Motion in one and two dimensions slide deck

Physics 20

Unit A: Motion in one and two dimensions

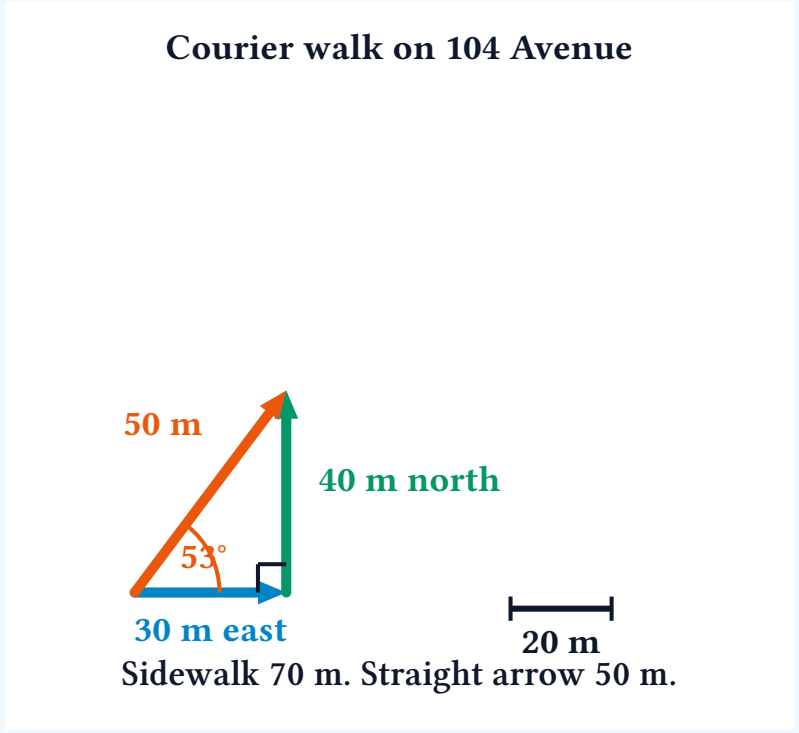
Scalars and vectors

A courier finishes 50 m from the start

- A courier in Edmonton walks 30 m east on 104 Avenue and then 40 m north to a warehouse door.
- The sidewalk path adds to 70 m, while the straight position change is 50 m north of east.

Magnitude and direction

- Pick a doorway as the start. Distance is how far the feet walked. Position is where you are from that doorway.
- A scalar is finished when you write the number and the unit. A vector still needs a direction, such as north of east.
- Displacement is written delta d. It means where you finished minus where you started, with a direction.



Key terms

position

Position is the location of an object relative to a chosen origin, stated with a distance and a direction. (d)

distance

Distance is the length of the path actually travelled, recorded as a magnitude and a unit.

displacement

Displacement is the straight change from the initial position to the final position, with direction included. (delta d)

scalar

A scalar is a quantity fully described by a magnitude and a unit.

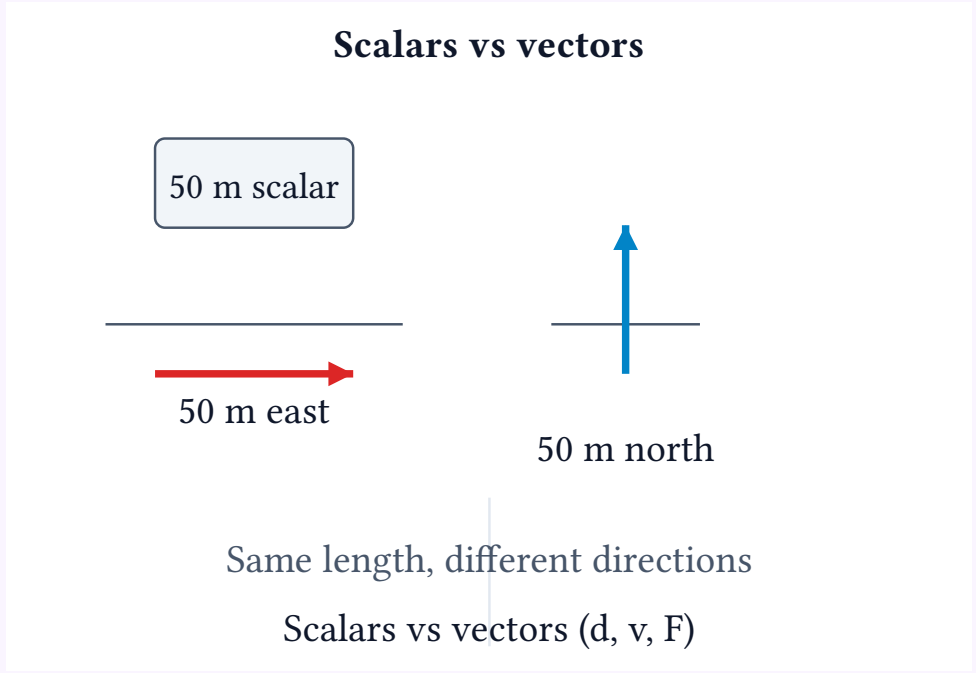
Key terms

vector

A vector is a quantity described by a magnitude, a unit, and a direction.

Scalars and vectors

- Distance, time, and speed are scalars. A number and a unit finish each one.
- Displacement, velocity, acceleration, and force each need a direction beside the number.
- Two 50 m arrows can point different ways. Same length, different vectors.



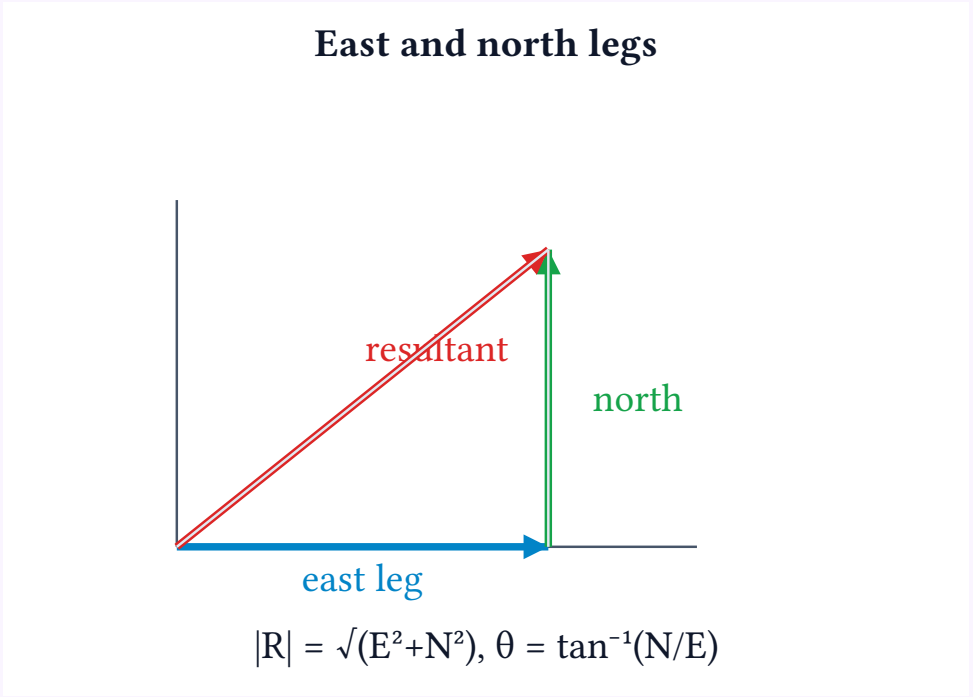
Scalars vs vectors (d, v, F)

A return to the doorway

- The courier later walks back to the original doorway along a 90 m route.
- Distance for the whole outing includes every metre of sidewalk.
- Displacement for the whole outing is 0 m because the final position matches the initial position.

East and north legs make one arrow

- Write the east leg and the north leg first. They stand in for the single arrow.
- Square each leg, add the squares, and take the square root. That length is the straight arrow.
- The angle is the tan inverse of the north leg divided by the east leg.



A drone’s two legs

- A survey drone flies 120 m west and then 50 m south.
- Find the distance and the displacement from the launch pad.
- Give the direction as an angle south of west.

Path and arrow

- A student walks 8.0 m north along a hallway and then 6.0 m east into a lab.
- State the distance and the displacement with direction.
- Name which result is a scalar and which result is a vector.

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Velocity and acceleration graphs

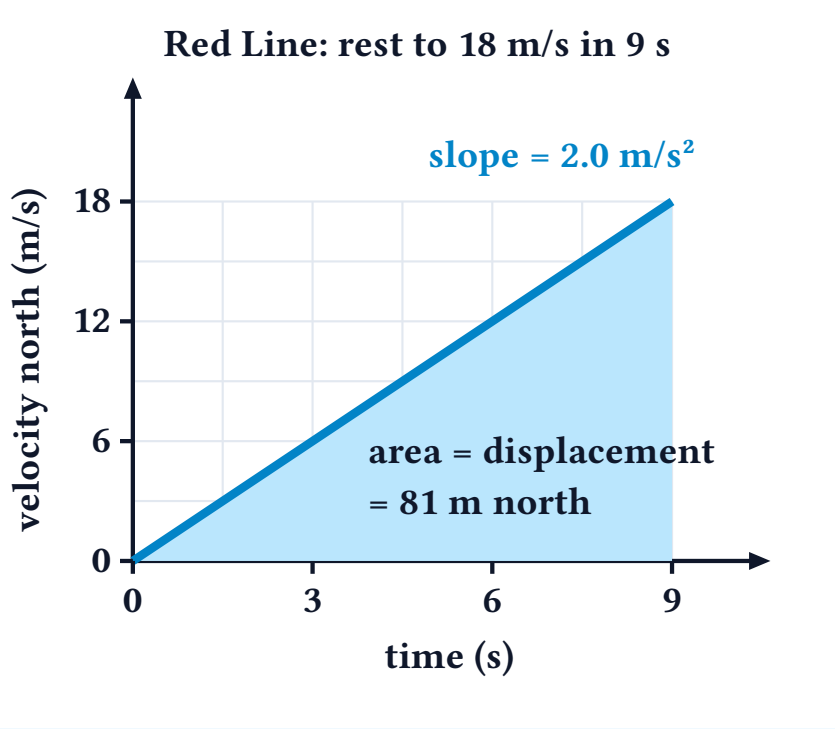
An LRT departure

- A Calgary CTrain on the Red Line leaves Somerset-Bridlewood from rest and reaches 18.0 m/s north in 9.00 s.
- Average velocity uses displacement over elapsed time, and acceleration uses the velocity change over elapsed time.



Rates and graphs

- Delta means final minus initial.
- Velocity v equals delta d divided by delta t. Here d is position and t is time.
- Acceleration a equals delta v divided by delta t.
- Uniform motion keeps the same velocity. Uniformly accelerated motion keeps the same acceleration.



Key terms

velocity

Velocity is displacement divided by elapsed time, and the statement includes the direction of the motion. (v = delta d / delta t)

acceleration

Acceleration is the change in velocity divided by elapsed time, and the statement includes direction. (a = delta v / delta t)

uniform motion

Uniform motion is motion at constant velocity, so equal displacements occur in equal time intervals.

uniformly accelerated motion

Uniformly accelerated motion is motion at constant acceleration, so velocity changes by equal amounts in equal times.

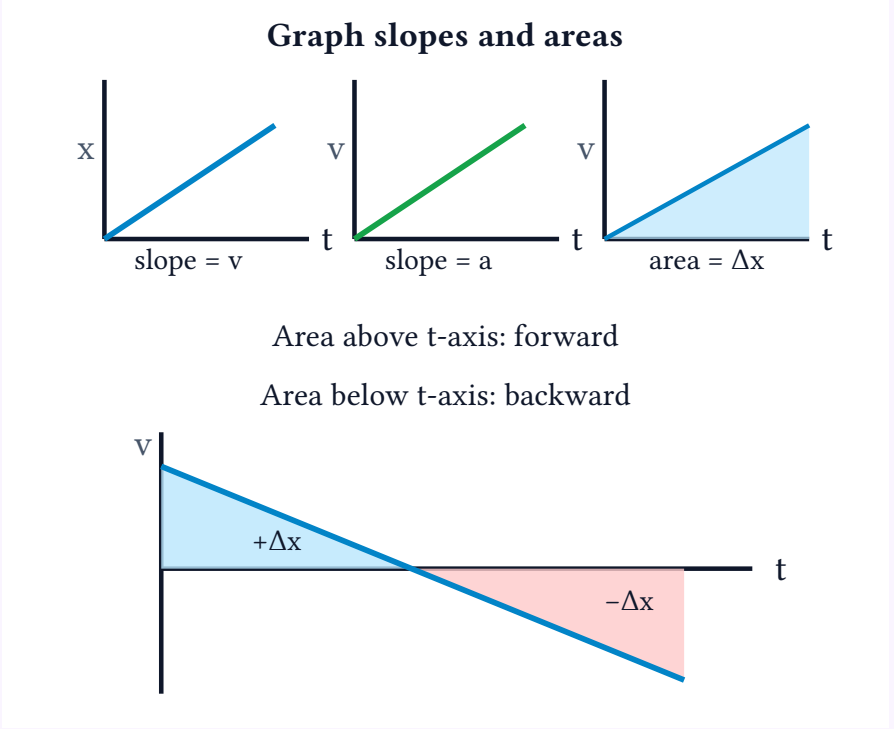
Key terms

delta notation

Delta notation writes a change as the final value of a quantity minus its initial value. $\Delta v = v_{final} - v_{initial} = 18.0\frac{m}{s} - 0\frac{m}{s} = 18.0\frac{m}{s}$. (Δ)

Slope and area of graphs

- The slope of a position time graph is the velocity.
- The slope of a velocity time graph is the acceleration.
- The area under the velocity time line equals the displacement. Area above the time axis is forward. Area below it is backward.

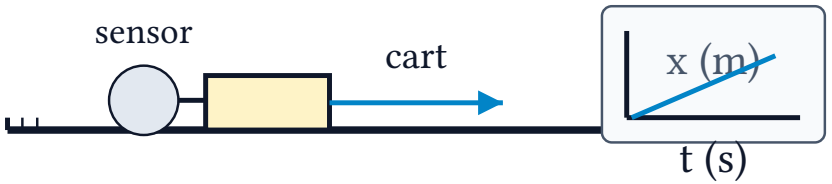


Three equations for constant acceleration

- From rest, $v = 0 + (2.0\ m/s^2)(9.00\ s) = 18\ m/s$ north.
- Displacement is $(1/2)(2.0\ m/s^2)(9.00\ s)^2 = 81\ m$ north.
- Check: $v^2 = 0 + 2(2.0\ m/s^2)(81\ m) = (18\ m/s)^2$.

Cart lab plan

- The lab question is: how do displacement, velocity, acceleration, and time connect for one cart?
- A motion sensor records position together with the clock time.
- Write metres and seconds, keep the digits the timer supports, and write each change as final minus initial.



Cart and motion sensor

Record x and t; use Δ = final − initial

A sensor record of a slowing cart

- The motion sensor shows a cart at 6.00 m/s east, then at 2.00 m/s east after 4.00 s.
- Find the acceleration and the displacement during that interval.
- State the acceleration direction relative to the chosen positive direction.

Formula and graph area

- A lab cart starts from rest and accelerates at 0.800 m/s^2 west for 5.00 s.
- Find the final velocity and the displacement.
- The triangle under the velocity time line has an area equal to the displacement.

Image credits

Bernard Spragg, Calgary Lightrail. C Train, CC0 1.0

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Unit A: Motion in one and two dimensions

Relative motion and projectiles

A kayak pointed north on the Bow

- A kayak near Prince’s Island points north at 2.00 m/s relative to the water while the Bow River current is 1.50 m/s east.
- The shore sees both of those velocities at once, so the two arrows add as vectors.

Projectile components

- The kayak's velocity past the shore equals its velocity through the water plus the water's velocity past the shore.
- A component is the part of the velocity along east or along north.
- Measure the angle from the axis you named, and keep it under 90 degrees.
- Projectile motion keeps a steady horizontal component and a vertical component with acceleration 9.81 m/s^2 downward.

Key terms

relative velocity

Relative velocity is the velocity of one object measured by an observer who may also be moving. In v_AC, A is the object and C is the observer. (v_AC = v_AB + v_BC)

component

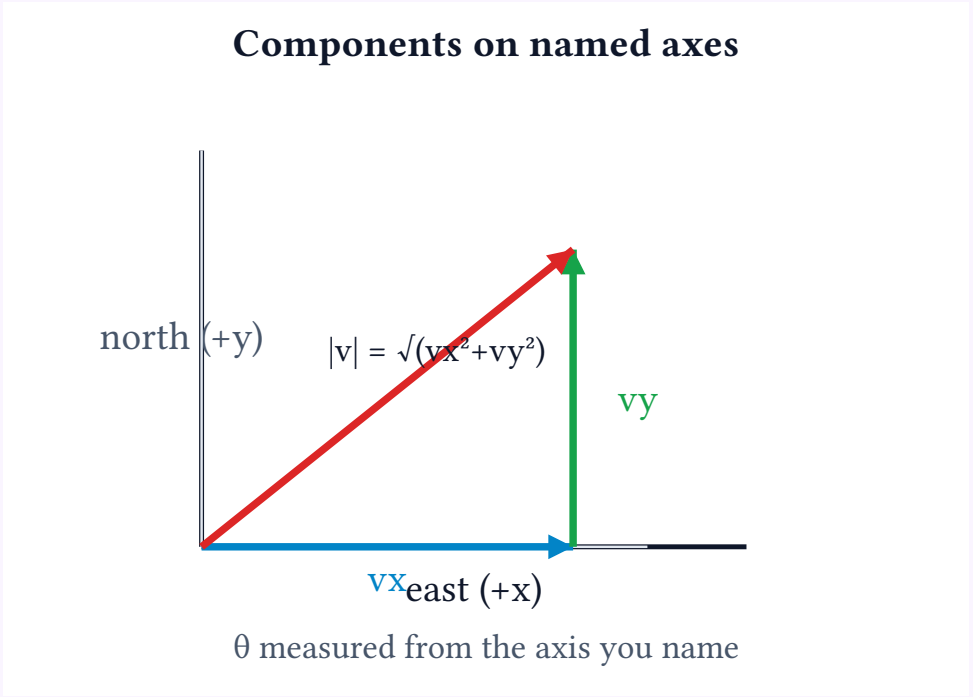
A component is the signed part of a vector along one named axis, such as north or horizontal.

projectile motion

Projectile motion near Earth splits into a steady horizontal velocity and a vertical motion with acceleration 9.81 m/s² downward.

Components along named axes

- Place each velocity on its own axis before you combine the arrows.
- The magnitude is the square root of the sum of the squared components.
- State the angle from the axis you named, such as 37 degrees east of north.



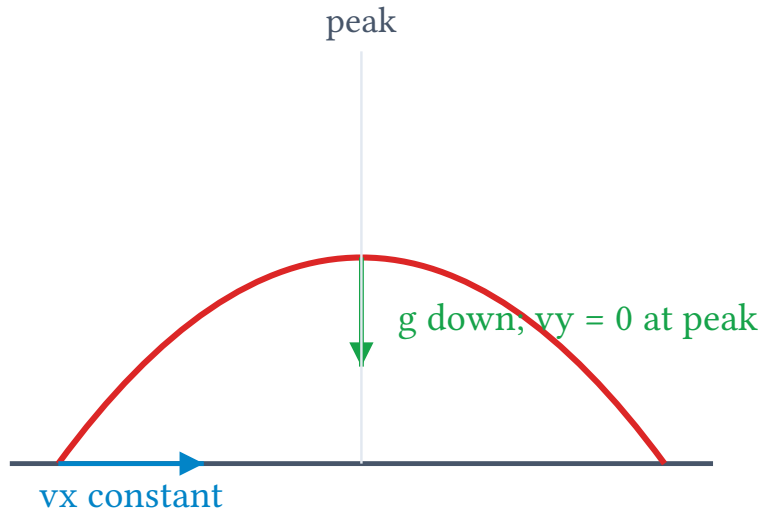
Shore velocity of the Bow kayak

- The kayak component relative to the water is 2.00 m/s north.
- The current component relative to the shore is 1.50 m/s east.
- The shore resultant is 2.50 m/s at 36.9 degrees east of north.

Horizontal rate and vertical free motion

- With air left out, the horizontal velocity stays the same for the whole flight.
- The vertical velocity changes steadily. g is 9.81 m/s squared downward.
- Time of flight comes from the vertical motion, and range is the horizontal velocity times that time.

Horizontal and vertical motion split



g = 9.81 m/s² down sets flight time; range = vx·t

A parcel from a loading dock

- A parcel is tossed horizontally at 5.00 m/s from a dock 1.77 m above the pavement.
- The vertical displacement determines the time of flight.
- The range is the horizontal velocity times that time.

A kick at forty degrees

- A football at McMahon is kicked at 16.0 m/s at 40 degrees above the horizontal.
- Upward is positive, so the vertical acceleration is $-9.81\ \text{m/s}^2$.
- Find the time of flight and the range.

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Kinematics in technology and free fall

A Bow pathway commute

- A rider covers 5.40 km along the Bow River pathway from Sunnyside to East Village in 20.0 min.
- Average speed is 5.40 km divided by 20.0 min. People who time a pathway or a bus route use that same division.

Speed and free fall

- Average speed uses total distance over elapsed time and stays a scalar.
- In a vacuum tube, a heavy object and a light object both speed up at 9.81 m/s squared downward.
- Builders test a runway length, a merge lane, or a traffic light time on paper before they pour concrete.

Key terms

average speed

Average speed is the total distance travelled divided by the elapsed time, reported as a magnitude with a unit. (speed = distance / time)

free fall

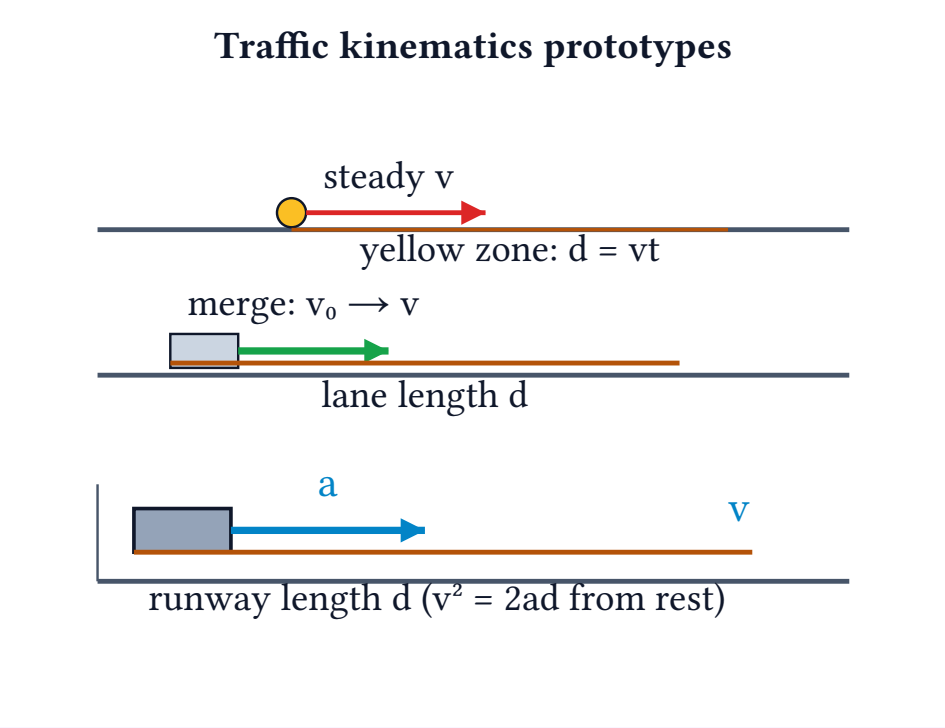
Free fall is motion under gravity alone in the vacuum model, with acceleration 9.81 m/s² downward near Earth.

prototype

A prototype is an early working version of a design, used to test whether the kinematics meet the plan.

Motion in traffic

- During the takeoff roll, the speed up connects the liftoff speed to how long that roll lasts.
- From rest, the runway length comes from v squared = 2 a d.
- Merging lane length and yellow light timing use the same kinematics with different knowns.



A 540 m prototype runway

- The trainer reaches 54.0 m/s from rest at 2.70 m/s².
- Runway length: (54.0 m/s)² / (2 × 2.70 m/s²) = 540 m.
- Roll time: 54.0 m/s / 2.70 m/s² = 20.0 s.

A shared lunar landing

- In vacuum a hammer and a feather share one free fall acceleration.
- The shared landing revised the older idea that a heavier object falls faster.
- People who design roads and runways use these same motion rules, and cart work stays inside a marked zone.



A vacuum tube in the classroom

- A steel nut and a feather drop from rest through 1.23 m in a vacuum tube.
- Free fall near Earth uses $g = 9.81\ \mathrm{m/s^2}$ downward for both objects.
- Both objects reach the bottom together.

A yellow light and a marked zone

- A prototype signal on Gateway Boulevard serves cars in uniform motion at 14.0 m/s.
- The intersection distance is 42.0 m.
- Find the yellow light time. If the cart setup differs from the approved procedure, stop and call the teacher.

Image credits

NASA, Apollo 15 F&H, public domain