

Energy conservation, bar charts and power

AP Physics 1 (algebra-based) · Worksheet answers

Each answer shows the law used, the substitution and the result with its unit in bold. Compare the method as well as the number: in AP free-response items, a correct setup earns marks even when the arithmetic slips.

Level: AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 3

Problem 1 Name the energy store

1. Elastic (spring) potential energy.
2. Gravitational potential energy (plus a little kinetic energy if it still moves sideways; at the very top of a vertical flight it is mostly potential).
3. Kinetic energy.
4. Gravitational potential energy.
5. The floor lies above the basement reference level, so $h > 0$ and $U_g = mgh$ is positive; only changes in U are physically meaningful. **Answer: potential energy depends on the chosen reference level.**

Problem 2 Lifting a water container

1. $\Delta U = mgh = 12 \text{ kg} \times 9.81 \text{ m/s}^2 \times 1.5 \text{ m} = \mathbf{177 \text{ J}}$ (176.6 J).
2. The gain is unchanged: **177 J**. The container's U at the shelf becomes zero and its U on the floor becomes -177 J , but the difference is the same.

Problem 3 Energy in a spring

1. $U_s = \frac{1}{2}kx^2 = \frac{1}{2} \times 400 \times (0.050)^2 = \mathbf{0.50 \text{ J}}$.
2. $x = 0.100 \text{ m}$ gives $\frac{1}{2} \times 400 \times (0.100)^2 = 2.0 \text{ J}$. **2.0 J**, which is four times as much, because U_s is proportional to x^2 .

Problem 4 Motor power

1. $P = W/t = 4500 \text{ J} \div 30 \text{ s} = \mathbf{150 \text{ W}}$.
2. $t = 120 \text{ s}$, so $W = Pt = 150 \text{ W} \times 120 \text{ s} = \mathbf{1.8 \times 10^4 \text{ J}}$.

Problem 5 Unit conversions

1. $2.5 \text{ kW} \times 1000 = \mathbf{2500 \text{ W}}$.
2. $0.75 \times 3.6 \times 10^6 \text{ J} = \mathbf{2.7 \times 10^6 \text{ J}}$.

3. $8400 \text{ J} \div 60 \text{ s} = \mathbf{140 \text{ W}}$.

Problem 6 Dropped cricket ball

1. $K = mgh = 0.15 \times 9.81 \times 1.8 = 2.649 \text{ J}$, so $K = \mathbf{2.6 \text{ J}}$.

2. $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 1.8} = \sqrt{35.3} = \mathbf{5.9 \text{ m/s}}$.

Problem 7 Reading a bar chart

1. Six squares of U : $6 \times 0.50 \text{ J} = \mathbf{3.0 \text{ J}}$.

2. Two squares of E_{th} : $2 \times 0.50 \text{ J} = \mathbf{1.0 \text{ J}}$.

3. $U = mgh$, so $h = 3.0 \text{ J} \div (0.20 \text{ kg} \times 9.81 \text{ N/kg}) = 3.0 \div 1.962 = \mathbf{1.5 \text{ m}}$.

4. $K = 4 \times 0.50 \text{ J} = 2.0 \text{ J}$, so $v = \sqrt{2K/m} = \sqrt{2 \times 2.0 \div 0.20} = \sqrt{20} = \mathbf{4.5 \text{ m/s}}$.

Problem 8 Spring-launched ball

1. $U_s = \frac{1}{2} \times 200 \times (0.060)^2 = \mathbf{0.36 \text{ J}}$.

2. At the top the speed is zero, so all the spring energy has become gravitational: $mgh = 0.36 \text{ J}$. $h = 0.36 \div (0.050 \times 9.81) = 0.36 \div 0.4905 = \mathbf{0.73 \text{ m}}$ above the release position.

Problem 9 Crate on a rough ramp

1. $\Delta U = mgh = 25 \times 9.81 \times 1.2 = \mathbf{294 \text{ J}}$.

2. $K = \frac{1}{2}mv^2 = \frac{1}{2} \times 25 \times (2.0)^2 = \mathbf{50 \text{ J}}$.

3. $E_{\text{int}} = 294.3 - 50 = \mathbf{244 \text{ J}}$.

4. $E_{\text{int}} = f_k d$, so $f_k = 244.3 \div 3.0 = \mathbf{81 \text{ N}}$.

Problem 10 Climbing power

1. $\Delta U = mgh = 65 \times 9.81 \times 4.2 = \mathbf{2.68 \times 10^3 \text{ J}}$ (2678 J).

2. $P = \Delta U/t = 2678 \div 9.0 = \mathbf{298 \text{ W}}$.

Problem 11 Motorbike on the highway

1. At constant velocity the net force is zero, so the engine force equals the resistive force: $\mathbf{350 \text{ N}}$.

2. $P = Fv = 350 \times 20 = \mathbf{7.0 \times 10^3 \text{ W}}$ (7.0 kW).

3. $t = 900 \text{ s}$, so $E = Pt = 7000 \times 900 = \mathbf{6.3 \times 10^6 \text{ J}}$, and $6.3 \times 10^6 \div 3.6 \times 10^6 = \mathbf{1.75 \text{ kWh}}$.

Problem 12 Kettle energy

1. $E = Pt = 1500 \text{ W} \times 180 \text{ s} = \mathbf{2.7 \times 10^5 \text{ J}}$.

2. $2.7 \times 10^5 \div 3.6 \times 10^6 = \mathbf{0.075 \text{ kWh}}$. (Check: $1.5 \text{ kW} \times 0.050 \text{ h} = 0.075 \text{ kWh}$.)

Problem 13 Reading an energy graph

1. $P = \text{slope} = 240 \text{ J} \div 4.0 \text{ s} = \mathbf{60 \text{ W}}$.
2. The line is flat, so $\mathbf{0 \text{ W}}$: the motor is switched off or idle.
3. $P = (640 - 240) \text{ J} \div 4.0 \text{ s} = \mathbf{100 \text{ W}}$.
4. $P_{\text{avg}} = 640 \text{ J} \div 10 \text{ s} = \mathbf{64 \text{ W}}$.

Problem 14 Swinging pendulum

1. $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.20} = \sqrt{3.924} = \mathbf{2.0 \text{ m/s}}$ (1.98 m/s).
2. $K = mgh = 0.30 \times 9.81 \times 0.20 = \mathbf{0.59 \text{ J}}$.
3. Half the speed means a quarter of the kinetic energy, so $\frac{1}{4}$ of the energy is kinetic and $\frac{3}{4}$ is potential. $h = \frac{3}{4} \times 0.20 = \mathbf{0.15 \text{ m}}$.

Problem 15 Minimum height for a loop

1. At the top both weight and the normal force point down; at the limit the normal force is zero, so $mg = mv^2/R$, which gives $v^2 = gR$.
2. Take the bottom as $h = 0$. $mgH = mg(2R) + \frac{1}{2}mv^2 = mg(2R) + \frac{1}{2}mgR = 2.5mgR$. So $H = 2.5R = 2.5 \times 3.0 \text{ m} = \mathbf{7.5 \text{ m}}$.

Problem 16 Block and spring on rough floor

1. $U_s = \frac{1}{2} \times 500 \times (0.20)^2 = \mathbf{10 \text{ J}}$.
2. $f_k = \mu_k mg = 0.30 \times 2.0 \times 9.81 = \mathbf{5.9 \text{ N}}$.
3. All the spring energy ends as thermal energy: $10 \text{ J} = f_k d$, so $d = 10 \div 5.886 = \mathbf{1.7 \text{ m}}$ from the release position.

Problem 17 Uphill cycling

1. $F = mg \sin\theta = 80 \times 9.81 \times \sin 5.0^\circ = 784.8 \times 0.0872 = \mathbf{68 \text{ N}}$.
2. The rider moves at constant speed, so $P = Fv = 68.4 \times 4.0 = \mathbf{2.7 \times 10^2 \text{ W}}$ (274 W).
3. $P_{\text{chem}} = 274 \div 0.24 = \mathbf{1.1 \times 10^3 \text{ W}}$.

Problem 18 Pumping water from a well

1. $1500 \text{ kg} \div 60 \text{ s} = \mathbf{25 \text{ kg/s}}$.
2. Lifting: mgh per second $= 25 \times 9.81 \times 12 = 2943 \text{ W}$. Kinetic: $\frac{1}{2}mv^2$ per second $= \frac{1}{2} \times 25 \times (3.0)^2 = 112.5 \text{ W}$. Total useful power $= 3055 \text{ W} \approx \mathbf{3.1 \times 10^3 \text{ W}}$.
3. $P_{\text{in}} = 3055 \div 0.70 = 4365 \text{ W} \approx \mathbf{4.4 \times 10^3 \text{ W}}$.

Problem 19 Mass on a vertical spring

1. At maximum extension the mass is momentarily at rest. Take the lowest point as the final state: $mgx = \frac{1}{2}kx^2$, so $x = 2mg/k = 2 \times 0.50 \times 9.81 \div 40 = \mathbf{0.25 \text{ m}}$ (0.245 m).
2. At $x/2 = 0.1226 \text{ m}$: $K = mg(x/2) - \frac{1}{2}k(x/2)^2 = 0.6015 - 0.3007 = 0.3007 \text{ J}$. $v = \sqrt{2 \times 0.3007 \div 0.50} = \mathbf{1.1 \text{ m/s}}$.
3. The net force is zero at $x = mg/k = 0.12 \text{ m}$, but the mass arrives there with kinetic energy, so it overshoots; the spring force then exceeds the weight and decelerates it.

Problem 20 Spot the error

1. He used the length of the slope (5.0 m) as the height. The height is the vertical drop: $h = 5.0 \sin 30^\circ = 2.5 \text{ m}$.
2. $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 2.5} = \sqrt{49.05} = \mathbf{7.0 \text{ m/s}}$.
3. **No change**: mass cancels in $mgh = \frac{1}{2}mv^2$, so a 4.0 kg cart reaches the same speed (ignoring friction).