AQA AS Work, Energy, Power and Materials solutions

Matching solutions and teaching prompts for the class review

Specification points covered

- 3.4.1.7(a–c) Work done, energy transfer and W = Fs.
- 3.4.1.7(d–f) Kinetic and gravitational potential energy.
- 3.4.1.8(a–d) Power, P = W/t, P = Fv and efficiency.
- 3.4.2.1(a–d) Hooke's law, stiffness and elastic strain energy.
- 3.4.2.1(e–h) Tensile stress, tensile strain and Young modulus.
- 3.4.2.1(i–k) Stress–strain curves, elastic and plastic behaviour.
- 3.4.2.2(a–d) Measuring Young modulus and analysing uncertainties.
- 8.2.RP4 Determination of Young modulus by experiment.

Teaching focus

Distinguish the force doing work from the resultant force controlling acceleration.
Separate stiffness of an object from Young modulus of its material.

1. Lifting the stretcher

1. Define work done, power and efficiency. Include the energy-transfer idea in each definition. [3 marks]

Answer / mark points: Work done is energy transferred by a force moving its point of application through a displacement; W = Fs when force and displacement are parallel. Power is the rate of energy transfer or work done per unit time. Efficiency is useful energy transferred or useful power output divided by total energy input or total power input.

Teacher prompt / common error: Definitions should be energy-transfer statements, not only memorised equations.

2. A rescue winch lifts a 180 kg stretcher vertically through 35.0 m at constant speed. Calculate the useful work done against gravity. [2 marks]

Answer / mark points: Useful work = mgh = 180 × 9.81 × 35.0 = 6.18×10^4 J = 61.8 kJ.

Teacher prompt / common error: Constant speed makes the kinetic-energy change zero, not the work done zero.

3. The lift takes 48.0 s. Calculate the useful output power of the winch. [2 marks]

Answer / mark points: P = W/t = $6.18 \times 10^4/48.0 = 1.29 \times 10^3$ W = 1.29 kW.

Teacher prompt / common error: Use useful output energy when calculating useful output power.

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2. Power on the access slope

4. The electrical input power is 1.75 kW. Calculate the efficiency of the winch. [2 marks]

Answer / mark points: Efficiency = 1.2875/1.75 = 0.736 = 73.6%.

Teacher prompt / common error: Compare powers in the same units and give either a ratio or percentage clearly.

5. A tracked carrier of total mass 240 kg climbs an 18.0° slope at a constant 1.20 m s^{-1}. Resistive forces total 180 N. Calculate the required driving force and useful mechanical power. Explain why P = Fv uses the driving force here even though the resultant force is zero. [4 marks]

Answer / mark points: At constant speed the driving force balances the downhill forces: F = mg sin 18.0° + 180 = 908 N. P = Fv = 908 × 1.20 = 1.09 kW. The resultant force is zero because forces balance, but the motor still exerts 908 N through a distance each second and transfers energy against gravity and resistance; therefore use the driving force, not the zero resultant force, in P = Fv.

Teacher prompt / common error: P = Fv uses the driving force doing work; a zero resultant force only means zero acceleration.

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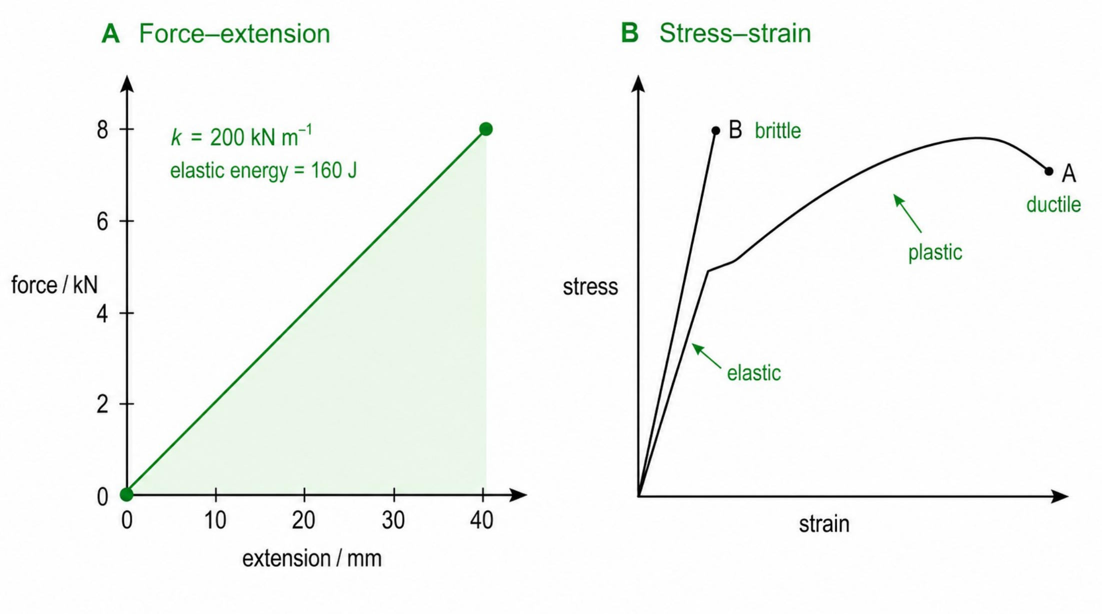
3. Elastic line and material behaviour

6. Panel A of the figure shows the force–extension graph for an elastic rescue line. Calculate the elastic strain energy stored at an extension of 40.0 mm. [3 marks]



Answer / mark points: Elastic energy is the area under the force–extension graph: $E = ½FΔL = ½(8000)(0.0400) = 160$ J. Credit conversion of kN and mm.	
Teacher prompt / common error: Convert 8 kN to newtons and 40 mm to metres before finding area.	

7. Use panel A to calculate the stiffness of the line. [2 marks]

Answer / mark points: $k = F/ΔL = 8000/0.0400 = 2.00 \times 10^5$ N m^{-1} = 200 kN m^{-1}.	
Teacher prompt / common error: Stiffness is the gradient of force against extension, not a Young modulus.	

8. Panel B shows stress–strain curves for materials A and B. Identify the ductile and brittle material. For material A, distinguish its elastic and plastic behaviour and explain how the graph shows that it can absorb more energy before fracture. [3 marks]

Answer / mark points: A is ductile and B is brittle. The initial straight part of A is elastic: removing the load returns the material to its original length. After yield, deformation is plastic and a permanent extension remains. Material A has a much larger area under its stress–strain curve before fracture, so it has greater toughness or energy absorbed per unit volume.	
Teacher prompt / common error: Elastic/plastic describes recovery; ductile/brittle describes deformation before fracture.	

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4. Selecting the cable

9. A steel cable has length 18.0 m, cross-sectional area 1.80×10^{-4} m² and Young modulus 1.90×10^{11} Pa. Calculate its extension under a tension of 22.0 kN. [3 marks]

Answer / mark points: $E = FL/(A\Delta L)$, so $\Delta L = FL/(AE) = (22.0 \times 10^3 \times 18.0)/(1.80 \times 10^{-4} \times 1.90 \times 10^{11}) = 1.16 \times 10^{-2}$ m = 11.6 mm.
Teacher prompt / common error: Use the original cable length and cross-sectional area in the Young-modulus relation.

10. For the cable in Question 9, calculate the tensile stress and tensile strain. State what each quantity represents. [3 marks]

Answer / mark points: Stress = $F/A = 22.0 \times 10^3/(1.80 \times 10^{-4}) = 1.22 \times 10^8$ Pa = 122 MPa; it is force per unit cross-sectional area. Strain = $\Delta L/L$ = $0.01158/18.0 = 6.43 \times 10^{-4}$; it is extension divided by original length and has no unit.
Teacher prompt / common error: Stress has unit Pa; strain is dimensionless.

11. Candidate cable materials have these properties. S: Young modulus 190 GPa, yield stress 620 MPa, failure strain 0.18. T: 210 GPa, 1000 MPa, 0.020. U: 80 GPa, 350 MPa, 0.35. The cable requires yield stress above 500 MPa and visible ductile deformation before failure. Select the best material and justify why each alternative is accepted or rejected. [4 marks]

Answer / mark points: Select S. It exceeds the 500 MPa yield requirement and its failure strain of 0.18 provides substantial ductile warning while retaining a high modulus. T has a higher yield stress and stiffness but its 0.020 failure strain gives little ductile deformation. U is very ductile but fails the yield-stress requirement and is much less stiff.
Teacher prompt / common error: A material must meet both the numerical limit and the design requirement for warning before failure.

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5. Energy control and testing

12. During a controlled descent the 180 kg stretcher loses 12.0 m of height and reaches a speed of 3.00 m s^{-1} from rest. Calculate the energy transferred from the stretcher's mechanical energy to other stores. [3 marks]

Answer / mark points: Loss of gravitational potential energy = 180 × 9.81 × 12.0 = 21.19 kJ. Final kinetic energy = ½(180)(3.00^2) = 0.810 kJ. Energy transferred to thermal, sound or deformation stores = 21.19 - 0.810 = 20.4 kJ.

Teacher prompt / common error: Mechanical energy transferred equals lost GPE minus the KE gained.

13. Design an experiment to determine the Young modulus of a metal wire. Include measurement of original length and diameter, repeated diameter readings with a micrometer, incremental loading within the elastic region, extension measurement, stress and strain calculation, a graph, uncertainty reduction and safety. [6 marks]

Answer / mark points: Award one mark for each valid point, to six: measure a long original wire length between fixed reference marks; measure diameter with a micrometer at least three positions and in perpendicular directions, then average and calculate area; add known loads in small increments while remaining below the elastic limit; measure extension with a pointer and scale, travelling microscope or suitable sensor after each load; calculate stress F/A and strain ΔL/L; plot stress against strain and obtain Young modulus from the gradient of the linear region; repeat loading or unloading and use a long thin wire to reduce percentage uncertainty; secure the wire, use eye protection and catch falling masses. Zero correction and avoiding parallax earn uncertainty credit.

Teacher prompt / common error: Diameter uncertainty is amplified in area, so several micrometer readings are essential.

Language and method check

Award independent, creditworthy physics steps; do not award extra marks for repeated statements.
Accept equivalent methods when the physical reasoning, units and final precision remain consistent.

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