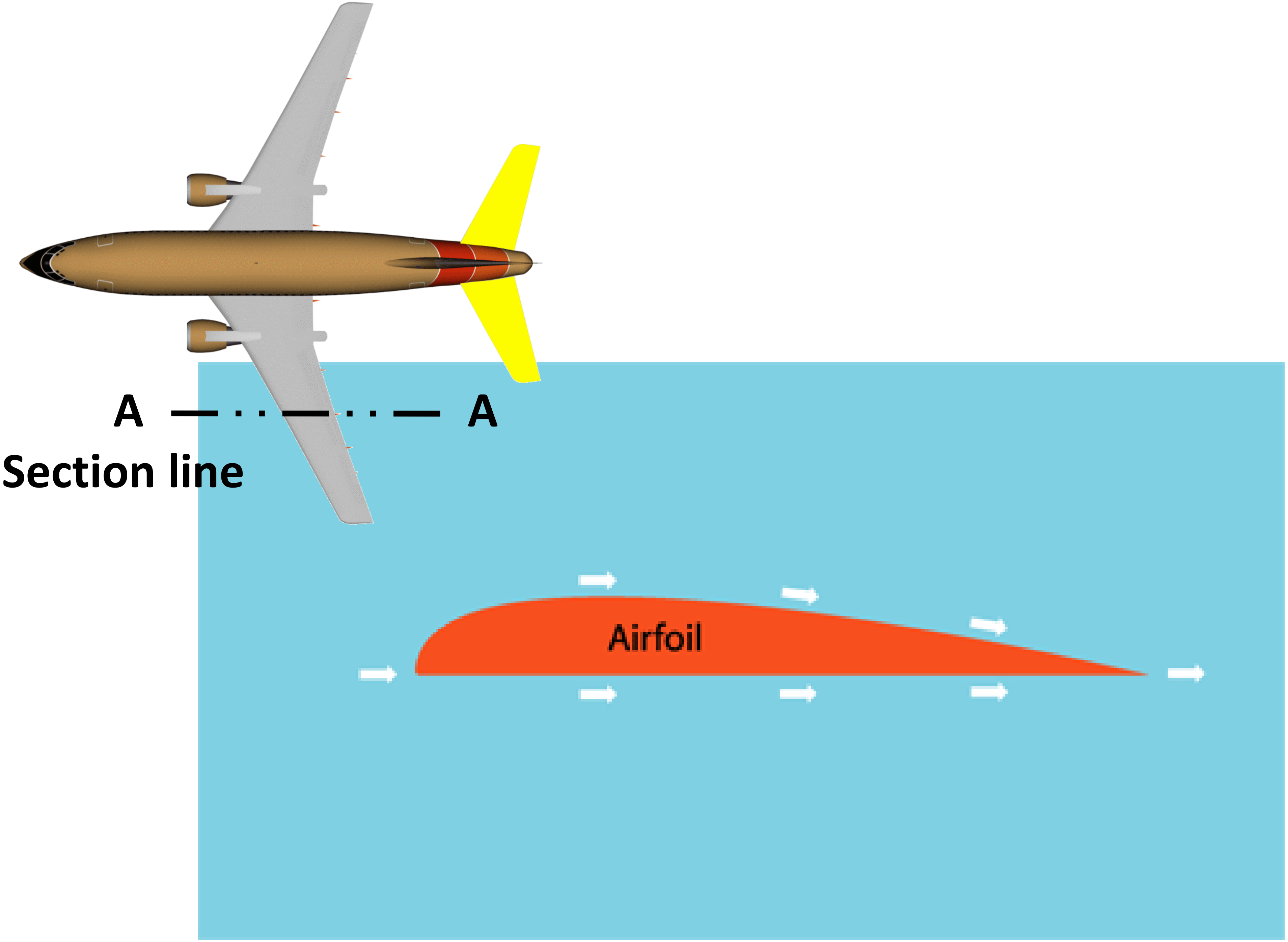
With DRAG Condition

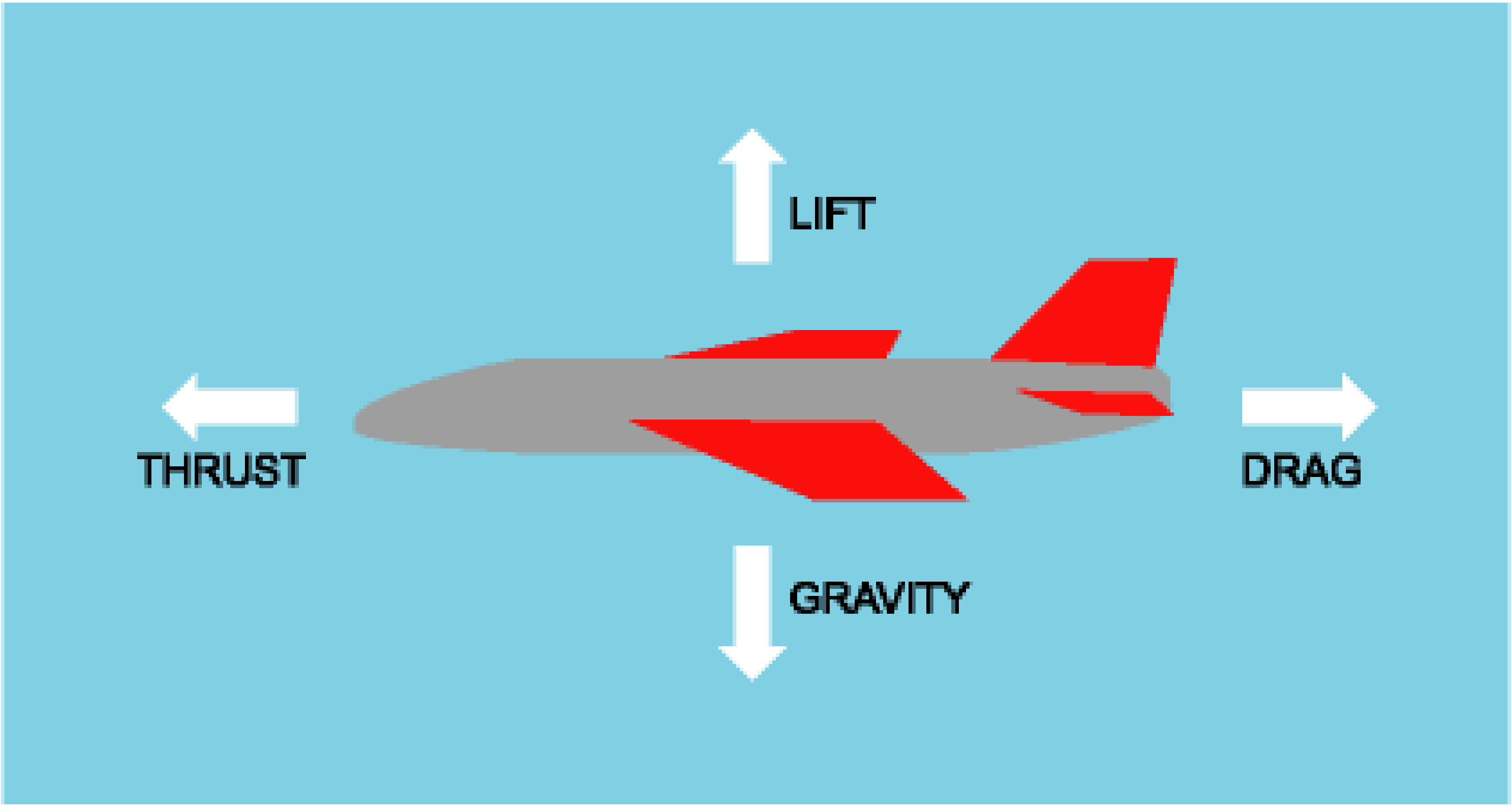
Drag force

A drag force is the resistance force caused by the motion of a body through a fluid, such as water or air. A drag force acts opposite to the direction of the oncoming flow velocity

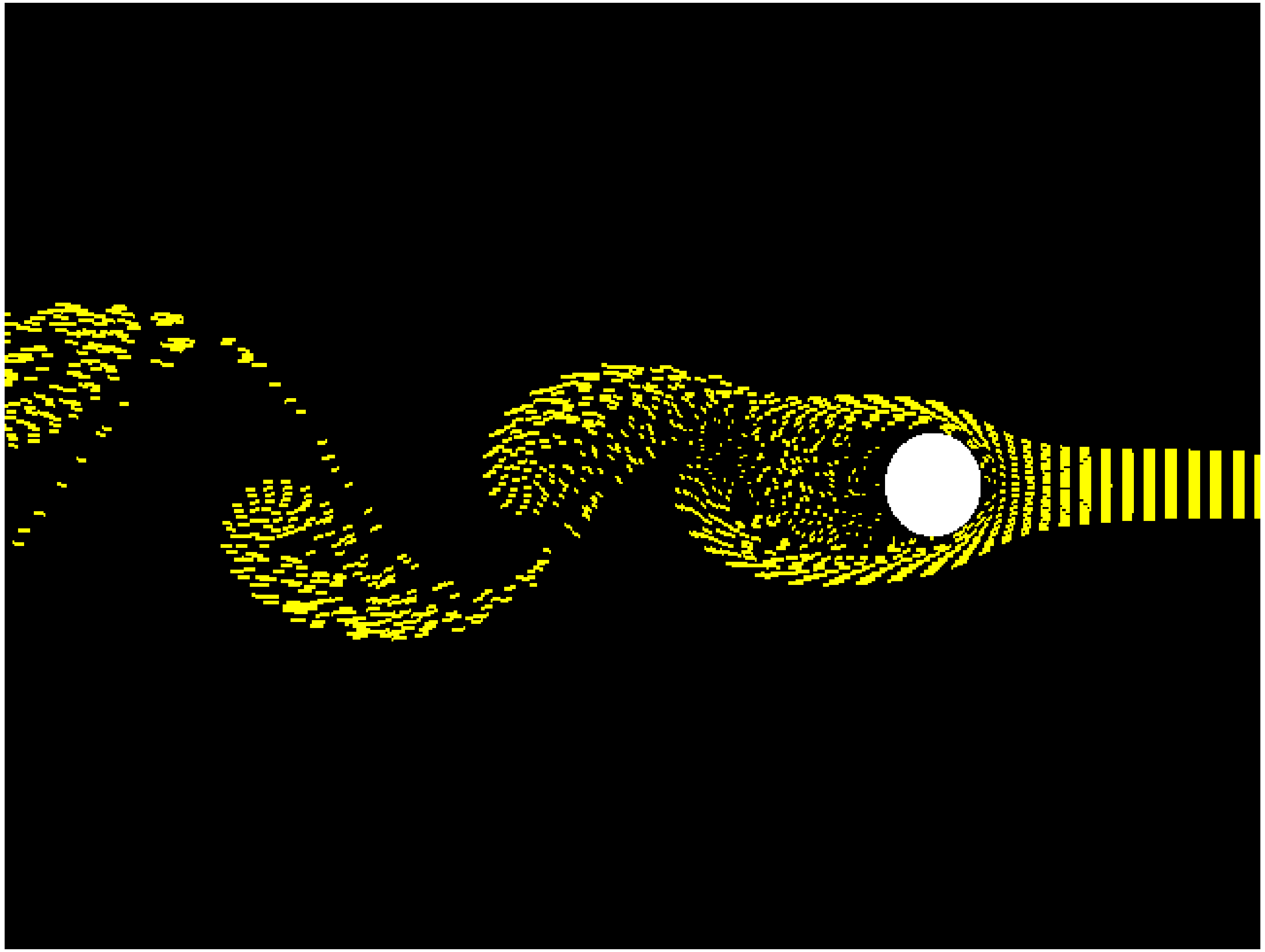





A
A
Section line
Airfoil


LIFT
THRUST
DRAG
GRAVITY

Golf ball



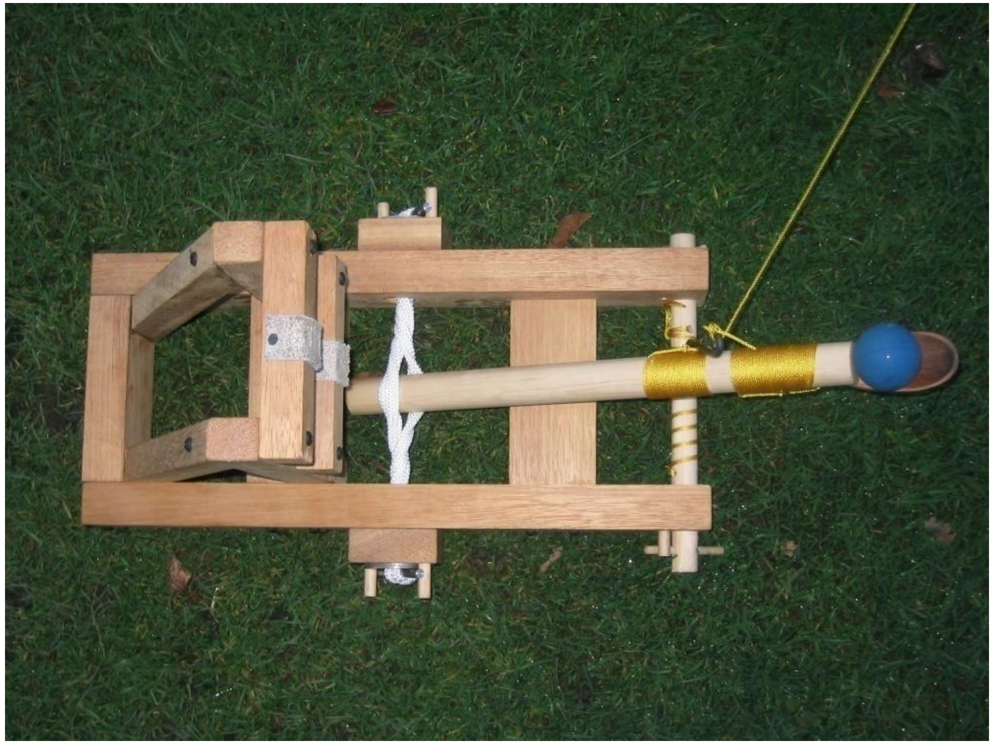
Drag on a Smooth ball

Drag on a ball with dimple

Assignment 2 - Add Drag!

The "projectile" which our Mangonel will fire will be a squash-ball which is spherical See fig 1.

a.



b.

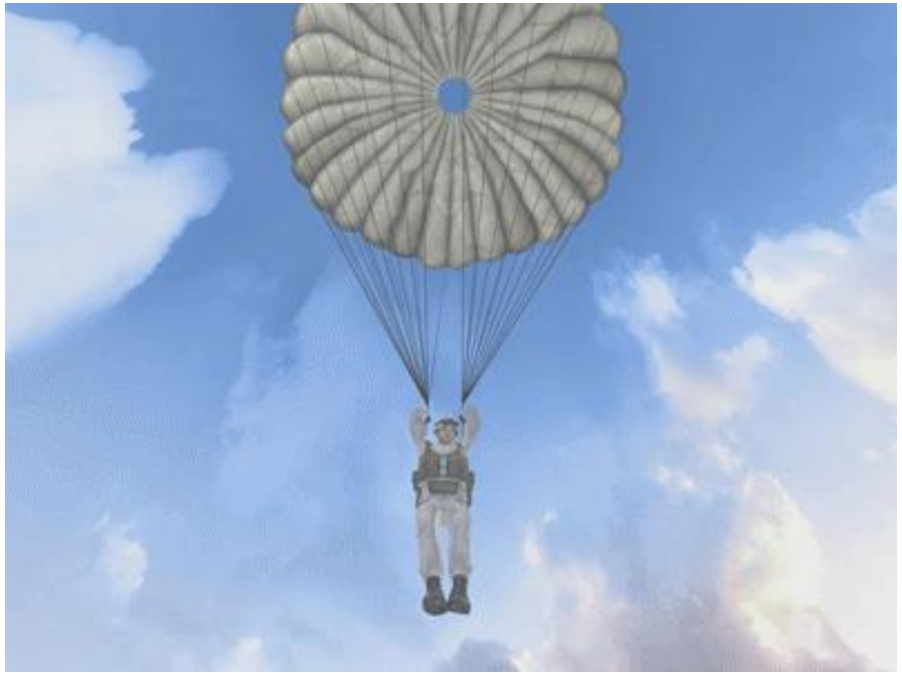
Fig 1. Prototype of our Mangonel!

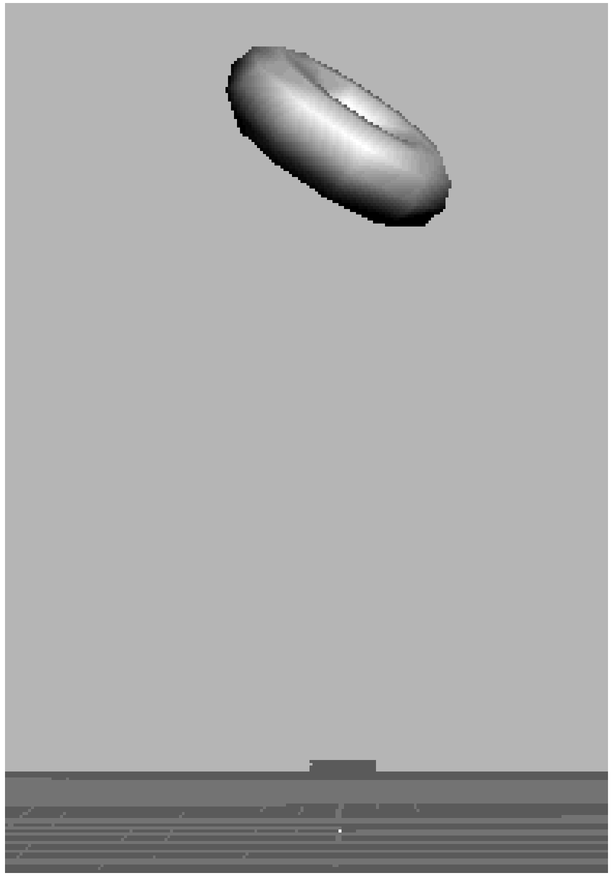
Factors that control drag

Drag reduces the distance travelled by the ball before it hits the ground.

- What are the factors that control drag? and
- How can you reduce it?

If you can reduce drag then your object will travel further!





Empirical formula of drag

The equation that expresses the drag force (F_d) experienced by an object moving in air is:

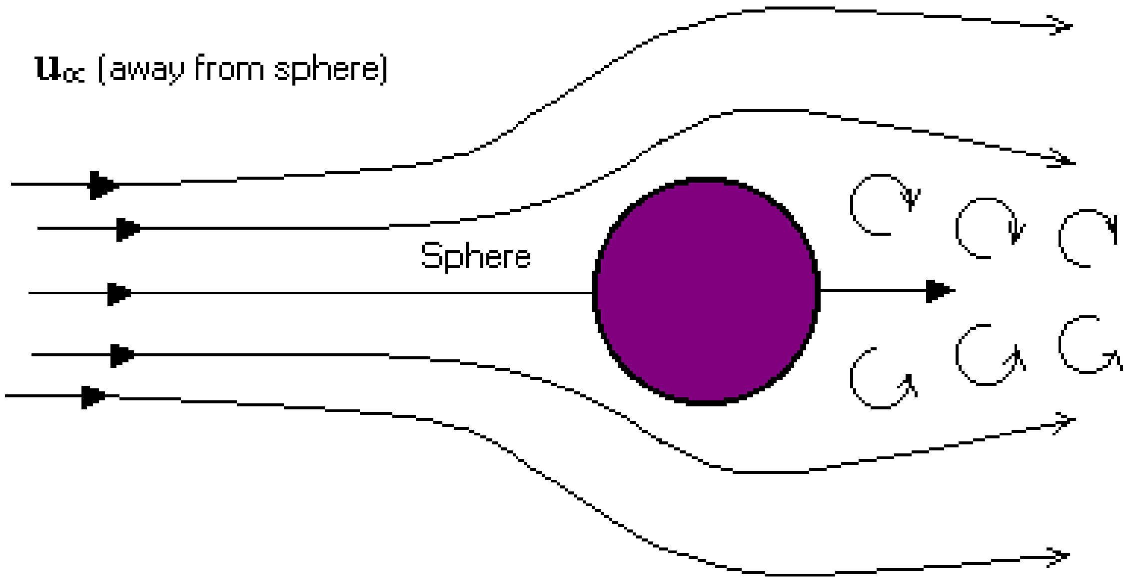
$$\boxed{F_d = 1/2\ \rho\ A\ V^2\ C_d}$$

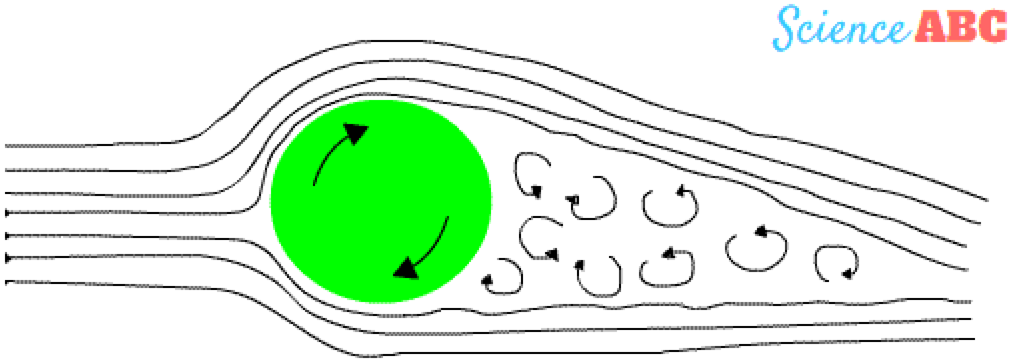
ρ =Density of air

A =Projected area of the body

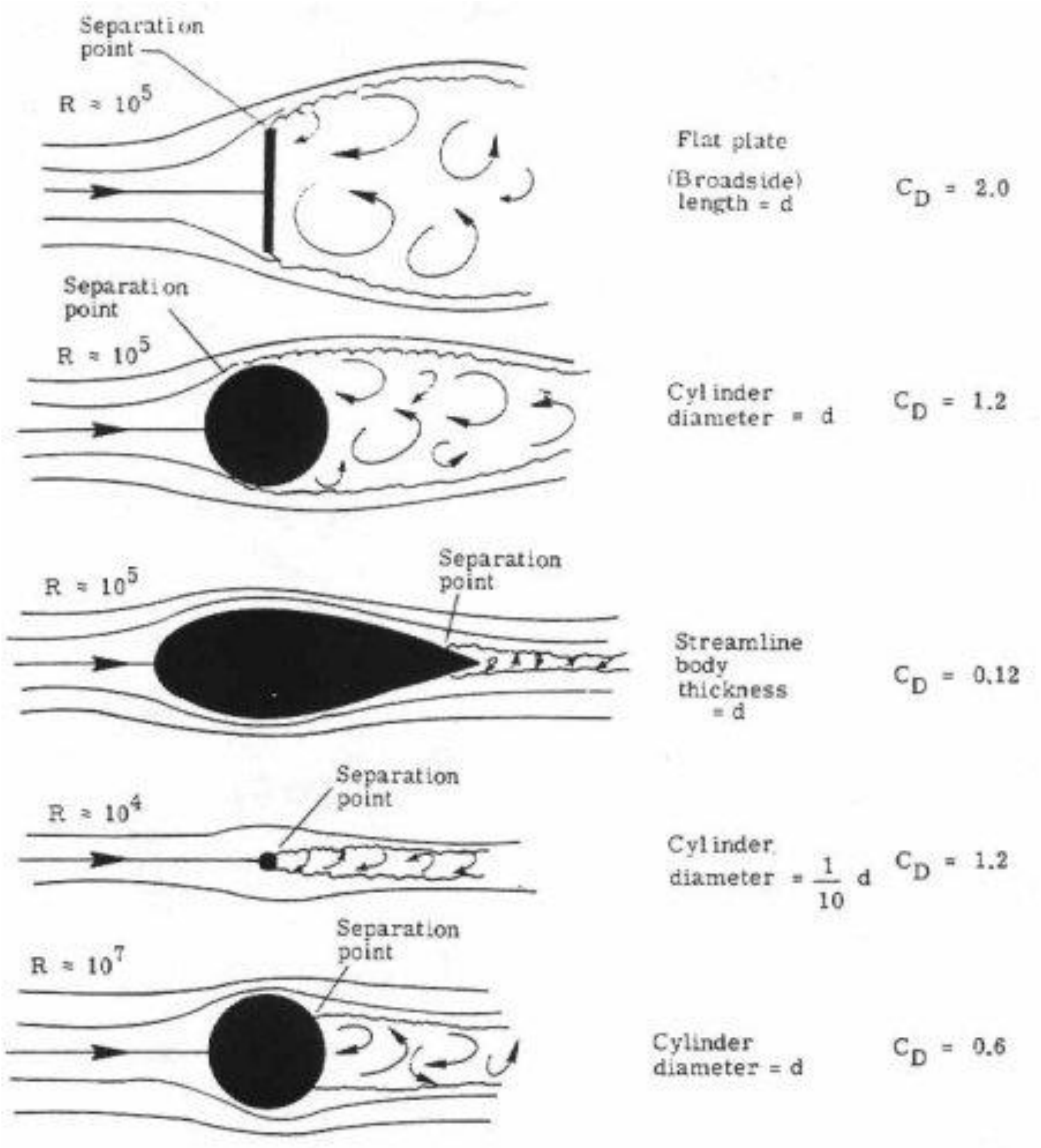
V =Velocity of the body

C_d =Drag Coefficient





Empirical formula of drag



Assignment 2 - Add Drag!

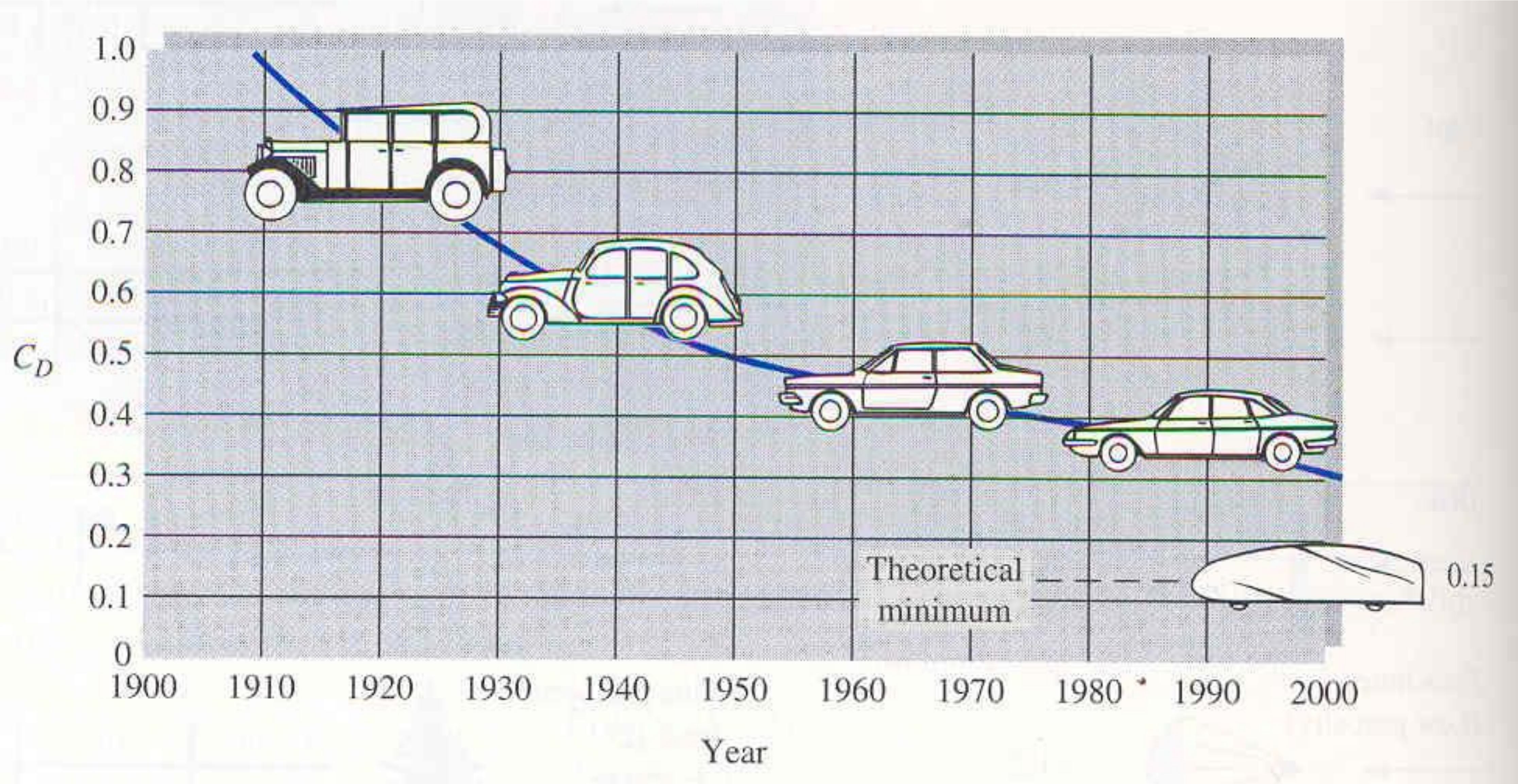
$$\boxed{F_d = 1/2\ \rho\ A\ V^2\ Cd}$$

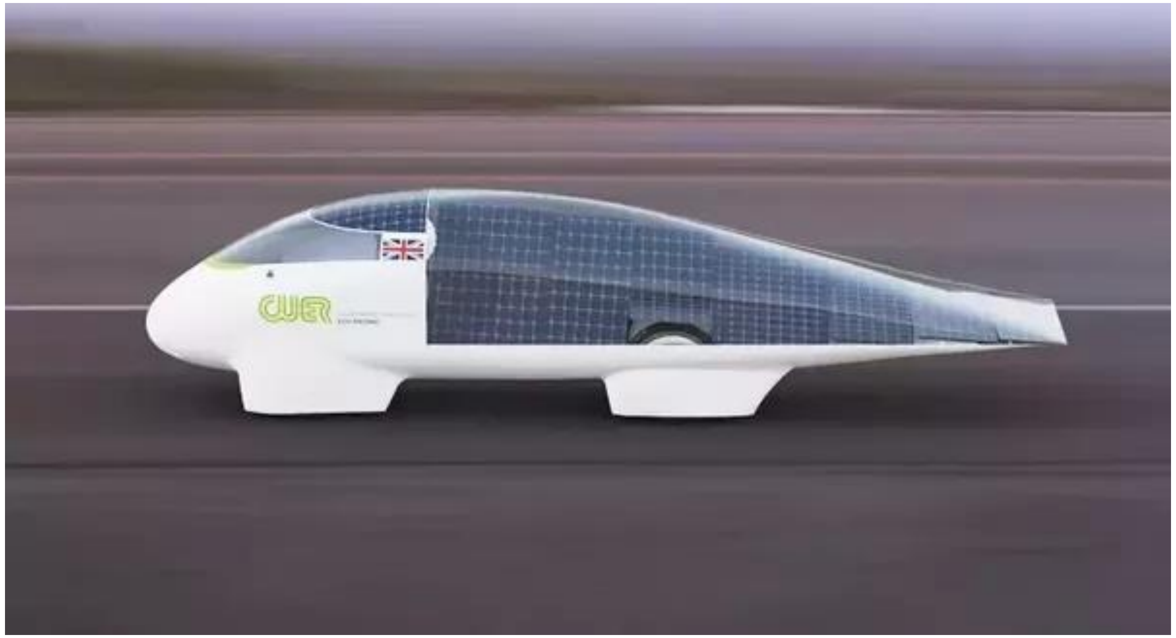
So, we see the drag force increases with size (A) and velocity (V^2).

It makes sense to reduce the size but what about the velocity?

If we reduce the velocity the drag force reduces but the missile wont go as far!

Concept of darg




CUER

Acceleration due to drag

Newton's 2nd Law

$$F_d = 1/2\ \rho\ A\ V^2\ C_d = m a_d$$

$$a_d = 1/(2m)\ C_d\ \rho\ A\ V^2$$

The magnitude of the acceleration is thus expressed

$$|a_d| = \underbrace{1/(2m)\ C_d\ \rho\ A}_{\textbf{Constant (k)}}\ (v_x^2 + v_y^2)$$

Thus

$$a_{xd} = a_d \operatorname{Cos}(ß)$$

$$a_{yd} = a_d \operatorname{Sin}(ß)$$

$$a_{xd} = k\ (v_x^2 + v_y^2) \operatorname{Cos}(ß)$$

$$a_{yd} = k\ (v_x^2 + v_y^2) \operatorname{Sin}(ß)$$

$$a_x = 0 - k\ (v_x^2 + v_y^2) \operatorname{Cos}(ß) \quad \text{and} \quad a_y = -9.81 - k\ (v_x^2 + v_y^2) \operatorname{Sin}(ß)$$

where

$$ß = \tan^{-1}(v_y / v_x)$$

Assignment 2 - Add Drag!

Input Data		
Vel	15.00	Change to see impact!!!!
delt t	0.01	
theta (degrees)	60.00	Change to see impact!!!!
theta (radians)	1.05	
Drag Data		
rho	1.20	The value at atmospheric conditions
Cd	0.40	This is a typical value, however try and change it!
m	0.050	Change to see impact!!!!
D	0.045	Change to see impact!!!!
Area	0.0016	
Constant, K	0.01	

Position	t	x	y	vx	vy	beta [rads]	cos(beta)	sin(beta)	ax	ay
1.00	0.00	0.00	0.00	7.51	12.99	1.04667	0.50046	0.86576	-0.85919	-11.29633
2.00	0.01	0.08	0.13	7.50	12.87	1.04337	0.50331	0.86411	-0.85237	-11.27338
3.00	0.02	0.15	0.26	7.49	12.76	1.04003	0.50619	0.86242	-0.84559	-11.25067
4.00	0.03	0.22	0.38	7.48	12.65	1.03666	0.50910	0.86071	-0.83886	-11.22820
5.00	0.04	0.30	0.51	7.47	12.54	1.03323	0.51204	0.85896	-0.83217	-11.20597
6.00	0.05	0.37	0.64	7.46	12.42	1.02977	0.51502	0.85718	-0.82552	-11.18397
7.00	0.06	0.45	0.76	7.46	12.31	1.02626	0.51802	0.85537	-0.81892	-11.16220
8.00	0.07	0.52	0.88	7.45	12.20	1.02270	0.52106	0.85352	-0.81236	-11.14067
9.00	0.08	0.60	1.00	7.44	12.09	1.01910	0.52413	0.85164	-0.80584	-11.11937
10.00	0.09	0.67	1.12	7.43	11.98	1.01545	0.52723	0.84972	-0.79936	-11.09829
11.00	0.10	0.75	1.24	7.42	11.87	1.01176	0.53037	0.84777	-0.79292	-11.07744
12.00	0.11	0.82	1.36	7.42	11.76	1.00802	0.53354	0.84577	-0.78653	-11.05682
13.00	0.12	0.89	1.48	7.41	11.65	1.00422	0.53674	0.84375	-0.78018	-11.03642
14.00	0.13	0.97	1.59	7.40	11.54	1.00038	0.53998	0.84168	-0.77387	-11.01624
15.00	0.14	1.04	1.71	7.39	11.42	0.99649	0.54325	0.83957	-0.76760	-10.99628
16.00	0.15	1.12	1.82	7.38	11.31	0.99254	0.54656	0.83742	-0.76137	-10.97654

Calculate ß, for each step, depending on the velocity

Assignment 2 - Add Drag!

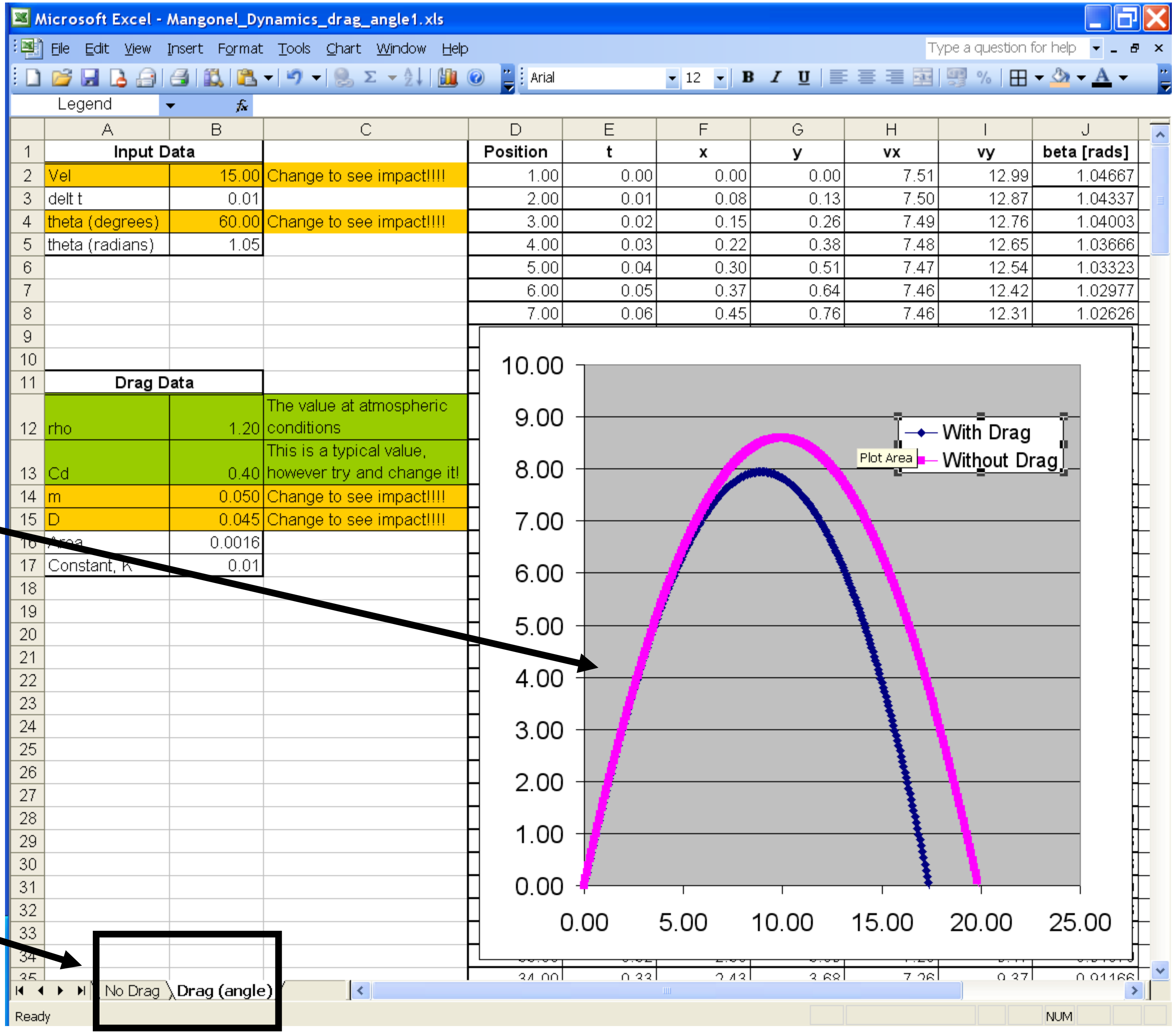
Input Data			Position	t	x	y	vx	vy	beta [rads]	cos(beta)	sin(beta)	ax	ay
Vel	15.00	Change to see impact!!!!	1.00	0.00	0.00	0.00	7.51	12.99	1.04667	0.50046	0.86576	-0.85919	-11.29633
delt t	0.01		2.00	0.01	0.08	0.13	7.50	12.87	1.04337	0.50331	0.86411	-0.85237	-11.27338
theta (degrees)	60.00	Change to see impact!!!!	3.00	0.02	0.15	0.26	7.49	12.76	1.04003	0.50619	0.86242	-0.84559	-11.25067
theta (radians)	1.05		4.00	0.03	0.22	0.38	7.48	12.65	1.03666	0.50910	0.86071	-0.83886	-11.22820
			5.00	0.04	0.30	0.51	7.47	12.54	1.03323	0.51204	0.85896	-0.83217	-11.20597
			6.00	0.05	0.37	0.64	7.46	12.42	1.02977	0.51502	0.85718	-0.82552	-11.18397
			7.00	0.06	0.45	0.76	7.46	12.31	1.02626	0.51802	0.85537	-0.81892	-11.16220
			8.00	0.07	0.52	0.88	7.45	12.20	1.02270	0.52106	0.85352	-0.81236	-11.14067
			9.00	0.08	0.60	1.00	7.44	12.09	1.01910	0.52413	0.85164	-0.80584	-11.11937
Drag Data			10.00	0.09	0.67	1.12	7.43	11.98	1.01545	0.52723	0.84972	-0.79936	-11.09829
rho	1.20	The value at atmospheric conditions	11.00	0.10	0.75	1.24	7.42	11.87	1.01176	0.53037	0.84777	-0.79292	-11.07744
Cd	0.40	This is a typical value, however try and change it!	12.00	0.11	0.82	1.36	7.42	11.76	1.00802	0.53354	0.84577	-0.78653	-11.05682
m	0.050	Change to see impact!!!!	13.00	0.12	0.89	1.48	7.41	11.65	1.00422	0.53674	0.84375	-0.78018	-11.03642
D	0.045	Change to see impact!!!!	14.00	0.13	0.97	1.59	7.40	11.54	1.00038	0.53998	0.84168	-0.77387	-11.01624
Area	0.0016		15.00	0.14	1.04	1.71	7.39	11.42	0.99649	0.54325	0.83957	-0.76760	-10.99628
Constant, K	0.01		16.00	0.15	1.12	1.82	7.38	11.31	0.99254	0.54656	0.83742	-0.76137	-10.97654

Modify the accelerations for each step depending on ß and on the velocities

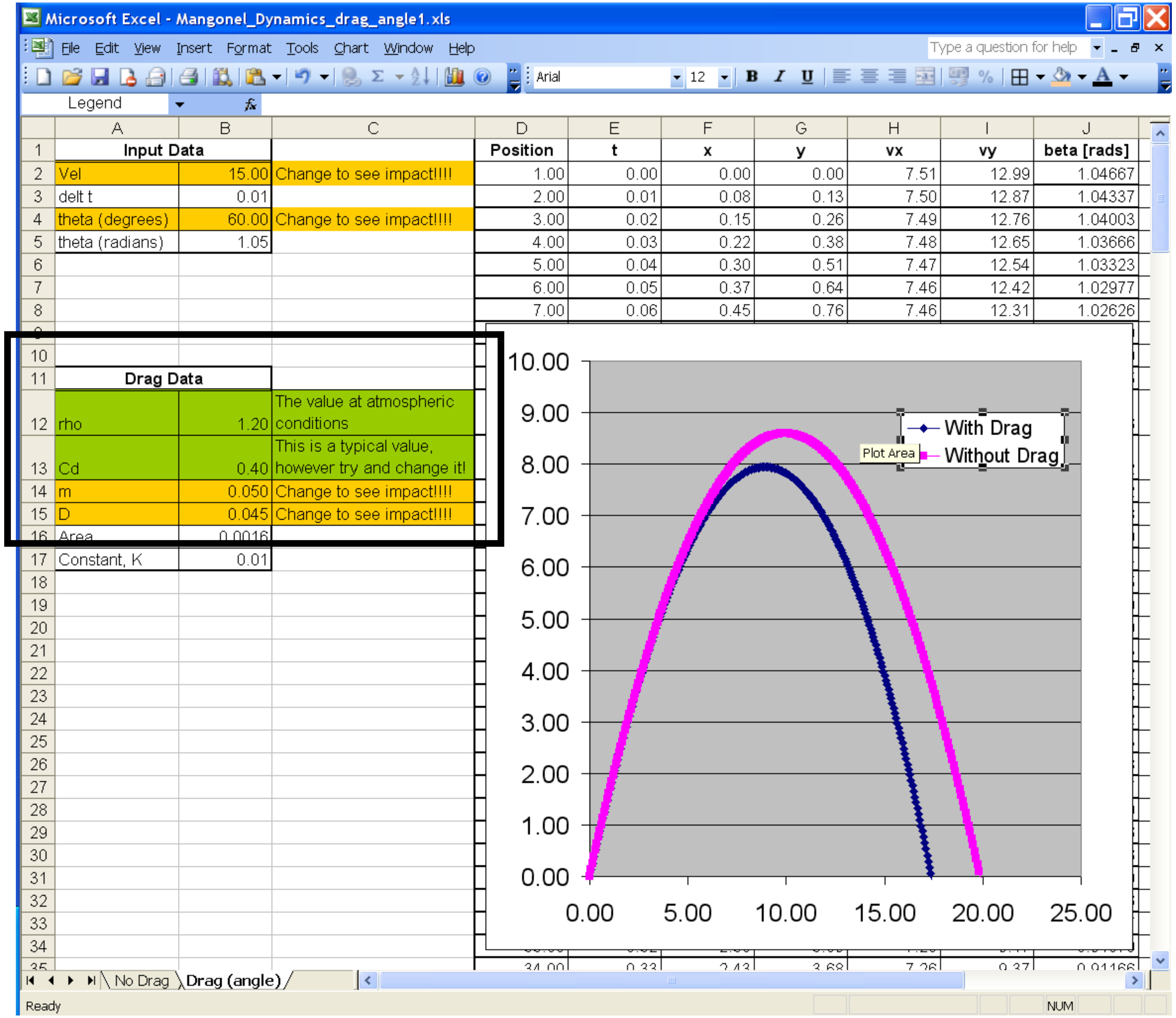
Assignment 2 - Add Drag!

Superimpose the "no drag" and "with drag" plots!

Two sheets!

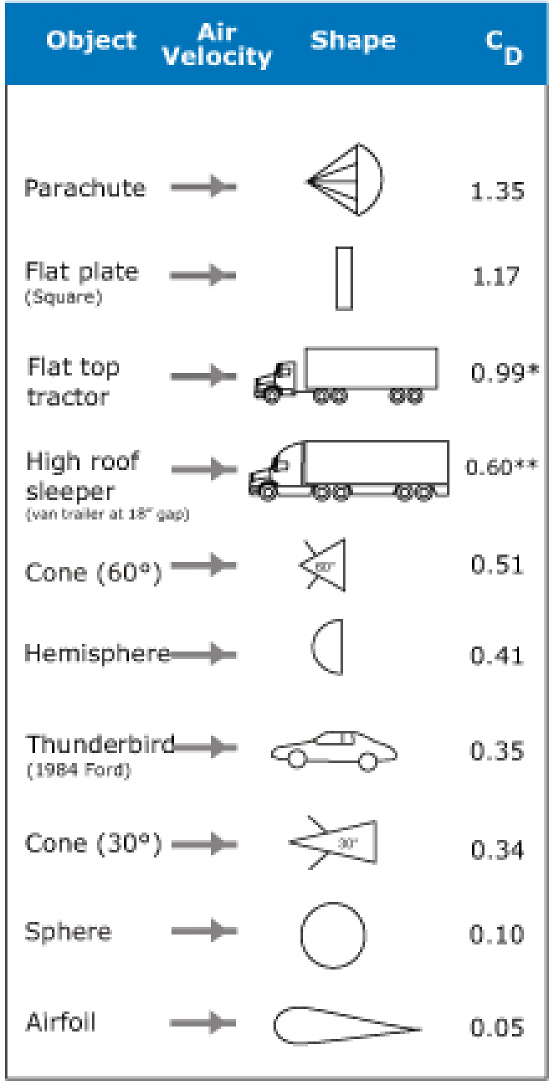


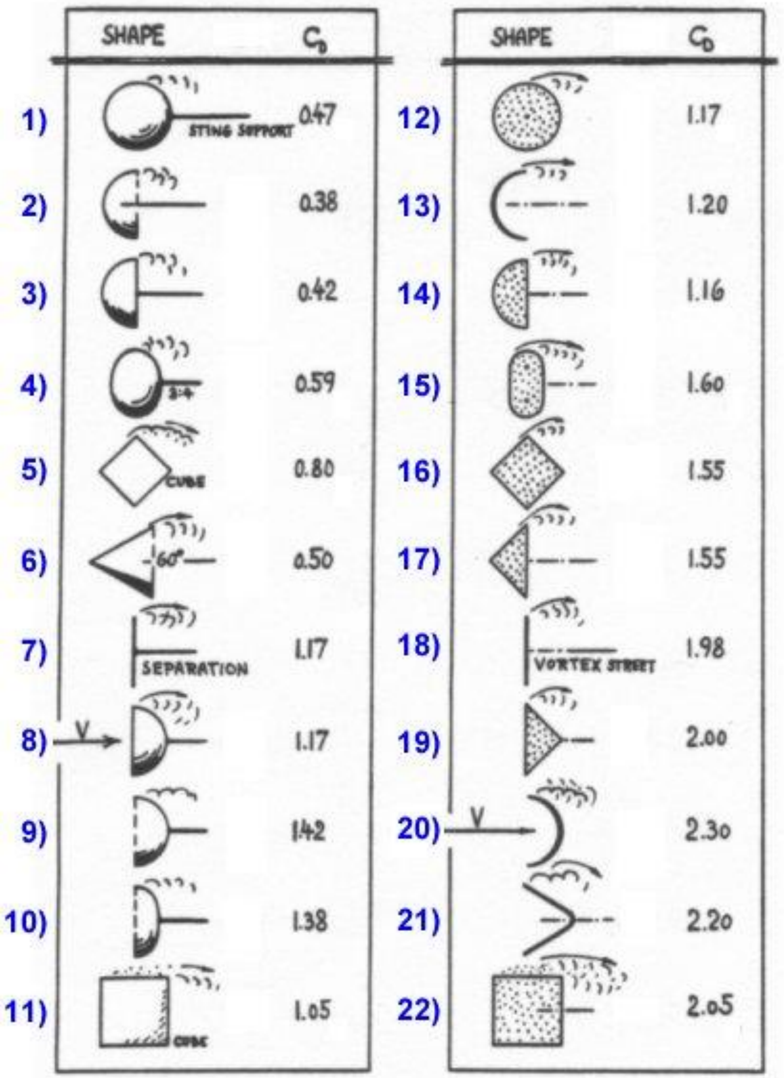
Assignment 2 - Add Drag!

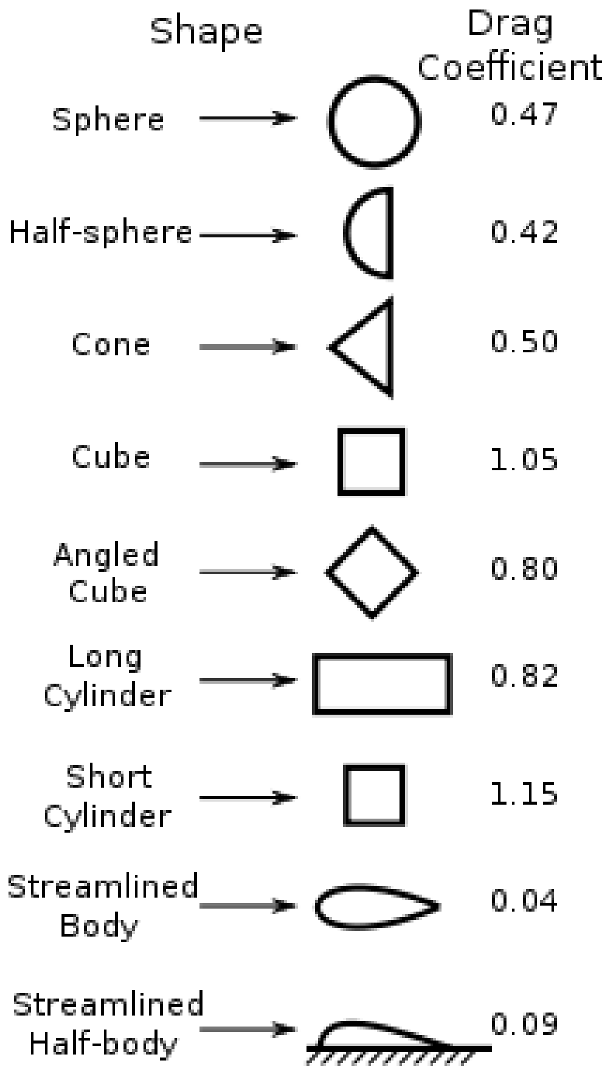


Adjust C_d, mass and the diameter the see effect as well as the initial velocity and launch angle!

Assignment 2 - Add Drag!







Measured Drag Coefficients

Assignment 2 - Add Drag!

		C_r	m kg	C_d	A m^2	v_{75W} km/h	v_{750W} km/h
Traditionele fiets		0,006	90	1,1	0,51	18	44
Racefiets		0,003	81	0,88	0,36	24	55
Tandem		0,0045	163	1,0	0,48	25	59
Superfiets HPV		0,006	90	0,10	0,44	40	102
Perfect streamliner		---		0,05	0,13	94	203
"Motor Pacing"		0,006	91	---		47	470
"Moon Bike"		0,0045	90	---		382	3820

Assignment 2 - Add Drag!

<u>What causes drag?</u>

The drag force is due to pressure losses caused by recirculation of flow. Simply put; eddies and vortices which are caused by abrupt changes in geometry.

In figure 3, although much smaller, the cylinder experiences the same drag force as the much larger but more aero-dynamic airfoil. This is due to the relatively greater amount of “turbulence” in the wake.

FIGURE 9.21 Two objects of considerably different size that have the same drag force: (a) circular cylinder C_D = 1.2, (b) streamlined strut C_D = 0.12.

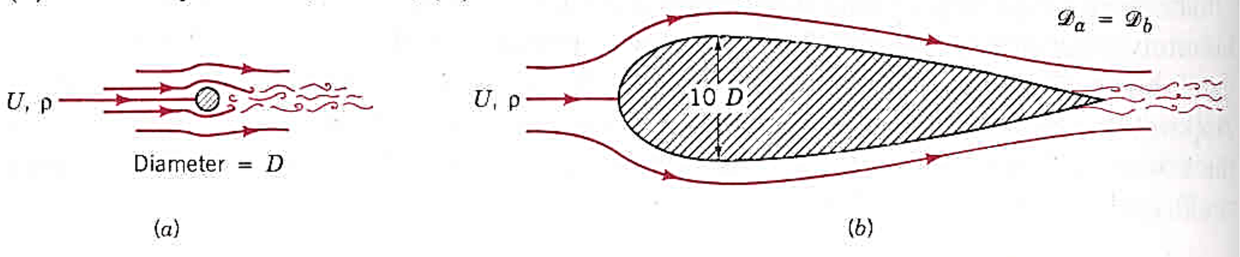


Fig 3.

Thanks for attending this lecture

Save Tree Save World