Exercise walk-through

1.2

Changes in energy – kinetic, elastic and gravitational (4.1.1.2)

AQA · GCSE · Physics

Energy stores and systems

- A ball thrown upwards: its kinetic store empties and the gravitational potential store fills. At the top, it stops for an instant.
- A car hitting a wall: the kinetic store empties; the thermal stores of the car and wall fill, and some energy is carried away by sound.
- A battery-powered toy car speeding up: the chemical store of the battery empties; the kinetic store of the car fills.

Calculating energy changes

- E_k is **kinetic energy** in J; m is mass in kg; v is speed in m/s.
- E_p is **gravitational potential energy** in J; h is the change in height in m; g is the **gravitational field strength** in N/kg (9.8 N/kg on Earth).
- E_e is **elastic potential energy** in J; k is the **spring constant** in N/m; e is the **extension** in m.

$$E_k = \frac{1}{2}mv^2 \qquad E_p = mgh \qquad E_e = \frac{1}{2}ke^2$$

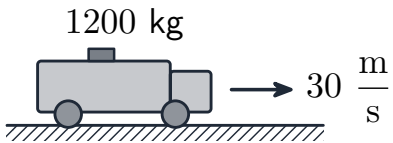
Power

- **Power** is the rate at which energy is transferred, or the rate at which work is done.
- A more **powerful** motor lifts the same load through the same height in less time.
- P is **power** in watts, E energy transferred in J, W the **work done** in J and t the time in s.
- A transfer of 1 J per second is a power of 1 **watt** (W).

$$P = \frac{E}{t} \qquad P = \frac{W}{t}$$

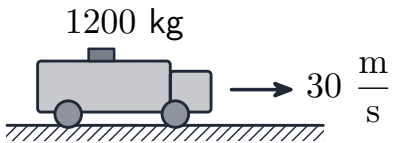
Exercise 2.1

2.1 Calculate the kinetic energy of a 1200 kg car travelling at 30 m/s. [2]



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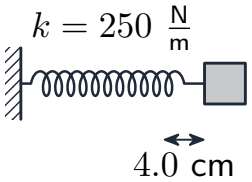
2.1 Known: mass and speed.

$$E_k = \tfrac{1}{2}mv^2 = \tfrac{1}{2} \times 1200 \text{ kg} \times (30 \text{ m/s})^2 = \mathbf{5.4 \times 10^5} \text{ J}$$

(1 mark substitution, 1 mark answer with unit.)

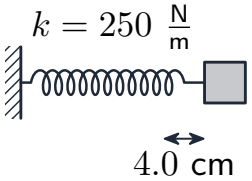
Exercise 2.2

2.2 A spring has spring constant 250 N/m. Calculate the elastic potential energy stored when its extension is 4.0 cm. [3]



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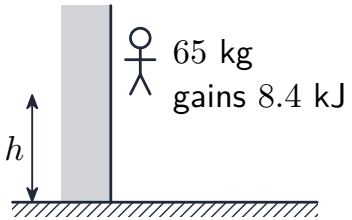
2.2 Convert first: 4.0 cm = 0.040 m (C1).

$$E_e = \tfrac{1}{2}ke^2 = \tfrac{1}{2} \times 250 \text{ N/m} \times (0.040 \text{ m})^2 = \mathbf{0.20} \text{ J}$$

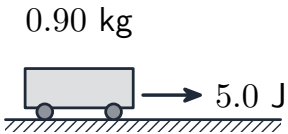
(substitution 1, answer with unit 1.)

Exercise 2.3

2.3 A 65 kg climber gains 8.4 kJ of gravitational potential energy climbing a wall ($g = 9.8$ N/kg). Calculate the height gained. [3]

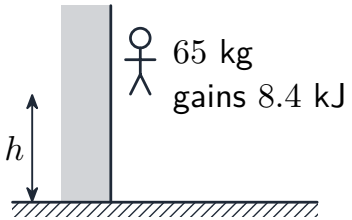


2.4 A toy train of mass 0.90 kg has kinetic energy 5.0 J. Calculate its speed. [2]

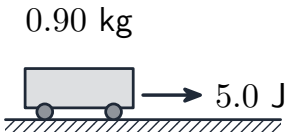


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Full solution on next slide

Full solution 2.3

2.3 Convert: 8.4 kJ = 8400 J (C1). Rearrange then substitute.

$$E_p = mgh \quad \Rightarrow \quad h = \frac{E_p}{mg} = \frac{8400\ \text{J}}{65\ \text{kg} \times 9.8\ \text{N/kg}} = \mathbf{13}\ \text{m (2 s.f.)}$$

(rearrangement 1, answer with unit 1.)

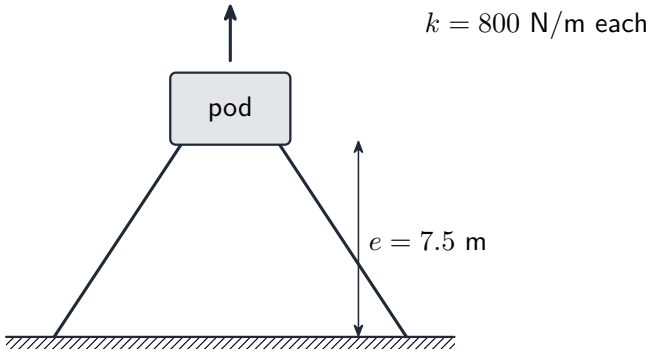
2.4 Known: mass and E_k; v is wanted, so rearrange before substituting.

$$E_k = \tfrac{1}{2}mv^2 \quad \Rightarrow \quad v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 5.0\ \text{J}}{0.90\ \text{kg}}} = \mathbf{3.3}\ \text{m/s}$$

(1 mark method, 1 mark answer with unit.)

Exercise 3.1

3.1 A ride at a theme park holds a 240 kg pod on two stretched bungee cords. Each cord behaves like a spring of spring constant 800 N/m. Before release each cord is stretched by 7.5 m.

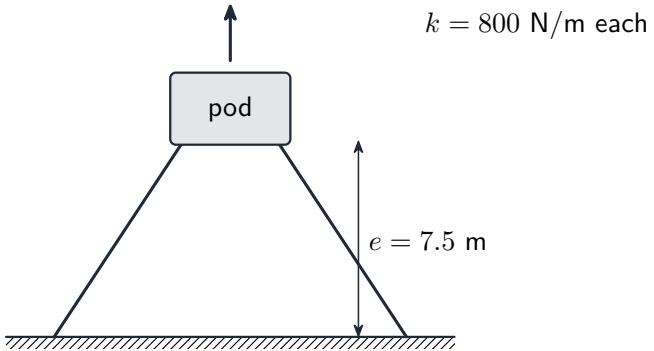


(a) Calculate the elastic potential energy stored in one cord. [3]

(b) Calculate the total elastic potential energy stored in the two cords. [1]

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Full solution on next slide

Full solution 3.1

3.1 (a) Known: $k = 800$ N/m, $e = 7.5$ m (already base units).

$$E_e = \tfrac{1}{2} k e^2 = \tfrac{1}{2} \times 800 \text{ N/m} \times (7.5 \text{ m})^2$$

$$E_e = \mathbf{22\,500} \text{ J}$$

(substitution C1, square of 7.5 evaluated A1, answer with unit A1.) (b) The two identical cords store the same energy each.

$$E_{total} = 2 \times 22\,500 = \mathbf{45\,000} \text{ J}$$

Exercise 3.2

3.2 The pod in question 3.1 is released and rises. At its highest point it has 24 000 J of gravitational potential energy ($g = 9.8$ N/kg).

(a) Calculate the maximum height the pod reaches above its release point. [3]

(b) The actual height reached is lower than this value. Explain why. [2]

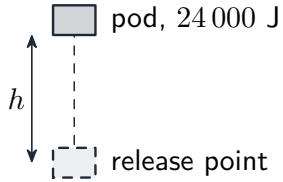


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3.2 (a) Known: E_p, m, g; rearrange for h.

$$E_p = mgh \quad \Rightarrow \quad h = \frac{E_p}{mg} = \frac{24\,000 \text{ J}}{240 \text{ kg} \times 9.8 \text{ N/kg}} = \mathbf{10} \text{ m}$$

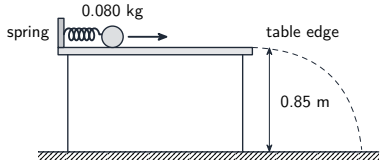
(rearrangement C1, substitution C1, answer with unit A1.) (b) As the pod rises it does work against air resistance, so some elastic potential energy is transferred to thermal stores of the air and the pod rather than to the gravitational potential store.

Exercise 3.3

3.3 A pinball machine fires a 0.080 kg ball with a compressed spring. The spring constant is 320 N/m and the compression is 6.0 cm. The ball leaves horizontally along the table, which is 0.85 m high. Air resistance is negligible until the ball leaves the table edge.

(a) Show that the elastic potential energy stored in the spring is about 0.58 J. [2]

(b) Calculate the speed of the ball as it leaves the spring. [3]



(c) The ball then falls from the table edge to the floor. Its kinetic energy just before landing is 0.63 J. Calculate the speed just before landing. [3]

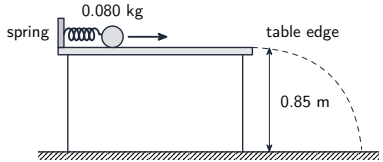
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3.3 (a) Convert: 6.0 cm = 0.060 m (C1).

$$E_e = \tfrac{1}{2}ke^2 = \tfrac{1}{2} \times 320 \times (0.060)^2 = 0.576 \text{ J} \approx 0.58 \text{ J} \checkmark$$

(shown statement A1.) (b) All E_e becomes E_k at launch.

Full solution on next slide

Full solution 3.3

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(shown statement A1.) (b) All E_e becomes E_k at launch.

$$E_k = \tfrac{1}{2}mv^2 \quad \Rightarrow \quad v = \sqrt{2E_k/m} = \sqrt{2 \times 0.576/0.080} = \mathbf{3.8} \text{ m/s (2 s.f.)}$$

(equating C1, rearrangement C1, answer A1.) (c) Just before landing the ball's kinetic energy is given (0.63 J), not re-derived.

$$v = \sqrt{2E_k/m} = \sqrt{2 \times 0.63/0.080} = \mathbf{4.0} \text{ m/s (2 s.f.)}$$

(method C1, answer A1, 2 s.f. A1.) (d) On the way down the gravitational potential store empties as well: the ball has both the launch energy and the energy from falling 0.85 m, so the kinetic store (and the speed) at the floor is larger than at launch. Mentioning "energy gained = $mg \times 0.85 = 0.67$ J, so E_k grows from 0.58 J to about 0.63 J once a little is dissipated" is a full-credit comparison.