

Classical Mechanics Project

This project is designed to explore and discuss Newton's Laws of motion. Analysis using the techniques learnt in class and numerical models will have to be implemented to determine the motion of the object(s).

Groups of 1-4 people

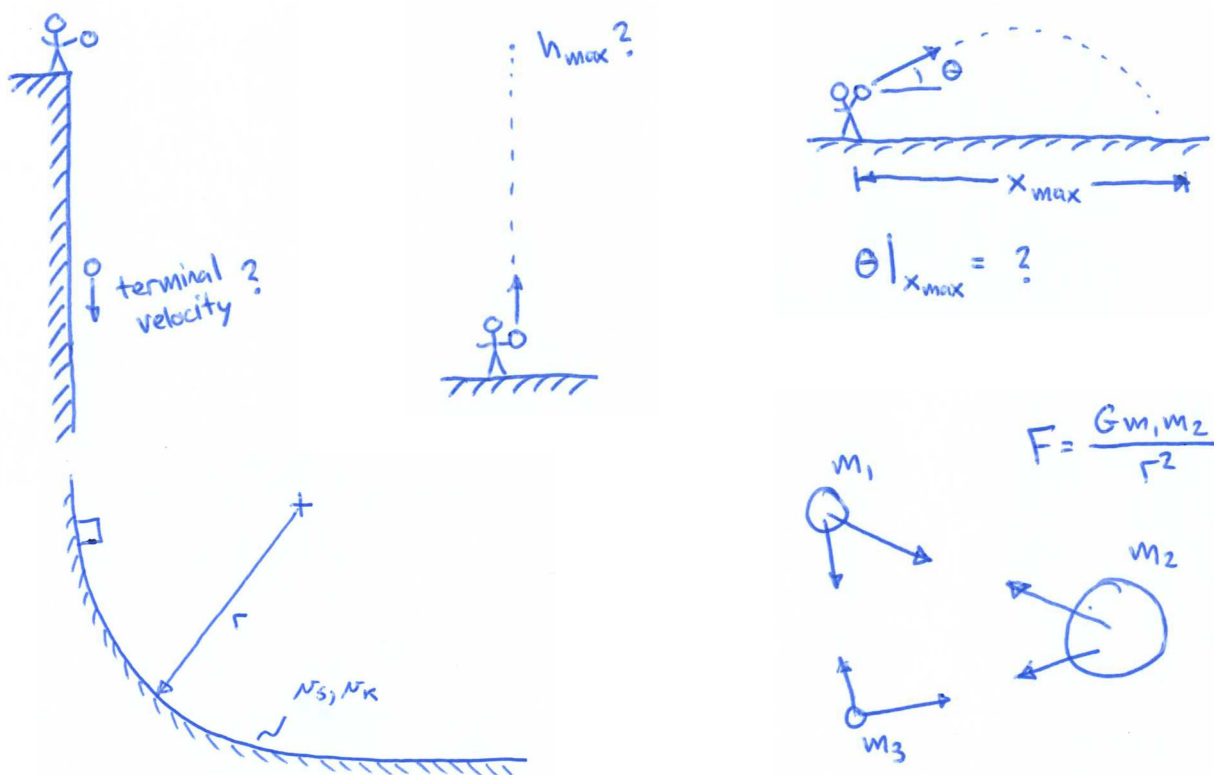
Presentation (worth 2% of final grade) and Report (worth 8% of final grade) due week 14
Report out of 8 marks

Outline

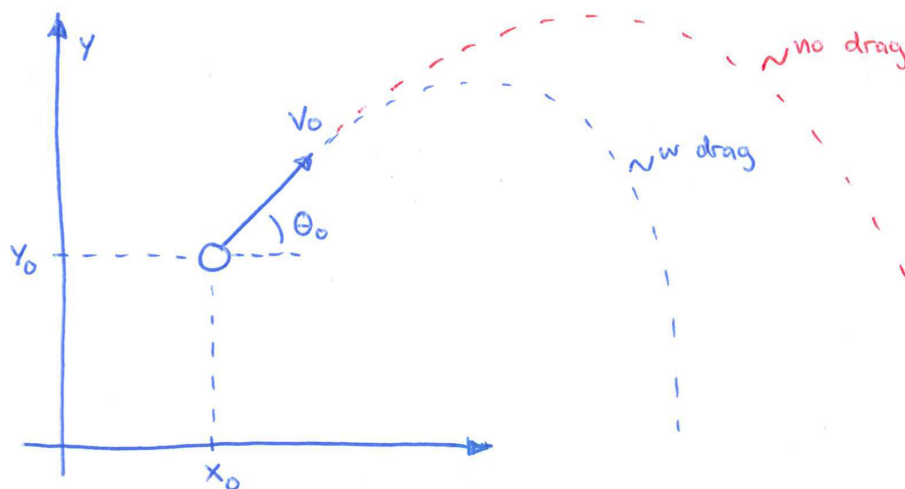
This report will outline the physics project by means of an example. It should only be used as a template and you should create your own report and excel file for your submission.

Choose a physics event.

Some examples are shown below: terminal velocity using drag, maximum height using drag, theta which results in the maximum distance, blocks sliding down curved surfaces and the 3 body problem.



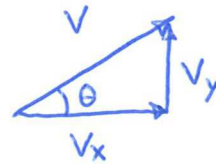
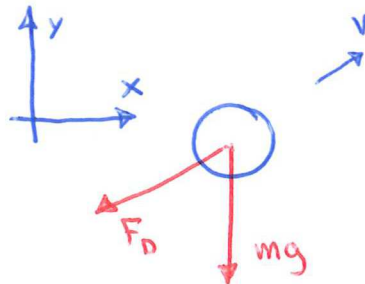
For this report the distance velocity acceleration (dva) graphs of a ball thrown with and without drag will be compared, as shown below.



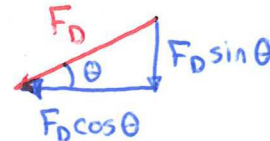
(3 mark) Analyze the physics event.

Free Body Diagram (FBD) of the ball:

FBD:



* F_D is opposite of the velocity vector.



Newton's 2nd Laws applied to the ball:

$$\sum F_x = m a_x = - F_D \cos \theta \quad (1)$$

$$\sum F_y = m a_y = - F_D \sin \theta - mg \quad (2)$$

where

$$F_D = \frac{1}{2} \rho A C_D v^2 \quad (3)$$

some additional equations to determine the velocity magnitude and direction.

and

$$v = \sqrt{v_x^2 + v_y^2} \quad (4)$$

$$\theta = \tan^{-1} \left(\frac{v_y}{v_x} \right) \quad (5)$$

kinematic equations to determine the position and velocity given an acceleration.

$$\vec{x} = \vec{x}_0 + \vec{v}_0(\Delta t) + \frac{1}{2} \vec{a}(\Delta t)^2 \quad (6)$$

$$\vec{v} = \vec{v}_0 + \vec{a}(\Delta t) \quad (7)$$

(2 marks) Implement into excel.

The acceleration of the ball depends on the velocity due to the drag and therefore can not be solved directly. An iterative numerical method must be implemented to solve for the velocity and then the acceleration as a function of time. An excel routine (shown below) was developed to estimate the solution at a given time and then in consecutive time steps (Δt).

setup excel file

t	x	y	v_x	v_y	v	θ	F_D	a_x	a_y
0	x_0	y_0	$v_0 \cos \theta_0$	$v_0 \sin \theta_0$	= (4)	= (5)	= (3)	= (1)	= (2)
= 0 + Δt	= (6)	= (6)	= (7)	= (7)	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...

where red indicates initial conditions.

The excel routine was constructed with inputs of the physical properties of the system, initial conditions and the numerical parameters, as:

:	kinematics		Shape	Drag Coefficient
	x_0	0 m	Sphere → 	0.47
	y_0	0 m	Half-sphere → 	0.42
	v_0	20 m/s	Cone → 	0.50
	θ_{0}	60 degrees	Cube → 	1.05
	g	9.81 m/s ²	Angled Cube → 	0.80
	Dynamics		Long Cylinder → 	0.82
	m	1 kg	Short Cylinder → 	1.15
	R	0.3 m	Streamlined Body → 	0.04
	$A =$	0.283 m ²	Streamlined Half-body → 	0.09
	ρ	1.2 kg/m ³		
	C_D	0.47		
	Numerical			
	dt	0.05 s		

The excel routine solved for the distance, velocity and acceleration of the ball with drag:

Data (With Drag)

t [s]	x [m]	y [m]	v_x [m/s]	v_y [m/s]	v [m/s]	theta [deg]	F_D [N]	a_x [m/s ²]	a_y [m/s ²]
0.0	0	0	10	17	20.0	60.0	31.9	-16	-26
0.1	0.5	0.8	9.2	16.0	18.5	60.1	27.2	-13.6	-23.4
0.1	0.9	1.6	8.5	14.9	17.1	60.2	23.4	-11.6	-21.5
0.2	1.3	2.3	7.9	13.8	15.9	60.1	20.2	-10.1	-19.9
0.2	1.7	3.0	7.4	12.8	14.8	59.8	17.5	-8.8	-18.6
0.3	2.1	3.6	7.0	11.9	13.8	59.5	15.1	-7.7	-17.5

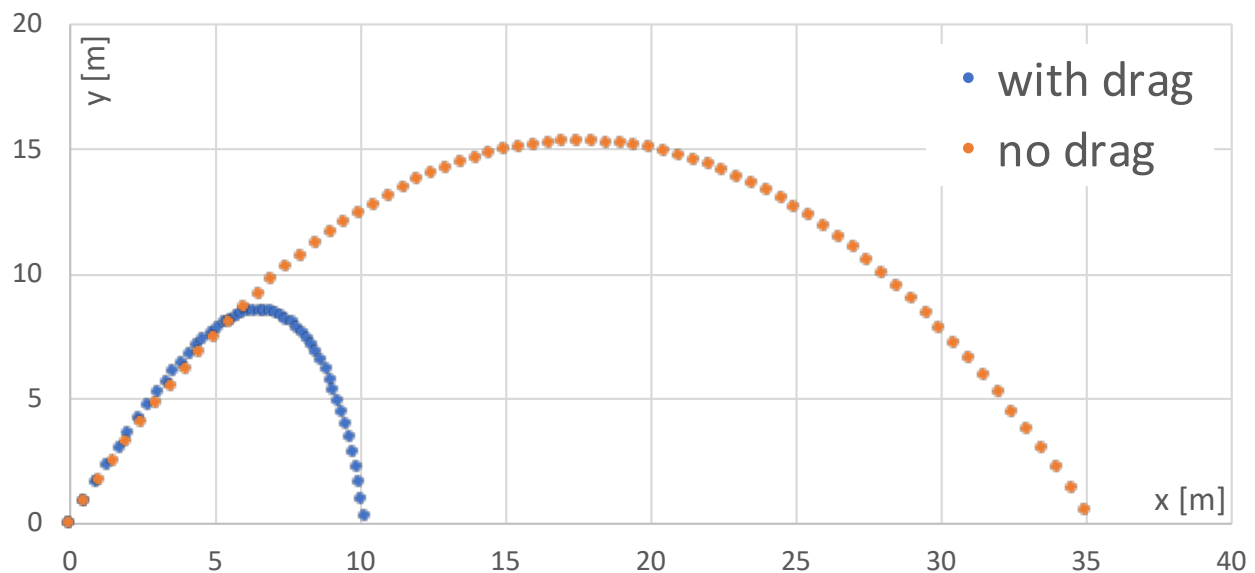
And with out drag

Data (no Drag)

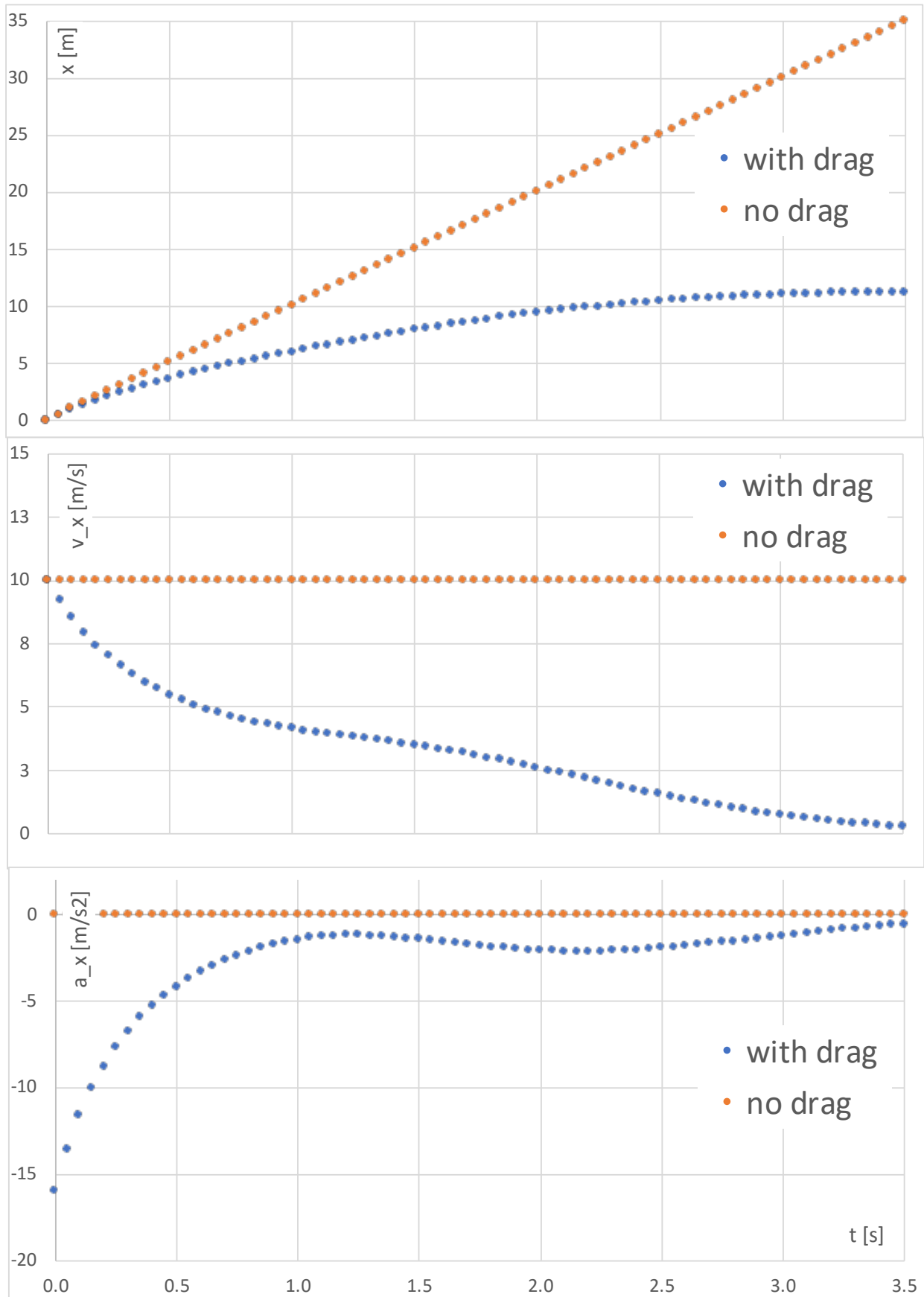
x [m]	y [m]	v_x [m/s]	v_y [m/s]	a_x [m/s ²]	a_y [m/s ²]
0	0	10	17	0	-10
0.5	0.9	10.0	16.8	0.0	-9.8
1.0	1.7	10.0	16.3	0.0	-9.8
1.5	2.5	10.0	15.8	0.0	-9.8
2.0	3.3	10.0	15.4	0.0	-9.8
2.5	4.0	10.0	14.9	0.0	-9.8

(2 marks) Plot results

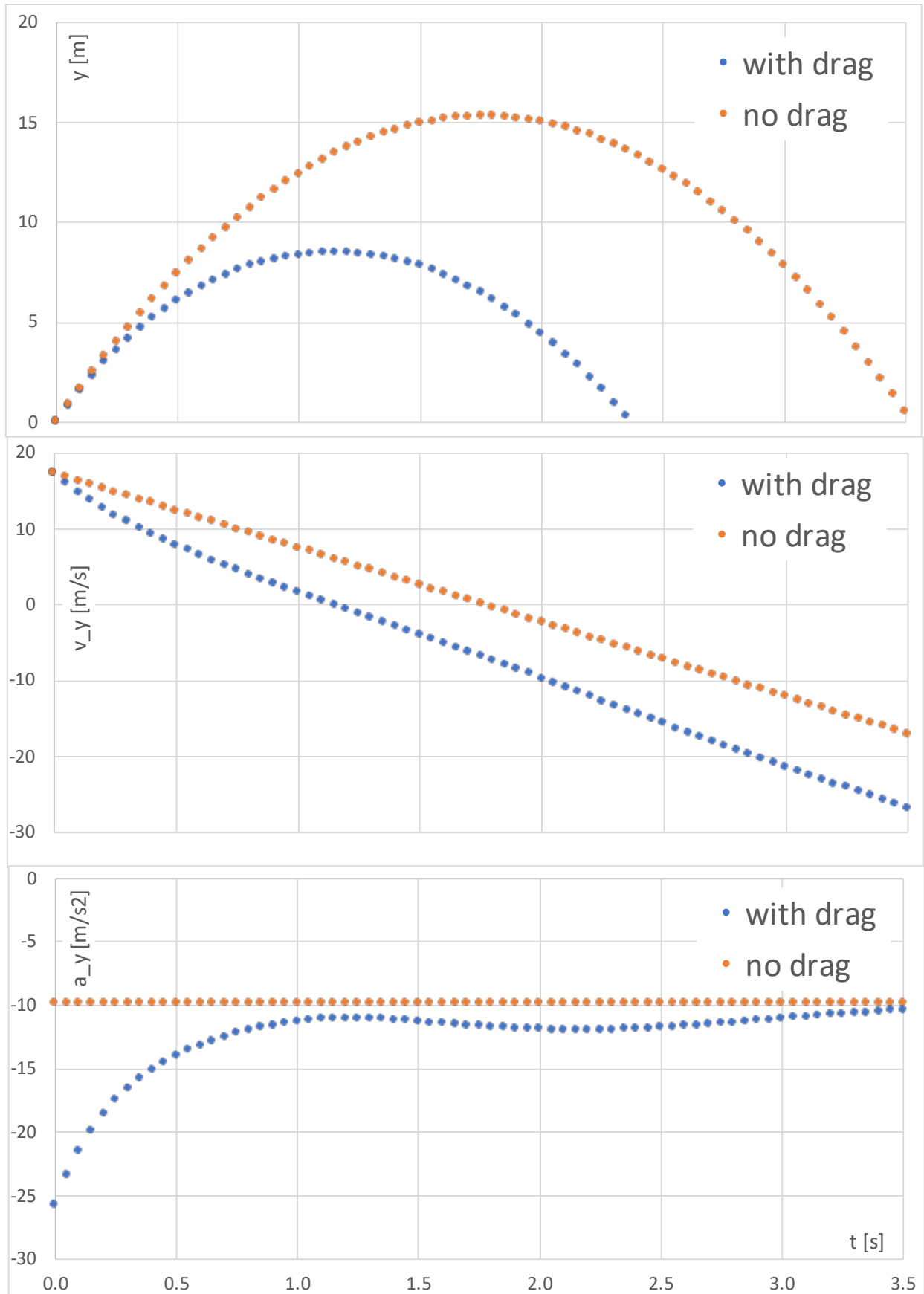
Below is a typical projectile trajectory of the ball with and without drag.



Below is the distance-velocity-acceleration graph for the x-direction.



Below is the distance-velocity-acceleration graph for the x-direction



(1 marks) Write up a report (such as this) that includes:

- a. a drawing of the physics event.
- b. (1 marks) FBD and angle calculations of the physics event.
- c. (2 marks) derivation of the acceleration using Newton's 2nd Law.
- d. (2 marks) numerical solution of the event.
- e. (1 marks) graph of objects motion.
- f. (1 marks) a distance-velocity-acceleration graph of the physics event.
- g. (1 marks) neatly laid out and formatted document.
- h. signed workload distribution (Appendix).

Appendix

Workload Distribution

Name	Signature	Percentage of load	Contribution to Project
------	-----------	--------------------	-------------------------