

Straight-line motion with graphs and equations

AP Physics 1 (algebra-based) · Worksheet answers

Each answer shows the equation, the substitution and the result with its unit in bold. Compare your sign convention with the one used here before comparing numbers, because a different positive direction flips signs but not magnitudes. Rounded values follow the significant figures of the data.

Level: AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 1

Problem 1 Distance and displacement

1. Distance = $40 + 25 = \mathbf{65\text{ m}}$.
2. $\Delta x = +40 - 25 = \mathbf{+15\text{ m}}$, that is 15 m east.
3. Average speed = $65 / 50 = \mathbf{1.3\text{ m/s}}$. Average velocity = $+15 / 50 = \mathbf{+0.30\text{ m/s}}$ (east).

Problem 2 Scalar or vector

Scalars (no direction): **distance, speed, time**.

Vectors (direction needed): **displacement, velocity, acceleration**.

In one dimension the sign of a vector tells its direction relative to the chosen positive direction: a negative value points the opposite way.

Problem 3 Train between two stations

1. $\Delta x = 14.0 - 2.0 = 12.0\text{ km} = \mathbf{12\ 000\text{ m}}$.
2. $8.0\text{ min} = 8.0 \times 60 = \mathbf{480\text{ s}}$.
3. $v = 12\ 000 / 480 = \mathbf{25\text{ m/s}}$; $\times 3.6$ gives $\mathbf{90\text{ km/h}}$.

Problem 4 Motorbike pulling away

1. $a = \Delta v / \Delta t = (23 - 5.0) / 6.0 = \mathbf{3.0\text{ m/s}^2}$.
2. $v = 23 + 3.0 \times 4.0 = \mathbf{35\text{ m/s}}$.

Problem 5 Reading a position-time graph

1. Slope: 0-4 s: $8/4 = \mathbf{+2.0\text{ m/s}}$; 4-8 s: $\mathbf{0\text{ m/s}}$ (at rest); 8-14 s: $(-4 - 8)/6 = \mathbf{-2.0\text{ m/s}}$.
2. Distance = $8 + 0 + 12 = \mathbf{20\text{ m}}$; displacement = $-4 - 0 = \mathbf{-4\text{ m}}$.
3. Average velocity = $-4/14 = \mathbf{-0.29\text{ m/s}}$; average speed = $20/14 = \mathbf{1.4\text{ m/s}}$.

Problem 6 Reading a velocity-time graph

1. Stage 1: $8/2 = +4.0 \text{ m/s}^2$; stage 2: **0**; stage 3: $(-4 - 8)/4 = -3.0 \text{ m/s}^2$.
2. Area = $\frac{1}{2} \times 2 \times 8 + 4 \times 8 = 8 + 32 = \mathbf{40 \text{ m}}$.
3. From 8 m/s with -3.0 m/s^2 : $t = 6 + 8/3 = \mathbf{8.7 \text{ s}}$.
4. From 6 s to 8.67 s: $\frac{1}{2} \times 2.67 \times 8 = 10.7 \text{ m}$; from 8.67 s to 10 s: $\frac{1}{2} \times 1.33 \times (-4) = -2.7 \text{ m}$. Position = $40 + 10.7 - 2.7 = \mathbf{48 \text{ m}}$.

Problem 7 Skateboard on a ramp

1. $\Delta x = v_0 t + \frac{1}{2} a t^2$ with $v_0 = 0$: it contains Δx , t and a , and the unknown is a .
2. $a = 2\Delta x/t^2 = 2 \times 6.0 / 2.0^2 = \mathbf{3.0 \text{ m/s}^2}$.
3. $v = at = 3.0 \times 2.0 = \mathbf{6.0 \text{ m/s}}$.

Problem 8 Metro train braking

1. $v^2 = v_0^2 + 2a\Delta x$ gives $a = (8.0^2 - 20^2) / (2 \times 168) = (64 - 400)/336 = \mathbf{-1.0 \text{ m/s}^2}$.
2. $t = (v - v_0)/a = (8.0 - 20)/(-1.0) = \mathbf{12 \text{ s}}$.

Problem 9 Falling coconut

1. $t = \sqrt{2h/g} = \sqrt{24.0/9.81} = \sqrt{2.446} = \mathbf{1.56 \text{ s}}$.
2. $v = gt = 9.81 \times 1.564 = \mathbf{15.3 \text{ m/s}}$; or $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 12.0} = \sqrt{235.4} = \mathbf{15.3 \text{ m/s}}$.

Problem 10 Velocity table of a thrown ball

1. $v = 9.0 - 9.81t$: **+4.1 m/s** (0.50 s), **-0.81 m/s** (1.00 s), **-5.7 m/s** (1.50 s), **-10.6 m/s** (2.00 s).
2. $v = 0$: $t = 9.0/9.81 = \mathbf{0.92 \text{ s}}$.
3. $h = v_0^2/(2g) = 81/19.62 = \mathbf{4.1 \text{ m}}$.

Problem 11 Signs of velocity and acceleration

1. Same signs: **speeding up**, moving right.
2. Opposite signs: **slowing down**, moving right.
3. Same signs: **speeding up**, moving left.
4. Opposite signs: **slowing down**, moving left.

Problem 12 Matatu sprint

1. $108 / 3.6 = \mathbf{30 \text{ m/s}}$.
2. $a = 30 / 7.5 = \mathbf{4.0 \text{ m/s}^2}$.
3. $\Delta x = \frac{1}{2}(v_0 + v)t = \frac{1}{2} \times 30 \times 7.5 = 112.5 \text{ m} \approx \mathbf{1.1 \times 10^2 \text{ m}}$.

Problem 13 Spot the sign error

1. She chose down as positive but then used the sign for an upward-positive axis. The acceleration points down, which is the positive direction she chose.
2. $a = +9.81 \text{ m/s}^2$, so $v = 0 + 9.81 \times 2.0 = +19.6 \text{ m/s}$, which means 19.6 m/s downward.

Problem 14 Scooter journey

1. $v = 1.5 \times 8.0 = 12 \text{ m/s}$.
2. Stage 1: $\frac{1}{2} \times 1.5 \times 8.0^2 = 48 \text{ m}$. Stage 2: $12 \times 20.0 = 240 \text{ m}$. Stage 3: $\frac{1}{2} \times 12 \times 5.0 = 30 \text{ m}$. Total = **318 m**.
3. $a = (0 - 12)/5.0 = -2.4 \text{ m/s}^2$. Total time = $8.0 + 20.0 + 5.0 = 33 \text{ s}$, so average velocity = $318/33 = 9.6 \text{ m/s}$.

Problem 15 Doubling the speed

1. $\Delta x = 15^2/(2 \times 5.0) = 22.5 \text{ m}$; $t = 15/5.0 = 3.0 \text{ s}$.
2. $\Delta x = 30^2/10 = 90 \text{ m}$; $t = 30/5.0 = 6.0 \text{ s}$.
3. With $v = 0$, Δx is proportional to v_0^2 , so doubling the speed gives four times the distance, while $t = v_0/a$ is proportional to v_0 , so the time only doubles.

Problem 16 Acceleration-time graph of a sled

1. Area gives Δv : $4.0 \times 5 = 20 \text{ m/s}$ at 5 s; no change until 8 s, so **20 m/s**; then $-2.0 \times 6 = -12$, so **8.0 m/s** at 14 s.
2. 0-5 s: $\frac{1}{2} \times 20 \times 5 = 50 \text{ m}$; 5-8 s: $20 \times 3 = 60 \text{ m}$; 8-14 s: $\frac{1}{2} \times (20 + 8.0) \times 6 = 84 \text{ m}$. Total = **194 m**.
3. A straight line rising from 0 to 20 m/s over 5 s, a flat line to 8 s, then a straight line falling to 8.0 m/s at 14 s.

Problem 17 Sandbag from a balloon

1. $v_0 = +4.0 \text{ m/s}$ (it keeps the balloon's velocity) and $a = -9.81 \text{ m/s}^2$.
2. $-60.0 = 4.0t - 4.905t^2$, so $4.905t^2 - 4.0t - 60.0 = 0$. $t = [4.0 + \sqrt{(16 + 4 \times 4.905 \times 60.0)}]/9.81 = (4.0 + 34.54)/9.81 = 3.93 \text{ s}$.
3. $v = 4.0 - 9.81 \times 3.93 = -34.5 \text{ m/s}$ (34.5 m/s downward). It rises $4.0^2/(2 \times 9.81) = 0.82 \text{ m}$ first, so the greatest height is **60.8 m**.

Problem 18 Design: acceleration of a cart

1. Release the cart from rest at the same start line each time. Measure the distance Δx from the start line to marks at several positions, and the time t for each with several repeats. Keep the ramp angle and the release point the same.
2. Plot Δx (vertical) against t^2 (horizontal). Since $\Delta x = \frac{1}{2}at^2$ with $v_0 = 0$, the graph is a straight line through the origin and **$a = 2 \times \text{slope}$** .
3. Time each distance at least three times and average, or use longer distances so the

reaction time of about 0.2 s is a smaller fraction of t.

Problem 19 Argument: acceleration at the top

1. Each 0.10 s step changes v by -0.98 m/s, so $a = -0.98/0.10 = -9.8$ m/s² for every pair.
2. The claim is wrong. The velocity passes through zero near $t = 1.22$ s, but it is changing at the same rate of -9.8 m/s² before, at and after that instant: it goes from $+0.23$ to -0.75 m/s in 0.10 s. Acceleration is the rate of change of velocity, not the velocity, so a ball momentarily at rest at the top still has **$a = 9.81$ m/s² downward**.

Problem 20 Sprinter split times

1. Section times: 1.85, 1.02, 0.93, 0.85, 0.82, 0.82 s, so $v = 5.4, 9.8, 10.8, 11.8, 12.2, 12.2$ m/s.
2. The last two sections have the same average velocity, so she reaches top speed about 12.2 m/s at roughly 40–50 m.
3. $v = 60/6.29 = 9.5$ m/s.
4. With a constant acceleration from rest, the first-section average would be 5.4 m/s, meaning $a = 2 \times 10/1.85^2 = 5.8$ m/s² and $v = 10.8$ m/s at 10 m. A constant a would then give the second section an average above 10.8 m/s, but only 9.8 m/s is measured, so the acceleration decreases.