



AutoTherm

Fluid Mechanics Validation Cases & Tutorial

AutoTherm Fluid Mechanics – Validation and Tutorials

FM01-Hydrostatic Pressure – Force on a Plane Surface

FM02-Exact Solution – Parallel Plate Channel

FM03-Control Volume Formulation – Linear Momentum

FM04–Energy Equation

FM05-Internal Flows – Pipe System

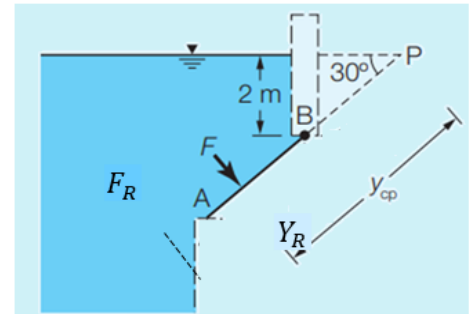
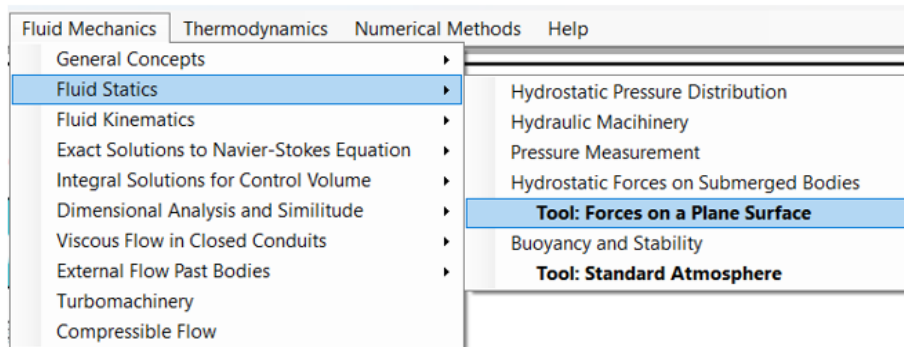
FM06-Forces Acting on a Moving Vehicle

FM07-Trajectory of a Solid Object

Example – Resultant Force on a Submerged Gate

The rectangular gate shown below has dimensions 3 m × 2 m and is pin-connected at B. Calculate

- the resultant force on the gate (F_R), and
- the center of pressure (y_R), measured along the gate from the free surface.



- Enter Input.

Accept the default value for water density

Enter 30° for the angle of the surface

Input		
ρ	1000	kg/m ³
θ	30	deg

- Specify the depth.

This may be specified by either entering the depth (h) at the top or the centroid of the plate, or the distance along the plane of the surface to the free surface (Y) to the top or centroid of the plate.

Enter the depth to the top of the surface.

Depth Information		
☐ YT		m
☐ YCG		m
☒ HT	2	m
☐ HCG		m

- Enter shape properties. This can be done using the Math Tool by clicking the “Use Shape Tool” button.

Choose Case-a Rectangle

Enter the dimensions

Click update. The form will close, and the necessary information will be automatically entered into the text boxes.

Surface Information

Use Shape Tool

I_{xc} 4.500 m⁴

I_{xyc} 0.000E00 m⁴

Area 6.000 m²

LT 1.500

Shape Properties

Input

Please SelectShape

Case-a: Rectangle

a 3 m

b 2 m

Results

Area m²

I_{xc} m⁴

I_{yc} m⁴

I_{xyc} m⁴

Distance to Centroid

From Top m

From Left m

Update

(a) Rectangle

(b) Circle

(c) Semicircle

(d) Triangle

(e) Quarter circle

Click update. The finished form is shown below.

Other fields are filled out.

The resultant force is 161.9 kN

This force is acting at YR = 5.636 m.
This is 13.6 cm directly below the centroid.

Hydrostatic Force on a Plane Surface

Input

ρ 998.2 kg/m³

θ 30 deg

Depth Information

☐ YT 4.00 m

☐ YCG 5.50 m

☒ HT 2.00 m

☐ HCG 2.75 m

Surface Information

Use Shape Tool

I_{xc} 4.50 m⁴

I_{xyc} 0.000E00 m⁴

Area 6.00 m²

LT 1.50

Results

PCG 26.93 kPa

FR 161.57 kN

YR 5.64 m

LX 0.000E00 m

LY 0.13636 m

Update

$F_R = \rho g h_{CG} A$

KEY RELATIONSHIPS

$p = \rho g h$

$F_R = \rho g h_{CG} A$

$y_{CP} = y + \frac{I_{xc}}{Ay}$

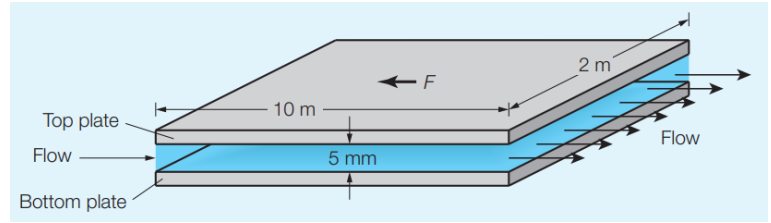
NOTES:

- h is the vertical depth from the free surface.
- F_R acts normal to the inclined surface at the Center of Pressure (CP).
- L_y is the distance from CG to CP parallel to the inclined surface.

Example – Laminar Flow Between Parallel Plates

A lubrication system requires SAE 30 oil ($\rho = 918 \text{ kg/m}^3$, $\mu = 0.440 \text{ Pa} \cdot \text{s}$) at 20°C to flow at 1.5 L/s between $10 \text{ m} \times 2 \text{ m}$ parallel plates spaced 5 mm apart, as shown below.

- What is the required pressure difference between the inflow and the outflow sections?
- What force must be used to keep each plate from moving?
- What is the maximum velocity between the plates?



Open the “Flow through Channel” tool in *Fluid Mechanics/Exact Solution to Navier-Stokes Equation*.

1. Choose the “Flow between Stationary Plates” option.
2. Click the *Enter Properties* option and enter the given values for the density and viscosity.
3. Enter **5 mm** for the channel height and **2 m** for the channel width.
4. Click the “Flow, Q” (volumetric) option and enter **1.5 L/s**.
5. Click **Update** to solve.

Select Case
☒ c) Flow Between Stationary Parallel Plates (Hele-Shaw flc) ①

Fluid Properties ☐ Select Fluid ☒ Enter Properties

User-Fluid

Press. 1.000 atm ②
 Temp. 20 C
 Fluid Properties
 ρ 918 kg/m³
 μ 0.44 Pa.s

Geometry
 Channel Height, 2h 5 mm ③
 Channel Width, w 2 m ③

☐ Press. Gradient, dp/dx -31.68 kPa/m
☐ Mean Velocity, V 0.15000 m/s
☒ Flow Rate, Q 1.50 L/s ④
 Mass Flow Rate, $\dot{m}$ 1.38 kg/s
 Wall Shear Stress Outer -0.07920 kPa Inner

Local Velocity
 y/h 0.0
 $V(r)$ 0.22500 m/s

⑤ Update

a) Flow Through a Circular Tube (Hagen-Poiseuille flow)
 Velocity Distribution
 Flow
 r
 x
 R

b) Flow Through Annulus
 Annulus Channel
 Velocity Distribution
 Flow
 r
 x
 R_i
 R_o

c) Flow Between Stationary Parallel Plates (Hele-Shaw flow)
 Velocity Profile
 Flow
 y
 x
 $2h$

Reynolds Number, Re 1.56

- $Re = 1.56$ confirms our laminar flow assumption is correct.

- To get the pressure difference, we need to multiply the pressure gradient -31.68 kPa/m by the channel length.

$$P_2 - P_1 = L \frac{dP}{dx} = (10)(-31.68) = -\mathbf{316.8\ kPa}$$

- The force to keep the plate from moving is the shear stress times the surface area of the plate:

$$F = |\tau_{top}|LW = (0.0792)(10)(2) = \mathbf{1.59\ kN}$$

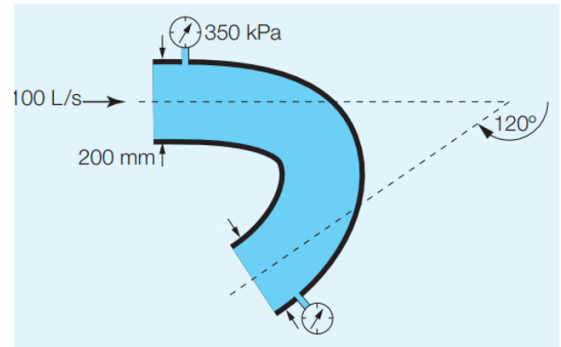
- The maximum velocity is at the center ($y/h=0$). This value is given in the form in the Local Velocity panel as $V(y/h=0) = 0.225\ \text{m/s}$

Example - Conservation of Momentum – Reducer-Bend

Consider the 120 ° reducer-bend shown below. The bend entrance has a diameter of 200 mm, and the exit has a diameter of 87.5 mm. When water at 20 °C flows at 100 L/s through the bend, the measured entrance pressure is 350 kPa. The bend is in the horizontal plane. What is the magnitude and direction of the force the water exerts on the bend?

Open the “Linear Momentum” tool in *Fluid Mechanics/Integral Solution for Control Volumes*.

6. Enter **200** and **37.5** for D1 and D2, and change the unit to mm.
7. In the Flow panel, enter **100** L/s for VDot.
8. Enter **350** kPa for P1.
9. **Uncheck** P2 to solve for it using Bernoulli’s equation.
10. Enter **120 °** for θ_2 .
11. Click **Update** to solve.



Linear Momentum

Select Case: a) Closed Section

Units: ☒ SI ☐ English

Fluid Properties

☒ Select Fluid: Water, 20 °C, $\rho = 998.37 \text{ kg/m}^3$

☐ Enter Properties

Geometry

☒ D1: 200 mm, D2: 87.5 mm

☐ A1: 314.16, A2: 60.13 cm²

Flow

☒ Vdot: 100 L/s

☐ Mdot: 99.84 kg/s

☐ V1: 3.18 m/s

☐ V2: 16.63 m/s

Gauge Pressure

☒ P1: 350 kPa

☐ P2: 217.00 kPa

Note: 1. Uncheck to use Bernoulli
2. P1 or P2 must be set

Inlet/Outlet Angles

θ_1 : 0.00 deg

θ_2 : 120 deg

Results

Rx: -12.80 kN, Ry: 2.57 kN

Update

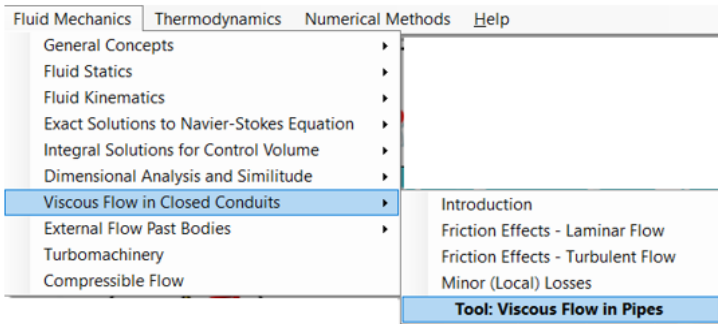
a) Closed Section

b) Jet Impingement

The resistance force components at -12.8 kN and 2.57 kN for the x and y directions, respectively.

Example – Hydraulic Turbine

Water is supplied to a hydraulic turbine at a flow rate of $150 \text{ ft}^3/\text{s}$ through a pipe with an inside diameter of 3.0 ft . The pressure at section (1) is 60 psig . The discharge diameter is 4.0 ft . The pressure at 10 ft below the turbine inlet at section (2) is 10 in. Hg vacuum . The head loss from section (1) to (2) is measured to be 17.7 ft , and the turbine has an overall efficiency of 85% . Calculate the power output that is supplied to the generator in horsepower.



- Select "Turbine Power" to solve for.

Solve For

☐ Pressure/DP
 ☐ Elevation/DZ
 ☐ Flow Rate
 ☐ Pump Power
 ☒ Turbine Power

- Leave material properties unchanged to select standard water.
- Select Volumetric Flow (Vdot) option and set it to $150 \text{ ft}^3/\text{s}$.

Flow Rate

☐ mdot
 ☐ Vdot

150

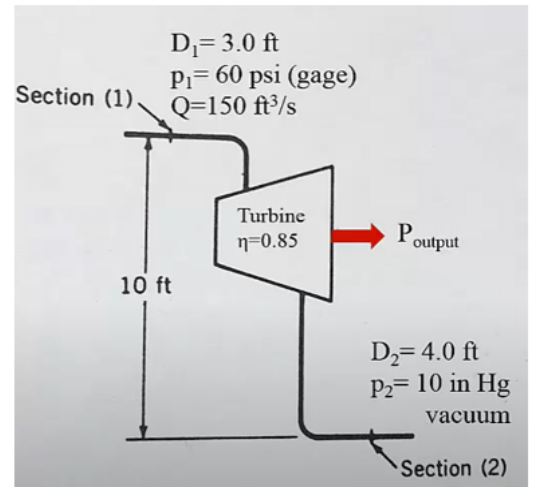
kg/s
 ft³/s

- Enter inlet / exit conditions:

Inlet / Exit Conditions

P1	60	psi	P2	-10	in-Hg
D1	3.0	ft	D2	4.0	ft
Z1	10	ft	Z2	0	ft

Note: The negative sign for P2 indicates vacuum pressure.



- Specify major and minor losses:

Since the total head loss is given click on “Specify hf” and enter 17.7 ft.

☒ Include Major Losses

cm m mm

No of Sections	Section No	Diameter	Length	Eps
	*			

Update

☒ Specify hf 17.7 ft

Uncheck “Include Minor Losses” checkbox to ignore minor losses.

- Include Turbine and set its efficiency to 85%. Leave turbine power blank to solve for it but change its unit to Hp to get the results in horsepower.

☒ Include Turbine

Power Output Hp

Efficiency 85 %

- Click “Update” to solve. The finished form is shown below.

Internal Flow - Energy

Solve For: ☐ Pressure/DP ☐ Elevation/DZ ☐ Flow Rate ☐ Pump Power ☒ Turbine Power

Fluid Properties: ☒ Select Fluid ☐ Enter Properties

Fluid Properties: Water, Pressure 1.000 atm, Temperature 20 C, ρ 998.37 kg/m³, μ 1.004E-03 Pa.s

Inlet / Exit Conditions: P1 60 psi, D1 3.0 ft, Z1 10 ft, P2 -10 in-Hg, D2 4.0 ft, Z2 0 ft

Flow Rate: ☐ mdot kg/s, ☒ Vdot 150 ft³/s

☐ Include Pump: Power Input W, Efficiency %

☒ Include Turbine: Power Output 2124.232 Hp, Efficiency 85 %

☒ Include Major Losses: cm m mm, No of Sections Update, Specify hf 17.7 ft

☐ Include Minor Losses: No of Devices Update, Specify hm m

Flow Heads: Pressure Head -1.499E02, Velocity Head -4.782E00, Elevation Head -1.000E01, Pump Head 0.000E00, Turbine Head 146.972, hf 17.700, hm 0.000E00

Change in Flow Energy: DP -4.475E02, DKE -1.428E01, DPE -2.985E01, Loss 52.838

Update

The turbine power is calculated to be 2,124.2 horsepower.

FM05-Internal Flows – Pipe System

This provides an automated environment for the analysis of pipe systems:

Internal Flow - Energy

Solve For
☒ Pressure/DP ☐ Elevation/DZ ☐ Flow Rate ☐ Pump Power ☐ Turbine Power

Fluid Properties
☒ Select Fluid ☐ Enter Properties
Water
Pressure: 1.000 atm
Temperature: 20 C
Fluid Properties:
 ρ : 998.37 kg/m³
 μ : 1.004E-03 Pa.s

Flow Rate
☒ mdot ☐ Vdot
kg/s
gpm

Inlet / Exit Conditions
P1: kPa
D1: cm
Z1: m
P2: kPa
D2: cm
Z2: m

Include Pump
Power Input: W
Efficiency: 100 %

Include Turbine
Power Output: W
Efficiency: 100 %

Include Major Losses
No of Sections:
Update
Specify hf: m

	Section No	Diameter	Length	Eps
*				

Include Minor Losses
No of Devices:
Update
Specify hm: m

	Device ID	Inlet Section ID	Minor Loss Coefficient, K
*			

Flow Heads
Pressure Head
Velocity Head
Elevation Head
Pump Head
Turbine Head
hf
hm

Change in Flow Energy
DP
DKE
DPE
Loss
kPa

Update

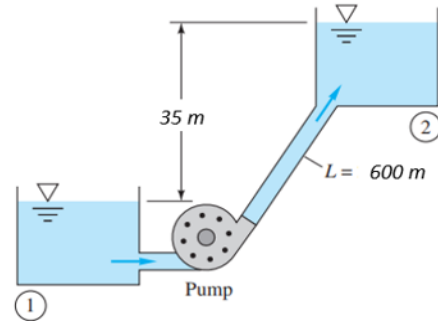
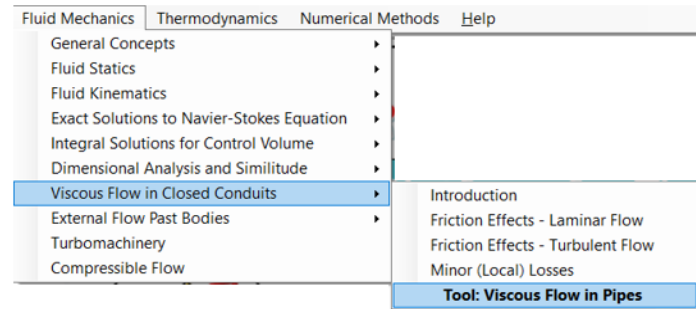
1. Select Analysis Type. Solving for the flow rate will engage the iterative solver.
2. Enter material properties either by selecting fluid or entering density and dynamic viscosity.
3. Enter the flow rate, either volumetric or mass flow rate.

Example – Internal Flows: Pipe system with Pump

Water at 20 °C is to be pumped through 600 m of pipe from reservoir (1) to (2) at a flow rate of 0.1 m³/s. Assuming a smooth pipe ($\epsilon/D = 0$) of diameter 15 cm and a pump efficiency of 75 percent:

- Calculate the head loss (h_{loss}) for this system.
- Estimate the electrical power required by the pump in kW.

Assume all minor (local) losses are negligible.



- Select "Pump Power" to solve for.

Solve For

☐ Pressure/DP ☐ Elevation/DZ ☐ Flow Rate ☒ Pump Power ☐ Turbine Power

- Leave material properties unchanged to select standard water.
- Select Volumetric Flow (Vdot) option and set it to 0.1 m³/s.

Flow Rate

☐ mdot kg/s

☒ Vdot 0.1 m³/s

- Enter inlet / exit conditions:

Inlet / Exit Conditions

P1	0	kPa	P2	0	kPa
D1	100	m	D2	100	m
Z1	0	ft	Z2	35	m

- Inlet and exit are open to atmosphere, so they are at 0 gage pressure.
 - Velocity at the inlet and exits are negligible; therefore, we can assign equal diameter to each.

- Specify major and minor losses:

☒ Include Major Losses

cm m mm

No of Sections: 1

Update

	Section No	Diameter	Length	Eps
▶	1	15	600	0
*				

☐ Specify hf 0 m

Uncheck "Include Minor Losses" checkbox to ignore minor losses.

- Include Pump and set its efficiency to 75%. Leave pump power blank to solve for it but change the requested unit to kW.

☒ **Include Pump**

Power Input kW

Efficiency %

- Click Update. The finished form is shown below.

Internal Flow - Energy

Solve For

☐ Pressure/DP
 ☐ Elevation/DZ
 ☐ Flow Rate
 ☒ Pump Power
 ☐ Turbine Power

Fluid Properties

☒ Select Fluid
 ☐ Enter Properties

Water

Pressure

1.000

atm

Temperature

20

C

Fluid Properties

ρ

998.37

kg/m3

μ

1.004E-03

Pa.s

Inlet / Exit Conditions

P1

0

kPa

P2

0

kPa

D1

100

m

D2

100

m

Z1

0

ft

Z2

35

m

Flow Rate

☐ mdot kg/s
 ☒ Vdot m3/s

☒ **Include Pump**

Power Input

147.624

kW

Efficiency

75

%

☐ **Include Turbine**

Power Output

kW

Efficiency

%

Include Major Losses

No of Sections

1

Update

	Section No	Diameter	Length	Eps
	1	15	600	0
	>>			

☐ Specify hf m

☐ **Include Minor Losses**

No of Devices

Update

	Device ID	Inlet Section ID	Minor Loss Coefficient, K
	*		

☐ Specify hm m

Flow Heads

Pressure Head

0.000E00

Velocity Head

0.000E00

Elevation Head

35.000

Pump Head

113.046

Turbine Head

0.000E00

hf

78.046

hm

0.000E00

Change in Flow Energy

DP

0.000E00

DKE

0.000E00

DPE

342.790

Loss

764.388

Update

The required pump power is 147.6 kW.

AutoTherm

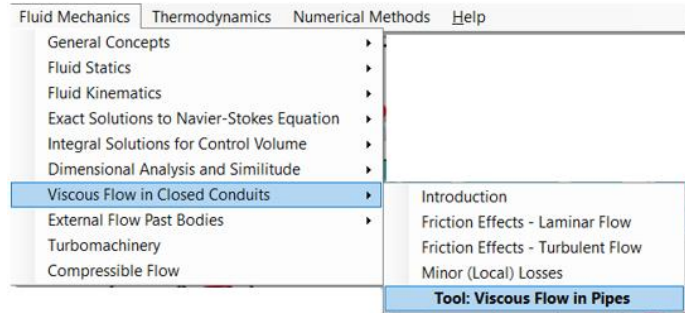
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Example – Internal Flows: Pipe system with Pump

Water at 60 °F flows from the basement to the second floor through a 0.75-inch-diameter copper pipe (drawn tubing) at a rate of $Q = 12.0$ gal/min and exits through a 0.5-inch-diameter faucet, as shown in the figure.

Determine the pressure at point (1) if:

- (a) Viscous effects are neglected,
- (b) The only losses included are major losses, or
- (c) All losses are included.



- Select “Pressure” to solve for.

Solve For

☒ Pressure/DP ☐ Elevation/DZ ☐ Flow Rate ☐ Pump Power ☐ Turbine Power

- Material Properties.

Fluid Properties ☒ Select Fluid ☐ Enter Properties

Water

Pressure: 1.000 atm ρ 1.939 slug/ft³ ②

Temperature: 60 F ① μ 2.334E-05 lb.s/ft² ③

Update ④

1. Change Temperature to 60 °F.
2. Change density unit to slug/ft³ (for display only)
3. Change viscosity unit to lb.s/ft²
4. Click Update

Finished panel shown.

Note: changing the units has no impact on calculations.

- Select Volumetric Flow (Vdot) option and set it to 12 gal/min (gpm).

Flow Rate

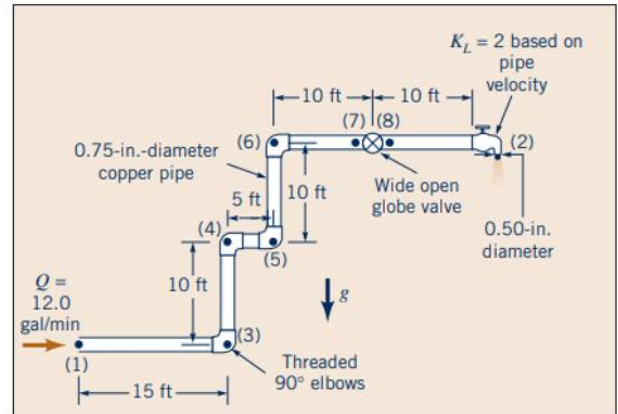
☐ mdot ☐ Vdot 12 gpm

- Enter inlet / exit conditions:

Inlet / Exit Conditions

P1		psi	①	P2	0	psi	②
D1	0.75	in	③	D2	0.5	in	④
Z1	0	ft	⑤	Z2	20	ft	⑥

1. Leave P_1 blank (to solve for) but change unit to psi.
 2. Change P_2 to 0 psi (open to atmosphere).
 3. Set D_1 to 0.75 in.
 4. Set D_2 to 0.5 in.
 5. Set Z_1 to 0 ft.
 6. Set Z_2 to 20 ft ($L_2 + L_4$).
- Finished panel shown.



FM06-Forces Acting on a Moving Vehicle

This tool provides an environment for modeling a moving vehicle (e.g., a car, truck, or train) on a track to determine the forces involved and the power required to maintain constant velocity. The tool allows the user to consider the effects of 1) headwind (positive toward the vehicle, negative from behind), 2) road grade, 3) rolling resistance, and 4) aerodynamic drag force.

Forces on a Moving Vehicle

Fluid Properties

☒ Select Fluid

☐ Enter Properties

Air

Pressure

1.000

atm

Temperature

20

C

Fluid Properties

ρ

1.225

kg/m3

μ

0.0182E-03

Pa.s

Input

Velocity

mile/h

Incline

0.00

% Grade

Head Wind

0.00

mile/h

Af

m^2

Mass

kg

CD

0.00

Rolling Resistance

☒ Specified

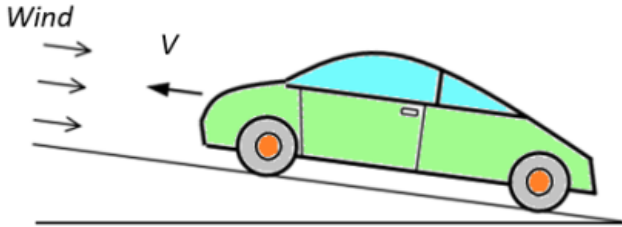
☐ Calculate using velocity and tire pressure

Tire Pressure

psi

Wind

V



Drag Force

Rolling Resistance

Gravitational Force

kN

Power

W

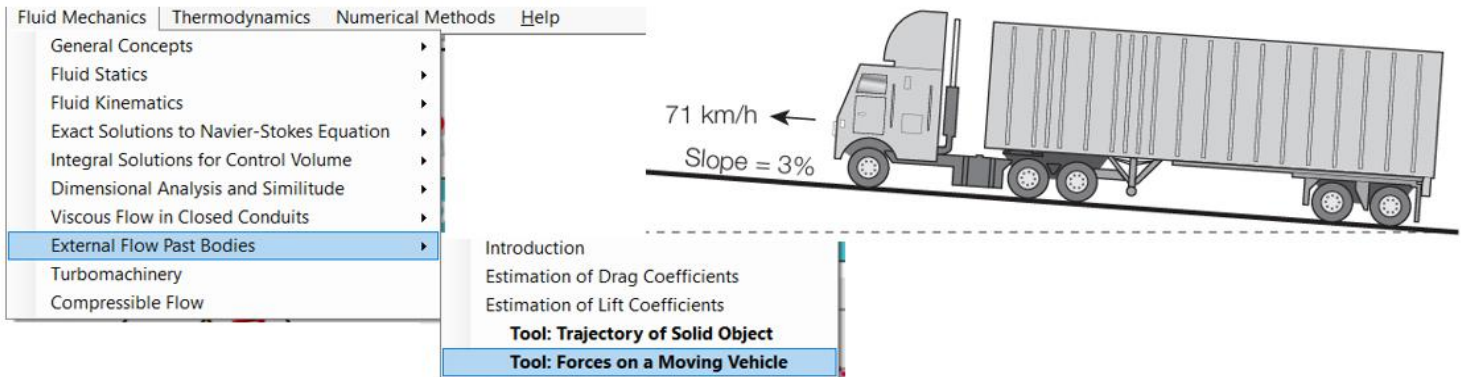
Update

Example – External Flows: Tractor-Trailer Driving Uphill (Source: Chen – Problem 10.46)

The fully loaded tractor-trailer shown below drives up a 3% incline at a steady speed of 71 km/h. The tractor-trailer has a frontal area of 2.60 m wide by 4.10 m high and is powered by a 373-kW engine. The total mass of the tractor-trailer and its payload is approximately equal to the legal limit of 36,750 kg. It is estimated that the rolling resistance coefficient is 0.008 and the drag coefficient is 0.50. What power must be supplied by the engine to overcome the resistance to motion caused by the weight, rolling resistance, and aerodynamic drag?

1. What percentage of the rated engine power is required to overcome these effects?
2. What is the maximum velocity on a 6% incline?

Assume standard air.



Enter input data

1. Air Properties

- Accept defaults for standard air.

Fluid Properties			
☒ Select Fluid		☐ Enter Properties	
Air		Fluid Properties	
Pressure	1.000 atm	ρ	1.225 kg/m ³
Temperature	20 C	μ	0.0182E-03 Pa.s

2. Enter Data

Input				
Enter Velocity 71 km/hr.	Velocity	71 km/h	Incline	3 % Grade
No head wind specified	Head Wind	0.00 mile/h	Af	10.66 m ²
Mass = 35,675 kg	Mass	35675 kg	CD	0.5
Cr = 0.008	Rolling Resistance			
	☒ Specified			☐ Calculate using velocity and tire pressure
			Tire Pressure	psi

Enter 3% grade

Enter Frontal Area
 $2.6 \text{ m} \times 4.1 \text{ m} = 10.66 \text{ m}^2$

Drag coefficient = 0.5

Click Update to solve.

Forces on a Moving Vehicle

Fluid Properties

☒ Select Fluid ☐ Enter Properties

Fluid Properties

Pressure: 1.000 atm ρ : 1.225 kg/m³

Temperature: 20 C μ : 0.0182E-03 Pa.s

Input

Velocity: 71 km/h Incline: 3 % Grade

Head Wind: 0.00 mile/h A_f : 10.66 m²

Mass: 35675 kg C_D : 0.5

Rolling Resistance

☒ Specified ☐ Calculate using velocity and tire pressure

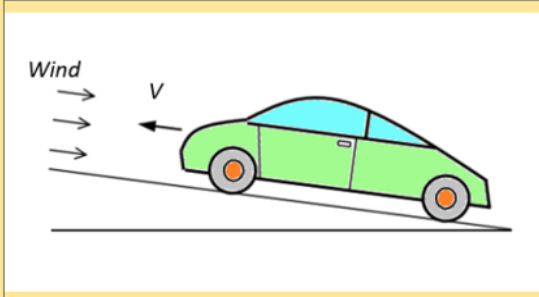
0.008 Tire Pressure: psi

Results

Drag Force: 1.270 Rolling Resistance: 2.799 Gravitational Force: 10.494 kN

Power: 287.210 kW

Update



The required engine power for maintain 71 km/h for current conditions is 287.2 kW, which is roughly 77% of the rated engine power.

b) Change the grade to 6% and rerun:

Forces on a Moving Vehicle

Fluid Properties

☒ Select Fluid ☐ Enter Properties

Fluid Properties

Pressure: 1.000 atm ρ : 1.225 kg/m³

Temperature: 20 C μ : 0.0182E-03 Pa.s

Input

Velocity: 71 km/h Incline: 6 % Grade

Head Wind: 0.00 mile/h A_f : 10.66 m²

Mass: 35675 kg C_D : 0.5

Rolling Resistance

☒ Specified ☐ Calculate using velocity and tire pressure

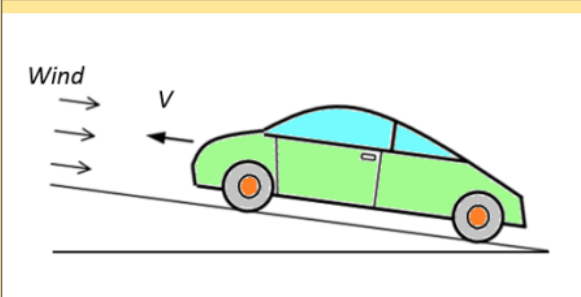
0.008 Tire Pressure: psi

Results

Drag Force: 1.270 Rolling Resistance: 2.795 Gravitational Force: 20.961 kN

Power: 493.552 kW

Update



The power requirement has increased to 493.6 kW, which exceeds the rated power of 350 kW.

Reducing the speed to 55 kg/h will reduce the power requirement to just below 350 kW.

FM07-Trajectory of a Solid Object

This tool provides an environment for modeling the trajectory of an object under three scenarios: 1) no air resistance (drag force) or simple Newtonian trajectory, 2) including air resistance and an opposing drag force changing proportional to the square of the object's instantaneous velocity, and 3) including additional aerodynamic force due to headwind or backwind.

Fluids _ External Flow

Input

V

m/s

g

9.81

m/s²

θ

0.00

deg

y_0

0.00

m

☐ Include air resistance

C_D

0.00

m

kg

ρ

1.225

kg/m³

A_f

m²

V_{air}

0.00

m/s

Results

Please Enter Value for Time, x_t , or y_t

☒ t

s

☐ x_t

m

☐ y_t

m

V_t

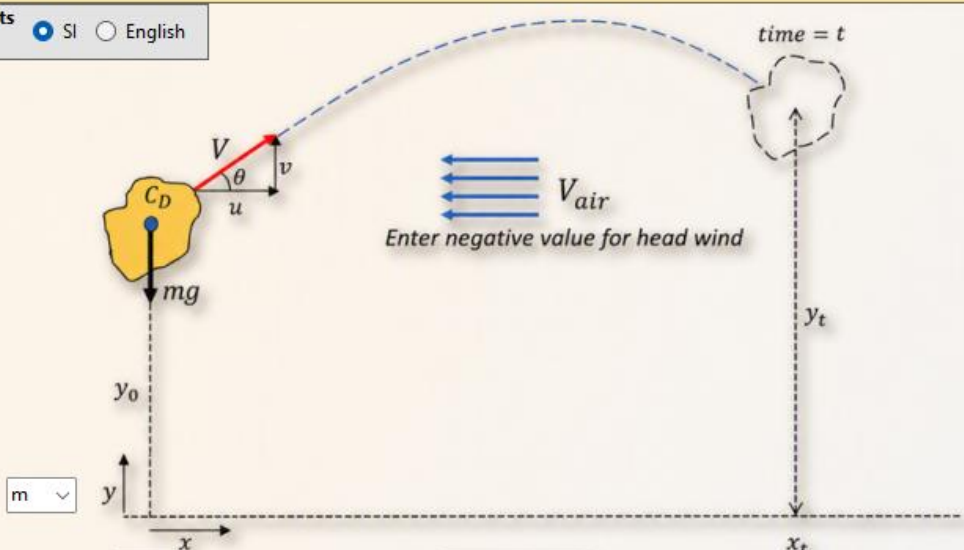
m/s

θ_t

deg

Units

☒ SI ☐ English



LEGEND

V

=

Initial Velocity

F

=

Thrust Force

m

=

Mass

C_D

=

Drag Coefficient

θ

=

Trajectory Angle

g

=

Gravitational Acceleration

V_{air}

=

Air Velocity (Enter negative value for head wind)

u

=

Horizontal Component of Initial Velocity ($u = V \cos \theta$)

v

=

Vertical Component of Initial Velocity ($v = V \sin \theta$)

x, y

=

Horizontal and Vertical Positions

(x_0, y_0)

=

Initial Launch Position

(x_t, y_t)

=

Position at Time t

Solve

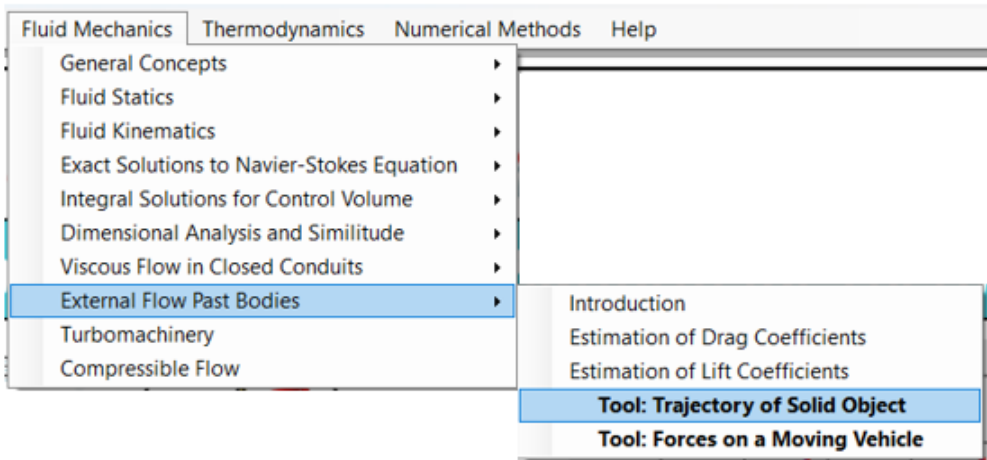
 AutoTherm

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Example: A baseball player throws a ball at a speed of 102 miles/hour with a trajectory angle of 30 degrees, released from his shoulder height of 5 ft, in a flat field. Determine the distance (in feet) and the time (in seconds) the ball will travel until it hits the ground for the following conditions:

1. No air resistance
2. Still air
3. Head wind of 10 miles/hour.

Assume a baseball has a diameter of 2.9 inches and weighs 5 ounces, with a drag coefficient of 0.3.



a) Neglect air resistance

- Enter 102 miles/h for velocity → mile/h
- Enter 30 ° for the angle → deg
- Enter 5 ft for the initial height → ft
- Do not include air resistance → ☐ Include air resistance

CD

m kg

ρ kg/m3

Af m^2

Vair m/s

- Change requested units to ft
- Enter 0 for the final height.
- Click Solve

Results

Please Enter Value for Time, X_t , or Y_t

☐ t

 s

☐ X_t

 ft

☒ Y_t

 ft

V_t

 m/s

θ_t

 deg

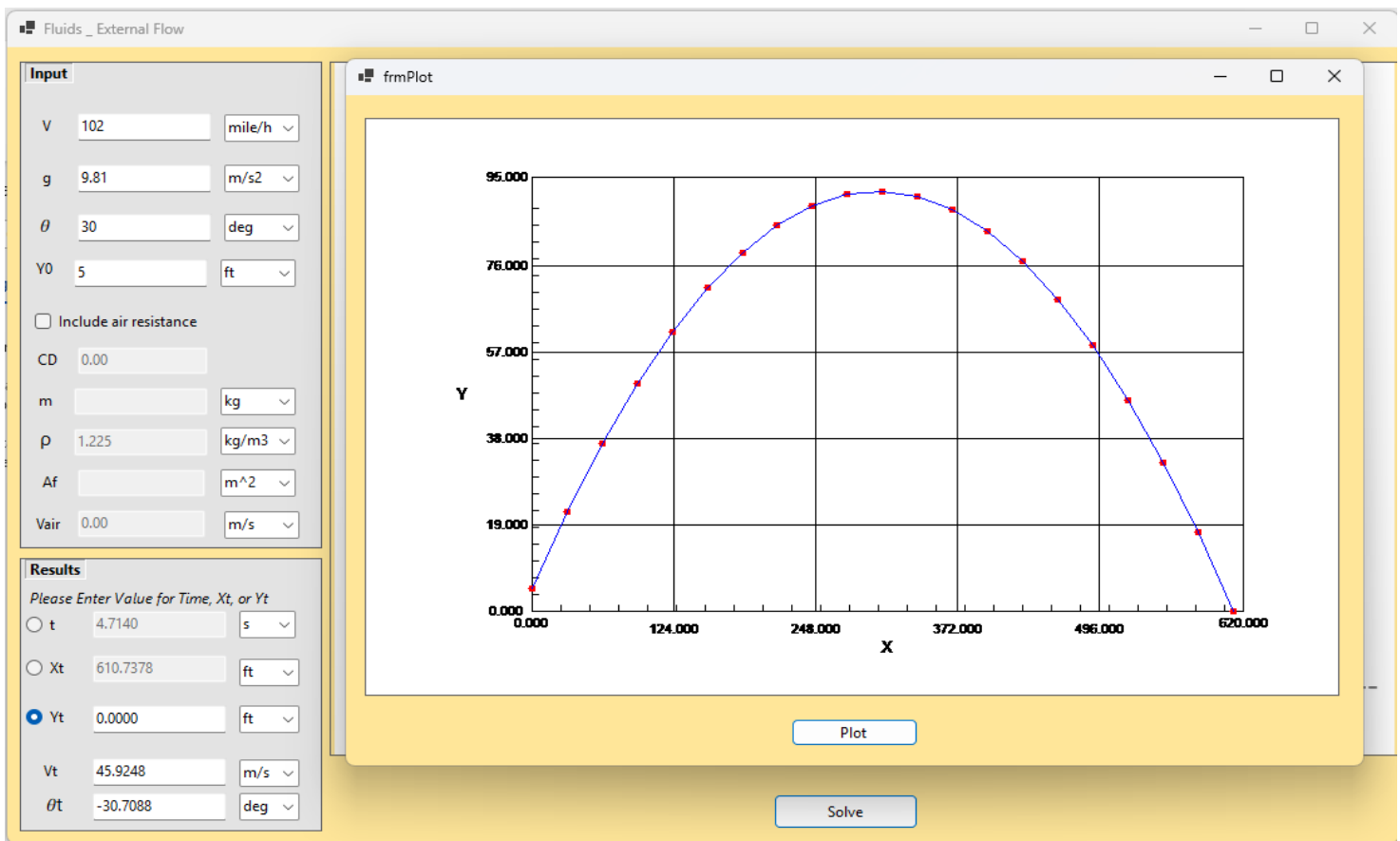
ft

y

x

ft

Solve



- The distance traveled to hit the ground ($y=0$) is 610.7 ft.
- The ball is predicted to be in the air for 4.7 sec.
- The plot shows a symmetric flight path with no air resistance.

b) Include air resistance (Still Air)

- Turn ON the air resistance.
- Enter 0.3 for Drag Coefficient.
- Enter 5 oz for.
- Keep air density for Standard Air.
- Enter frontal area value*.
- Enter 0 for air velocity (still air).

☒ Include air resistance

CD 0.3

m 5 oz

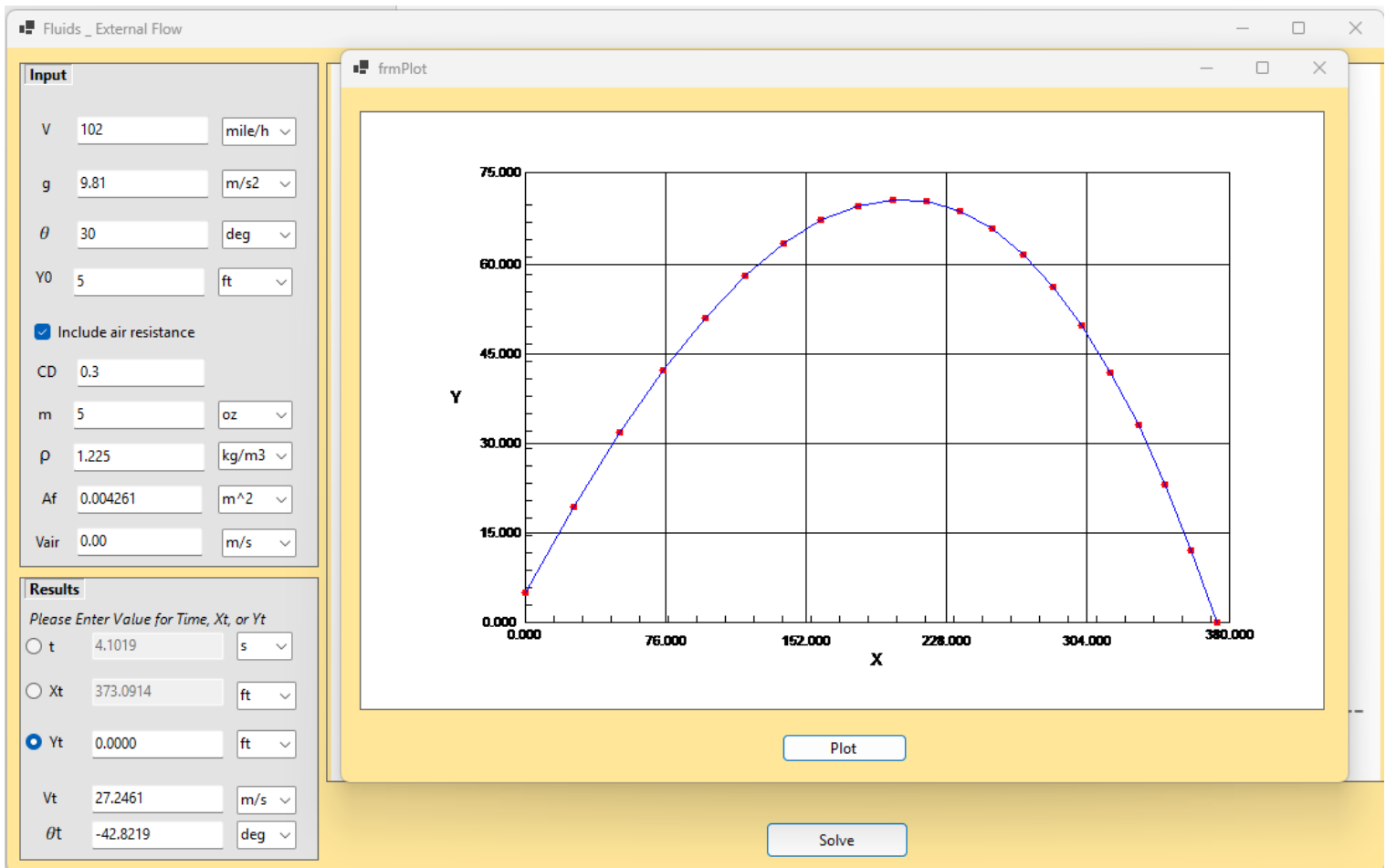
ρ 1.225 kg/m³

Af 0.004261 m²

Vair 0.00 m/s

* Note: the frontal area corresponds to the value for a sphere with 2.9 in diameter (1.45 in radius). The Math Tool: "3D Shapes" may be used for this.

- Click Solve



- The distance traveled to hit the ground ($y=0$) is 373.1 ft.
- The ball is predicted to be in the air for 4.1 sec.
- The plot shows a nonsymmetric flight path with air resistance.

c) Include air resistance (headwind -20 mph)

- Turn ON the air resistance.
- Keep all entries unchanged, except enter -20 mile/h for the air velocity

☒ Include air resistance

CD: 0.3

m: 5 oz

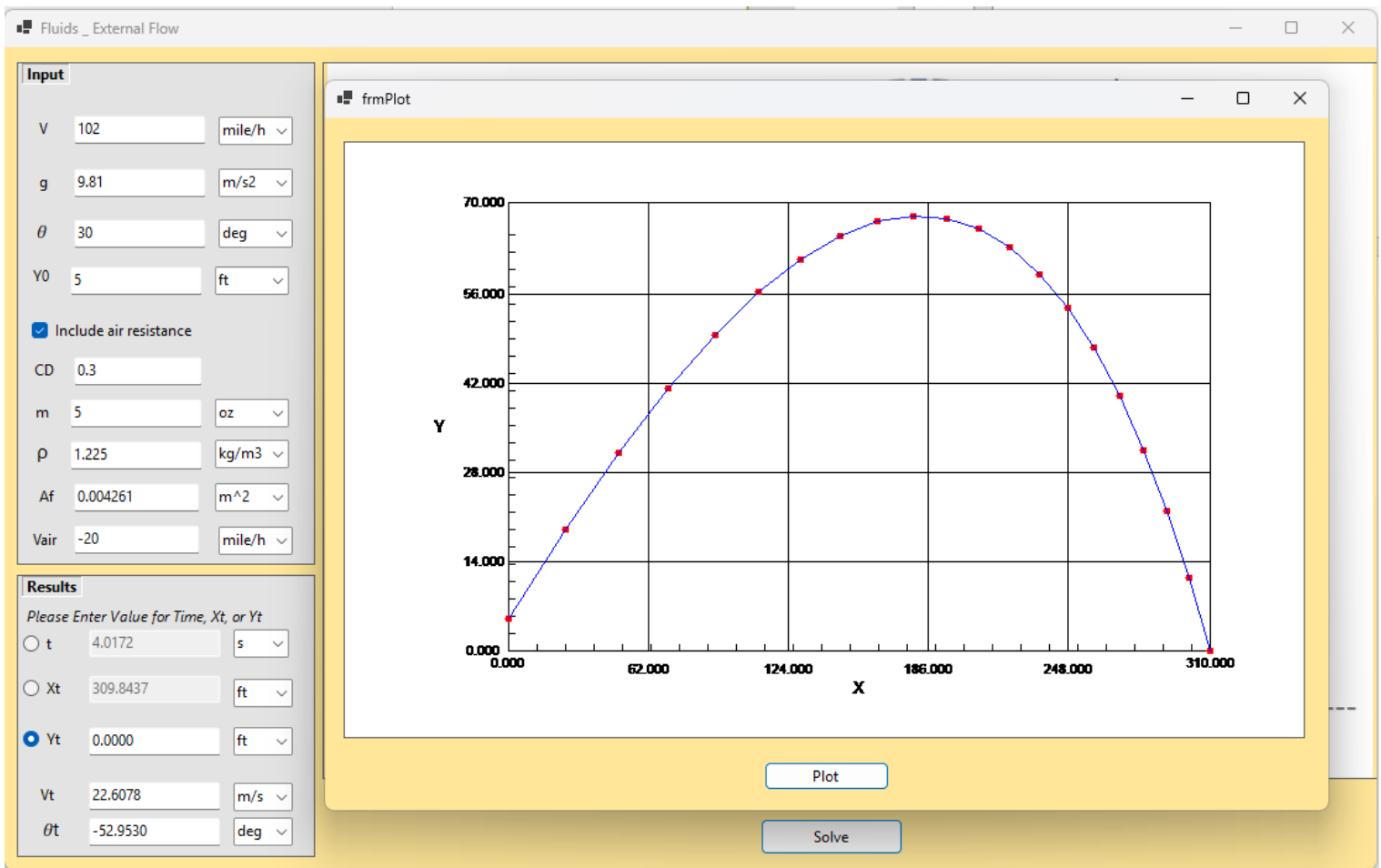
ρ : 1.225 kg/m³

Af: 0.004261 m²

Vair: -20 mile/h

* Note: The velocity must be negative to indicate headwind.

- Click Solve



- The distance traveled to hit the ground ($y=0$) is 309.8 ft.
- The ball is predicted to be in the air for 4.02 sec.
- The plot shows a nonsymmetric flight path with air resistance.