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SOLUTIONS
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OCR A A Level Forces on Slopes solutions

Matching solutions and teaching prompts for the class review

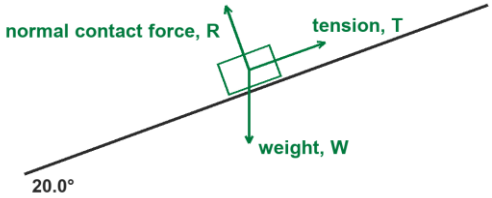
Specification points covered

- 3.2.1(a) Apply Newton's second law, F = ma.
- 3.2.1(c) Understand weight of an object, W = mg.
- 3.2.1(d) Define and identify tension, normal contact force, upthrust and friction.
- 3.2.1(e) Draw and interpret free-body diagrams.

Teaching focus

Use a free-body diagram to identify every force before resolving or applying F = ma. Make the direction convention explicit and distinguish a force from an acceleration.

1. Lower track: forces and resultant force



1. Calculate the weight of the instrument pod. [1 mark]

Answer / mark points: W = mg = 30.0 × 9.81 = 294 N (3 s.f.).

Teacher prompt / common error: One direct use of W = mg. Weight is a force, so the unit is N, not kg.

2. In the blank space below, draw a free-body diagram for the pod. Include and label all the forces acting on it. Friction is negligible. [3 marks]

Answer / mark points: A correct free-body diagram has: weight, W, vertically downward; tension, T, up the track and parallel to it; and normal contact force, R, perpendicular to the track. Do not include a 'force of motion'.

Teacher prompt / common error: For full credit, forces must act on the pod, not on the track or cable. A force diagram contains forces only, not velocity or acceleration arrows.

3. Calculate the component of the pod's weight parallel to the 20.0° track. State its direction. [2 marks]

Answer / mark points: Component of weight parallel to track = W sin 20.0° = 294.3 sin 20.0° = 101 N, down the track (3 s.f.).

Teacher prompt / common error: The parallel component is W sin θ for this slope geometry. It points down the track.

1. Lower track: forces and resultant force continued

4. Calculate the normal contact force exerted by the track on the pod. [2 marks]

Answer / mark points: R = W cos 20.0° = 294.3 cos 20.0° = 277 N (3 s.f.).
Teacher prompt / common error: The normal contact force is perpendicular to the track and is less than the weight on a slope.

5. The tension in the cable is 165 N. Calculate the acceleration of the pod. Friction is negligible. [2 marks]

Answer / mark points: Resultant force up track = 165 − 100.7 = 64.3 N. F = ma, so a = 64.3 / 30.0 = 2.15 m s^{-2} up the track.
Teacher prompt / common error: Use the resultant force, not the cable tension alone, in F = ma.

6. A pupil writes, 'the tension causes a 165 N acceleration'. Explain why this is not a correct description. Use the terms tension, resultant force and acceleration. [2 marks]

Answer / mark points: Tension is a force, measured in newtons, not an acceleration. The resultant force is found by combining all the forces; a non-zero resultant force produces acceleration, measured in m s^{-2}.
Teacher prompt / common error: Model the language precisely: force is measured in N; acceleration is measured in m s^{-2}. A force can cause acceleration, but it is not an acceleration.

7. The cable tension is adjusted so that it equals the component of weight parallel to the track. The pod is moving uphill. Describe its subsequent motion and explain your answer. [2 marks]

Answer / mark points: The pod continues uphill at constant velocity. Tension balances the down-slope component of weight, so the resultant force is zero and the acceleration is zero.
Teacher prompt / common error: Constant velocity means zero acceleration and therefore zero resultant force. It does not mean that no forces act.

2. Lower track: friction

8. The pod now experiences a frictional force of 18.0 N down the track. Calculate the cable tension required for it to move uphill at constant velocity. [2 marks]

Answer / mark points: For constant velocity, resultant force = 0. T = 100.7 + 18.0 = 118.7 N, so T = 119 N (3 s.f.).
Teacher prompt / common error: The tension must balance both down-slope weight component and friction.

9. The cable tension is increased to 160 N while the frictional force remains 18.0 N. Calculate the acceleration of the pod. [2 marks]

Answer / mark points: Resultant force = 160 − 100.7 − 18.0 = 41.3 N up track. a = 41.3 / 30.0 = 1.38 m s^{-2} up the track.
Teacher prompt / common error: The 18.0 N frictional force acts down the track, so subtract it when up the track is positive.

2. Friction continued

10. State the direction of the frictional force on the pod while it moves uphill. Explain why friction acts in this direction. [2 marks]

Answer / mark points: Friction acts down the track. It opposes the relative motion, or attempted relative motion, of the pod over the track; the pod moves uphill.
Teacher prompt / common error: Friction opposes relative motion, not the applied tension. The stated uphill motion fixes its direction here.

11. The track becomes wet and the frictional force decreases to 8.0 N while the tension stays at 160 N. Calculate the new acceleration. State how it compares with your answer to question 9. [2 marks]

Answer / mark points: Resultant force = 160 − 100.7 − 8.0 = 51.3 N. a = 51.3 / 30.0 = 1.71 m s^{-2} up the track. This is greater than in question 9 because the opposing frictional force is smaller.
Teacher prompt / common error: A smaller opposing force gives a larger resultant force and hence a larger acceleration for the same mass.

3. Steeper upper track

12. Calculate the component of the pod's weight parallel to the 30.0° track. State its direction. [2 marks]

Answer / mark points: Component of weight parallel to track = W sin 30.0° = 294.3 sin 30.0° = 147 N, down the track (3 s.f.).
Teacher prompt / common error: The steeper slope increases the component of weight parallel to the track.

13. Calculate the normal contact force exerted by the 30.0° track on the pod. [2 marks]

Answer / mark points: R = W cos 30.0° = 294.3 cos 30.0° = 255 N (3 s.f.).
Teacher prompt / common error: Use the perpendicular component, W cos θ. The normal contact force is not equal to W on a slope.

3. Steeper upper track continued

14. The frictional force is 20.0 N and the cable tension is 200 N. Calculate the acceleration of the pod on the 30.0° track. [2 marks]

Answer / mark points: Resultant force = 200 − 147.2 − 20.0 = 32.8 N up track. a = 32.8 / 30.0 = 1.10 m s^{-2} up the track.
Teacher prompt / common error: Keep a consistent positive direction and use the resultant force before dividing by mass.

15. The winch has a safe maximum cable tension of 220 N. Determine whether it can accelerate the pod at 1.50 m s^{-2} on the 30.0° track against a frictional force of 20.0 N. Show your reasoning. [3 marks]

Answer / mark points: Required tension = ma + component of weight + friction = (30.0 × 1.50) + 147.2 + 20.0 = 212 N. This is below 220 N, so the winch can do this safely.
Teacher prompt / common error: For three marks expect a required-tension calculation, comparison with 220 N and a clear safe/unsafe conclusion.

16. A protective sleeve increases the mass of the pod to 38.0 kg. The cable tension is 220 N and friction is 20.0 N. Calculate the acceleration on the 30.0° track. [2 marks]

Answer / mark points: Component of weight = 38.0 × 9.81 × sin 30.0° = 186 N. Resultant force = 220 − 186 − 20.0 = 13.6 N. a = 13.6 / 38.0 = 0.358 m s^{-2} up the track.
Teacher prompt / common error: Use the new 38.0 kg mass in both the weight component and F = ma.

17. A pupil says, 'At 30.0°, the normal contact force is 30% of the weight because the slope is 30.0°.' Explain why this is incorrect. State the correct relationship and use it to give the normal contact force for this pod. [3 marks]

Answer / mark points: The normal contact force is not found by taking the percentage given by the angle. It is the component of weight perpendicular to the track: R = W cos θ. Here R = 294.3 cos 30.0° = 255 N, about 87% of the weight.
Teacher prompt / common error: The angle does not directly represent a percentage. Link the normal contact force to the perpendicular component of weight, W cos θ.

Closing review

On a slope, use the component of weight parallel to the track when applying F = ma. The normal contact force is perpendicular to the track and equals W cos θ only when there are no other perpendicular forces.