

Friction, slopes, pulleys and springs

AP Physics 1 (algebra-based) · Worksheet answers

Each answer gives the forces, the equation, the substitution and the final result in bold. Check the direction of friction first: it always opposes the sliding or the tendency to slide.

Level: AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 2

Problem 1 Static or kinetic

1. **Static** (the book does not slide).
2. **Kinetic** (surfaces slide).
3. **Static** (no slipping at the contact point).
4. **Kinetic** once the sofa is moving.

Problem 2 Friction on a crate

1. $N = mg = 20 \times 9.81 = \mathbf{196\text{ N}}$.
2. $f_k = 0.30 \times 196.2 = \mathbf{59\text{ N}}$.

Problem 3 Stretching a spring

1. $F = kx = 250 \times 0.12 = \mathbf{30\text{ N}}$.
2. $x = 50 \div 250 = \mathbf{0.20\text{ m}}$.

Problem 4 Weight components

- $mg = 5.0 \times 9.81 = 49.05\text{ N}$.
1. $mg \sin 40^\circ = 49.05 \times 0.643 = \mathbf{31.5\text{ N}}$.
 2. $mg \cos 40^\circ = 49.05 \times 0.766 = \mathbf{37.6\text{ N}}$.

Problem 5 Harder to start than to keep going

1. Static friction can rise to a maximum $\mu_s N$, which must be exceeded to start the trolley. Once it slides the friction falls to the smaller value $\mu_k N$, so less force is needed.
2. **μ_s is greater than μ_k** for most surfaces.

Problem 6 Pushing a box

- $N = 12 \times 9.81 = 117.7\text{ N}$.
1. $f_{s,\max} = 0.45 \times 117.7 = \mathbf{53\text{ N}}$.
 2. 40 N is less than 53 N, so the box stays still and the friction is **40 N**.
 3. $f_k = 0.35 \times 117.7 = 41.2\text{ N}$; $a = (60 - 41.2) \div 12 = \mathbf{1.6\text{ m/s}^2}$.

Problem 7 Reading a friction graph

1. **30 N.**
2. **24 N.**
3. $N = 60 \text{ N}$, so $\mu_s = 30 \div 60 = \mathbf{0.50}$ and $\mu_k = 24 \div 60 = \mathbf{0.40}$.

Problem 8 Sliding down a ramp

1. $N = mg \cos 25^\circ = 98.1 \times 0.906 = \mathbf{88.9 \text{ N}}$.
2. $f = 0.15 \times 88.9 = \mathbf{13.3 \text{ N}}$.
3. $a = (mg \sin 25^\circ - f) \div m = (41.46 - 13.34) \div 10 = \mathbf{2.8 \text{ m/s}^2}$.

Problem 9 Braking distance

1. $a = \mu_k g = 0.80 \times 9.81 = \mathbf{7.85 \text{ m/s}^2}$.
2. $d = v^2 \div 2a = 625 \div 15.7 = \mathbf{39.8 \text{ m}}$.
3. $a = 3.92 \text{ m/s}^2$, $d = 625 \div 7.85 = \mathbf{79.6 \text{ m}}$.

Problem 10 Atwood machine

1. $a = (6.0 - 4.0) \times 9.81 \div 10 = \mathbf{1.96 \text{ m/s}^2}$.
2. $T = 4.0 \times (9.81 + 1.96) = \mathbf{47.1 \text{ N}}$.

Problem 11 Spring with a hanging mass

1. $mg = kx$, so $k = 0.30 \times 9.81 \div 0.060 = \mathbf{49 \text{ N/m}}$.
2. $x = 0.50 \times 9.81 \div 49.05 = \mathbf{0.10 \text{ m}}$ (10 cm).

Problem 12 Table and hanging mass

1. $a = m_{\text{hang}} g \div (m_{\text{total}}) = 2.0 \times 9.81 \div 5.0 = \mathbf{3.9 \text{ m/s}^2}$.
2. $T = 3.0 \times 3.92 = \mathbf{11.8 \text{ N}}$.

Problem 13 Table with friction

1. $f = 0.20 \times 3.0 \times 9.81 = \mathbf{5.9 \text{ N}}$.
2. $a = (19.62 - 5.89) \div 5.0 = \mathbf{2.7 \text{ m/s}^2}$.
3. $T = 3.0 \times 2.75 + 5.89 = \mathbf{14.1 \text{ N}}$.

Problem 14 Spot the error

1. Friction on a slope is μN with $N = mg \cos \theta$, not mg ; the student ignored the cosine.
2. $f = 0.30 \times 8.0 \times 9.81 \times \cos 30^\circ = \mathbf{20.4 \text{ N}}$.

Problem 15 When does it start to slide?

1. At the point of slipping $mg \sin \theta = \mu_s mg \cos \theta$; the mg cancels, so $\tan \theta = \mu_s$.
2. $\mu_s = \tan 28^\circ = \mathbf{0.53}$.
3. $\theta = \tan^{-1}(0.60) = \mathbf{31^\circ}$.

Problem 16 Pushing a crate uphill

1. Weight mg down; normal force N perpendicular to the slope; push F up the slope; kinetic friction down the slope (opposing the motion).
2. $F = mg \sin 30^\circ + \mu_k mg \cos 30^\circ = 98.1 + 42.5 = \mathbf{141 \text{ N}}$.
3. $a = g (\sin 30^\circ - 0.25 \cos 30^\circ) = 9.81 \times (0.500 - 0.2165) = \mathbf{2.8 \text{ m/s}^2}$.

Problem 17 Block on a slope and hanging mass

1. System: $4.0 \times 9.81 - 5.0 \times 9.81 \times \sin 30^\circ = 39.24 - 24.53 = 14.72 \text{ N} = 9.0a$, so $a = \mathbf{1.6 \text{ m/s}^2}$.
2. $T = 4.0 \times (9.81 - 1.635) = \mathbf{32.7 \text{ N}}$.
3. $2.0 \times 9.81 = 19.6 \text{ N}$ is less than 24.5 N , so the 5.0 kg block slides **down the slope** and lifts the hanging mass.

Problem 18 Spring pulling a block

1. $kx = \mu_s mg$, so $x = 0.50 \times 4.905 \div 80 = \mathbf{0.031 \text{ m}}$ (3.1 cm).
2. $x = 0.30 \times 4.905 \div 80 = \mathbf{0.018 \text{ m}}$ (1.8 cm).
3. The friction falls from $\mu_s N$ to $\mu_k N$, so a smaller spring force is enough to balance it.

Problem 19 Friction data

1. $F \div N = 0.39, 0.39, 0.39, 0.39$ ($1.9 \div 4.9 = 0.388, 3.8 \div 9.8 = 0.388, 5.8 \div 14.7 = 0.395, 7.7 \div 19.6 = 0.393$).
2. Gradient $= (7.7 - 1.9) \div (19.6 - 4.9) = \mathbf{0.39}$; it is the kinetic coefficient μ_k .
3. With zero normal force there is no contact force pressing the surfaces together, so the friction must be zero.

Problem 20 Design a test for μ_s

Place the block on the board and raise one end slowly until the block just begins to slide. Measure the angle θ with the protractor (or measure the height h and length l of the board and use $\sin \theta = h \div l$). At that point $mg \sin \theta$ equals the maximum static friction $\mu_s mg \cos \theta$, so $\mu_s = \mathbf{\tan \theta}$. Sources of error are the reading of the angle at the instant of slipping and a changing surface (dust or wear). Reduce the first by raising the board slowly, repeating at least five times and averaging; reduce the second by cleaning the surface and using fresh sections of the board.