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SOLUTIONS
ATTEMPT | CHECK | CORRECT | IMPROVE

OCR A A Level Physics | Work done solutions

Matching solutions and teaching prompts for the class review | 35 marks

Specification points covered

- 3.3.1(a) Define work done by a force and the unit joule.
- 3.3.1(b) Use W = F x cos θ for work done by a force.
- 3.3.1(c) State and apply the principle of conservation of energy.
- 3.3.1(d) Describe energy in different forms, its transfer and conservation.
- 3.3.1(e) Explain that transfer of energy is equal to work done.

Class review
Reveal working one step at a time. Insist that pupils identify the force component parallel to the displacement and use positive, zero or negative work to describe the direction of energy transfer.

1. Starting with the definition [3 marks]

The installation team begins by checking the language and units used in its planning notes.

(a) Define work done by a force and state what it means for one joule of work to be done. **[2 marks]**

(b) A stage light is pushed horizontally with a force of 75 N through 3.20 m. Calculate the work done by the force. **[1 mark]**

Answer / mark points: (a) Work done is the product of the force and the displacement in the direction of that force. [1]
One joule is the work done when a 1 N force moves its point of application 1 m in the force direction. [1]
(b) W = Fx = 75 × 3.20 = 240 J. [1]

Teacher prompt / common error: A force merely acting is not enough: there must be a displacement with a component in the force direction.

2. Direction matters [4 marks]

A technician moves equipment along the level tunnel floor.

(a) The technician walks 25 m while supporting a load with an upward force of 180 N. Calculate the work done by this upward force. **[1 mark]**

(b) A trolley is pulled 6.00 m by a horizontal force of 42 N. Calculate the work done. **[1 mark]**

(c) The same 42 N force is now directed at 55° to the trolley's horizontal displacement of 6.00 m. Calculate the work done. **[2 marks]**

Answer / mark points: (a) W = Fx cos 90° = 0 J because the support force is perpendicular to the displacement. [1]
(b) W = 42 × 6.00 = 252 J. [1]
(c) W = 42 × 6.00 × cos 55° [1] = 145 J. [1]

Teacher prompt / common error: Use the angle between the force and the displacement. Do not replace 55° with its complementary angle.

3. Moving the sculpture module [6 marks]

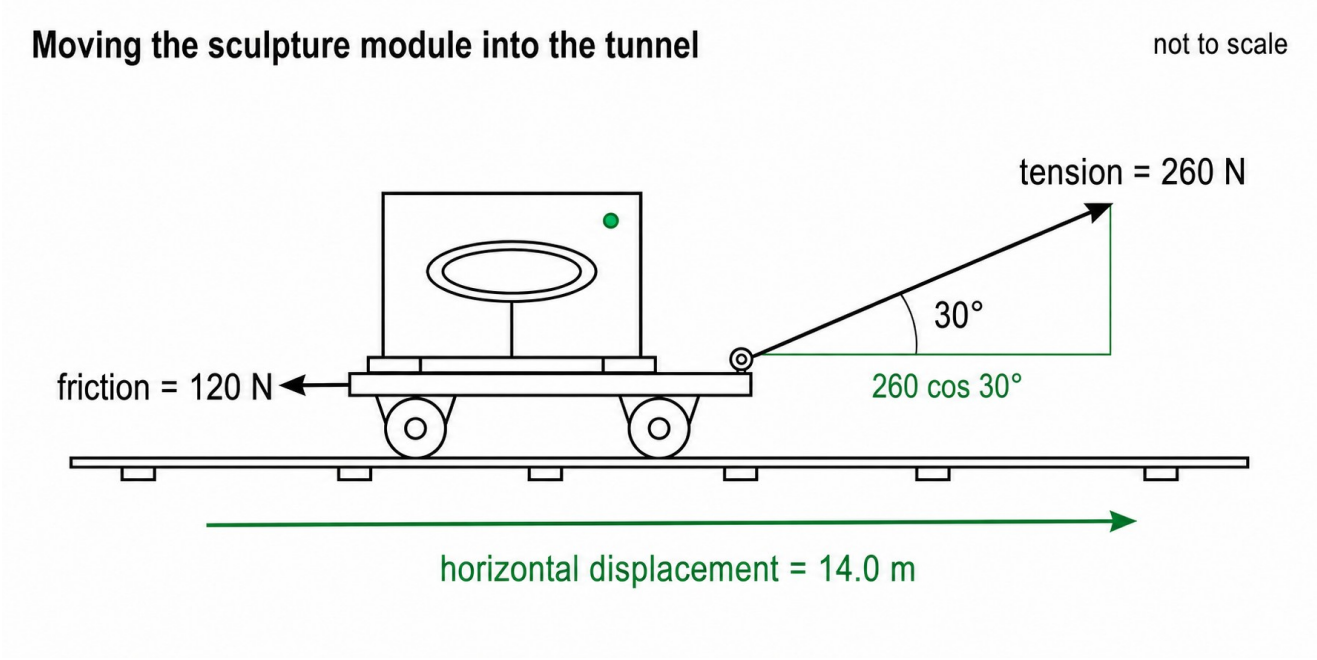
The Lumen Line is a kinetic light sculpture being installed inside a disused railway tunnel. Its main module is carried on a rail trolley.

(a) Calculate the work done on the trolley by the tension in the cable. **[2 marks]**

(b) Calculate the work done on the trolley by friction. Include the correct sign. **[1 mark]**

(c) Calculate the net work done on the trolley by all the forces. **[1 mark]**

(d) State the energy store that increases. Explain why the weight and normal contact force do no work on the trolley during this movement. **[2 marks]**



Answer / mark points: (a) Work by tension = 260 × 14.0 × cos 30° [1] = 3.15 kJ. [1]
(b) Work by friction = -120 × 14.0 = -1.68 kJ. [1]
(c) Net work = 3152 - 1680 = 1.47 kJ. [1]
(d) The trolley's kinetic energy store increases. [1] The weight and normal contact force are perpendicular to the horizontal displacement, so each does zero work. [1]

Teacher prompt / common error: The minus sign for friction is meaningful: friction transfers energy away from the trolley's mechanical energy stores.

4. Moving the counterweight [7 marks]

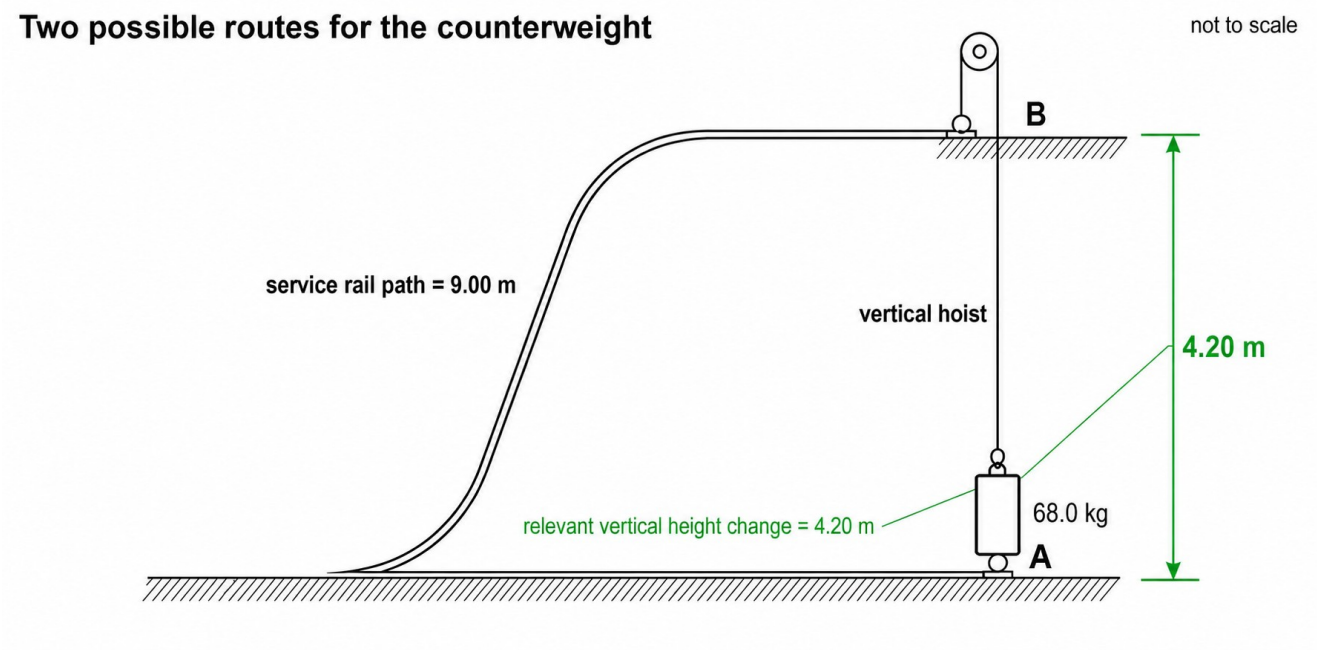
A 68.0 kg counterweight must be moved from A to B. It could be lifted vertically or moved along a longer service rail. Use g = 9.81 N/kg.

(a) State the distance that must be used to calculate the work done against the counterweight's weight. **[1 mark]**

(b) Calculate the work done against the weight in moving the counterweight from A to B. **[2 marks]**

(c) During the vertical lift, the hoist exerts a constant upward force of 760 N through 4.20 m. Calculate the energy transferred to thermal stores. **[2 marks]**

(d) Explain why, if resistive forces are ignored, the work done against the weight is the same for the vertical route and the service-rail route. **[2 marks]**



Answer / mark points: (a) Use the vertical height change, 4.20 m. [1]
(b) W = mgΔh = 68.0 × 9.81 × 4.20 [1] = 2.80 kJ. [1]
(c) Work done by hoist = 760 × 4.20 = 3192 J. [1] Thermal transfer = 3192 - 2802 = 390 J. [1]
(d) The gravitational energy change depends on the weight and vertical height change, not the route length. [1] With no resistance, conservation of energy therefore gives the same work done against the weight for either route. [1]

Teacher prompt / common error: The 9.00 m route is not the displacement in the direction of the weight; only the 4.20 m vertical component is relevant.

5. Checking a cable angle [3 marks]

During alignment, the direction of a cable cannot be measured directly.

(a) A cable force of 190 N does 870 J of work while the module moves 8.50 m. Determine the angle between the force and the displacement. **[2 marks]**

(b) A 95 N braking force then acts exactly opposite to the motion over 2.60 m. Calculate the work done by the braking force. **[1 mark]**

Answer / mark points: (a) cos θ = 870 / (190 × 8.50). [1] Therefore θ = 57.4°. [1]
(b) W = 95 × 2.60 × cos 180° = -247 J. [1]

Teacher prompt / common error: Negative work is not a negative amount of energy. It shows that energy is transferred from the moving system by the braking force.

6. A regenerative descent [4 marks]

During a test descent, the counterweight's gravitational energy store decreases by 5.60 kJ. The generator transfers 4.10 kJ to the battery's chemical energy store.

(a) Calculate the energy transferred to thermal stores. **[1 mark]**

(b) Explain how this example demonstrates conservation of energy and why it is inaccurate to say that the remaining energy has been 'lost'. **[3 marks]**

Answer / mark points: (a) Thermal transfer = 5.60 - 4.10 = 1.50 kJ. [1]
(b) The 5.60 kJ decrease in the gravitational energy store is transferred as 4.10 kJ to the battery's chemical store and 1.50 kJ to thermal stores. [1] These transfers add to 5.60 kJ, so the total energy is unchanged. [1] The thermal energy is dispersed to the surroundings rather than destroyed, so 'lost' is imprecise. [1]

Teacher prompt / common error: Use 'transferred' or 'dissipated', not 'used up'. A battery has a chemical energy store; 'electrical' describes a transfer pathway.

7. Choosing the towing arrangement [3 marks]

Two cable arrangements are proposed for moving a display carriage through the same horizontal distance of 16.0 m.

(a) Arrangement A uses 310 N at 20° to the motion. Arrangement B uses 360 N at 42° to the motion. Calculate the work done by each arrangement and determine which transfers more energy to the carriage. **[3 marks]**

Answer / mark points: Arrangement A: W = 310 × 16.0 × cos 20° = 4.66 kJ. [1]
Arrangement B: W = 360 × 16.0 × cos 42° = 4.28 kJ. [1]
Arrangement A transfers more energy, despite having the smaller force, because its force is more closely aligned with the displacement. [1]

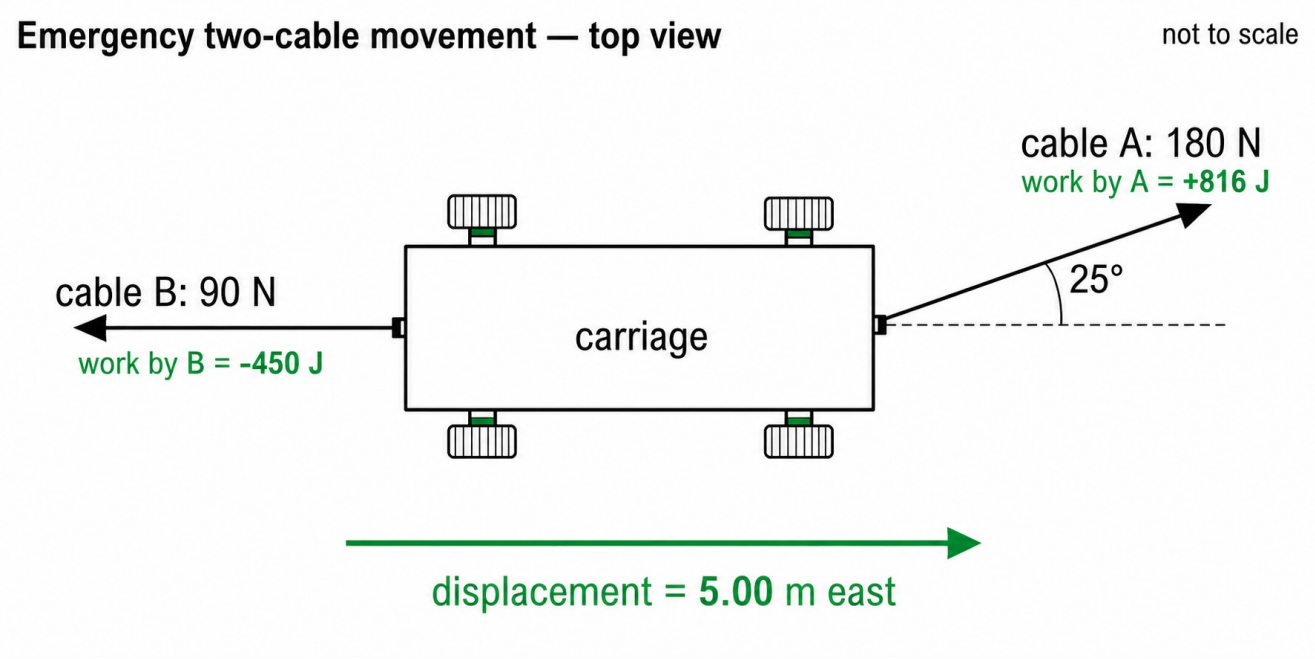
Teacher prompt / common error: Comparing force magnitudes alone is insufficient; compare the components parallel to the displacement or the calculated work values.

8. Emergency two-cable movement [5 marks]

In an emergency test, two cables act on the carriage while it moves 5.00 m east.

(a) Calculate the total work done on the carriage by cable A and cable B. **[3 marks]**

(b) A technician says, 'Both cables transfer energy to the carriage because both exert a force on it.' Evaluate this statement using precise physics language. **[2 marks]**



Answer / mark points: (a) Cable A: W = 180 × 5.00 × cos 25° = +816 J. [1] Cable B: W = 90 × 5.00 × cos 180° = -450 J. [1] Total work = 816 - 450 = +366 J. [1]
(b) The statement is only correct for cable A: its forward component does positive work and transfers energy to the carriage. [1] Cable B does negative work because it acts opposite to the displacement, so it transfers energy away from the carriage. [1]

Teacher prompt / common error: Train the language: a force does positive, zero or negative work; a quantity increases, decreases or stays the same. Do not say 'the force has energy'.

Review emphasis

Full-credit explanations identify the relevant energy stores, state the direction of transfer and use the force-displacement geometry explicitly.