

Equations of motion for constant acceleration

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet answers

Each answer lists the equation, the substitution and the result in bold. Use $g = 9.81 \text{ m/s}^2$. Small differences in the last digit are acceptable when your rounding differs. Compare your choice of equation as well as your numbers.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.4, IB A.1

Problem 1 Choose the equation

1. $s = ut + \frac{1}{2}at^2$.
2. $v^2 = u^2 + 2as$.
3. $s = \frac{1}{2}(u + v)t$.
4. $v = u + at$.

Problem 2 Tram departure

1. $v = u + at = 0 + 1.2 \times 15 = \mathbf{18 \text{ m/s}}$.
2. $18 \times 3.6 = \mathbf{64.8 \text{ km/h}}$.

Problem 3 Cyclist speeding up

1. $a = (10.0 - 4.0) \div 12 = \mathbf{0.50 \text{ m/s}^2}$.
2. $s = \frac{1}{2}(4.0 + 10.0) \times 12 = \mathbf{84 \text{ m}}$.

Problem 4 Falling mango

1. $t = \sqrt{(2s \div g)} = \sqrt{(10.0 \div 9.81)} = \mathbf{1.01 \text{ s}}$.
2. $v = gt = 9.81 \times 1.01 = \mathbf{9.9 \text{ m/s}}$.

Problem 5 Emergency stop

1. $90 \div 3.6 = \mathbf{25 \text{ m/s}}$.
2. $a = (0 - 25) \div 6.0 = \mathbf{-4.2 \text{ m/s}^2}$.
3. $s = \frac{1}{2} \times 25 \times 6.0 = \mathbf{75 \text{ m}}$.

Problem 6 Train journey graph

1. $a = 20 \div 10 = \mathbf{2.0 \text{ m/s}^2}$.
2. $\text{Area} = \frac{1}{2} \times 10 \times 20 + 20 \times 20 + \frac{1}{2} \times 5 \times 20 = 100 + 400 + 50 = \mathbf{550 \text{ m}}$.
3. $a = (0 - 20) \div 5 = \mathbf{-4.0 \text{ m/s}^2}$.

Problem 7 Stopping distance

1. $s = 20 \times 0.70 = \mathbf{14.0 \text{ m}}$.
2. $v^2 = u^2 + 2as$: $0 = 400 - 2 \times 6.5 \times s$, so $s = 400 \div 13 = \mathbf{30.8 \text{ m}}$.
3. $14.0 + 30.8 = \mathbf{44.8 \text{ m}}$.

Problem 8 Sprint start

1. $s = \frac{1}{2}at^2$, so $a = 2s \div t^2 = 20.0 \div 4.84 = \mathbf{4.13 \text{ m/s}^2}$.
2. $v = at = 4.13 \times 2.20 = \mathbf{9.09 \text{ m/s}}$.

Problem 9 Well depth

1. $s = \frac{1}{2}gt^2 = 0.5 \times 9.81 \times 2.4^2 = \mathbf{28.3 \text{ m}}$.
2. $v = gt = 9.81 \times 2.4 = \mathbf{23.5 \text{ m/s}}$.

Problem 10 Ball thrown down

1. $v^2 = u^2 + 2as = 25 + 2 \times 9.81 \times 12 = 260.4$, so $\mathbf{v = 16.1 \text{ m/s}}$.
2. $t = (v - u) \div g = (16.14 - 5.0) \div 9.81 = \mathbf{1.14 \text{ s}}$.

Problem 11 Tennis ball thrown up

1. $h = u^2 \div 2g = 324 \div 19.62 = \mathbf{16.5 \text{ m}}$.
2. $t = u \div g = 18 \div 9.81 = \mathbf{1.83 \text{ s}}$.
3. Total = $2 \times 1.835 = \mathbf{3.67 \text{ s}}$.

Problem 12 Ruler reaction test

1. $18.0 \text{ cm} = \mathbf{0.180 \text{ m}}$.
2. $t = \sqrt{(2s \div g)} = \sqrt{(0.360 \div 9.81)} = \sqrt{0.03670} = \mathbf{0.192 \text{ s}}$.

Problem 13 Lift motion

1. $a = 3.0 \div 2.5 = \mathbf{1.2 \text{ m/s}^2}$.
2. Area = $\frac{1}{2} \times 2.5 \times 3.0 + 6.0 \times 3.0 + \frac{1}{2} \times 2.5 \times 3.0 = 3.75 + 18.0 + 3.75 = \mathbf{25.5 \text{ m}}$.
3. Time = 11 s, so average speed = $25.5 \div 11 = \mathbf{2.3 \text{ m/s}}$.

Problem 14 Spot the sign error

1. She used a positive acceleration while taking up as positive. The acceleration is downwards, so $a = -9.81 \text{ m/s}^2$. **The sign of a is wrong.**
2. $v = 10 - 9.81 \times 0.50 = \mathbf{5.1 \text{ m/s upwards}}$.

Problem 15 Speeding up over a distance

1. $a = (v^2 - u^2) \div 2s = (400 - 64) \div 300 = \mathbf{1.12 \text{ m/s}^2}$.
2. $t = (20 - 8.0) \div 1.12 = \mathbf{10.7 \text{ s}}$.

Problem 16 Overtaking

1. A: $s = 18t$. B: $s = \frac{1}{2} \times 3.0 \times t^2 = 1.5t^2$.
2. $18t = 1.5t^2$, so $t = 18 \div 1.5 = \mathbf{12 \text{ s}}$.
3. $s = 18 \times 12 = \mathbf{216 \text{ m}}$; $v = 3.0 \times 12 = \mathbf{36 \text{ m/s}}$, twice A's speed.

Problem 17 Stone from a cliff

1. $h = 64 \div 19.62 = \mathbf{3.26 \text{ m}}$.
2. Take up as positive, $s = -40 \text{ m}$: $v^2 = 64 + 2 \times 9.81 \times 40 = 848.8$, so $v = \mathbf{29.1 \text{ m/s}}$ downwards.
3. $t = (8.0 + 29.13) \div 9.81 = \mathbf{3.79 \text{ s}}$.

Problem 18 Trolley data

1. $s \div t^2 = 1.25$ for every pair ($0.05 \div 0.04 = 1.25$; $1.25 \div 1.00 = 1.25$), so $s \propto t^2$.
2. From $s = \frac{1}{2}at^2$, the gradient equals $\frac{1}{2}a$.
3. $a = 2 \times 1.25 = \mathbf{2.5 \text{ m/s}^2}$.
4. $s = 1.25 \times 1.96 = \mathbf{2.45 \text{ m}}$.

Problem 19 Late braking

1. $s = u^2 \div 2a = 900 \div 16 = \mathbf{56.3 \text{ m}}$.
2. Reaction distance = 15 m, total = 71.3 m, which is less than 100 m: **it stops about 29 m before the tree.**
3. Reaction distance = 45 m, so 55 m remain: $v^2 = 900 - 2 \times 8.0 \times 55 = 20$, $v = \mathbf{4.5 \text{ m/s}}$.

Problem 20 Chasing stones

1. First: $s = 4.905t^2$. Second: $s = 15(t - 1) + 4.905(t - 1)^2$.
2. Equating: $4.905t^2 = 15t - 15 + 4.905t^2 - 9.81t + 4.905$, so $5.19t = 10.095$ and $t = \mathbf{1.95 \text{ s}}$.
3. $s = 4.905 \times 1.945^2 = \mathbf{18.6 \text{ m}}$.