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INTERNATIONAL A LEVEL MATHEMATICS • MECHANICS 2

Mechanics 2

Chapter 4: Work and Energy

Exam Questions by Topic

Pearson Edexcel International Advanced Level (WME02/01) • Calculator allowed • Take $g = 9.8\,\text{m}\,\text{s}^{-2}$

Multi-step exam questions at the difficulty of the real WME02 paper, with a full mark scheme

Chapters (tap a chapter to jump to it)		Qs	Marks	Page	My score
1	**Projectiles** Horizontal projection, projection at any angle, the equation of the path	10	84	separate file	
2	**Variable Acceleration** Calculus for motion in a line and in $\mathbf{i}, \mathbf{j}$ form	10	85	separate file	
3	**Centres of Mass** Particles, laminas, frameworks, suspended and tilting bodies	10	81	separate file	
4	**Work and Energy** Work done, kinetic and potential energy, the work–energy principle, power	10	82	2	
5	**Impulses and Collisions** Impulse as a vector, Newton's law of restitution, loss of kinetic energy	10	82	separate file	
6	**Statics of Rigid Bodies** Rods and ladders in equilibrium, friction, hinge forces	10	81	separate file	

Full mark scheme Free courses More worksheets

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CHAPTER 4 • KEY SKILLS

4 Work and Energy

Specification M2: Work and energy • 10 questions • 82 marks • about 98 minutes

1 Work done

Work = force × distance moved in the direction of the force. A force at θ to the motion does work $F\cos\theta \times d$

2 Work against gravity

Raising a mass m through a vertical height h takes mgh. On a slope, $h = d\sin\alpha$

3 Energy

Kinetic energy $\frac{1}{2}mv^2$; potential energy mgh. Change in kinetic energy is $\frac{1}{2}m\left(v^2-u^2\right)$, not $\frac{1}{2}m(v-u)^2$

4 Work–energy principle

Work done by driving forces − work against resistances = change in KE + change in PE. Count gravity once only.

5 Conservation

With no work against resistances, KE + PE is constant. The path and the angle do not matter.

6 Friction

Work against friction = $\mu R \times d$, with R from resolving perpendicular to the surface (cosine on a slope).

7 Power

$P = Fv$, where F is the driving force. 1 kW = 1000 W. Average power $= \dfrac{\text{work done}}{\text{time}}$

8 Greatest speed

At the greatest speed $a = 0$: driving force = resistance + weight component.

9 Varying resistance

With resistance kv and power P: $\dfrac{P}{v} - kv = ma$. At the greatest speed, a quadratic in v.

Skills map every skill above is tested at least once; interleaved skills come from GCSE or other chapters

Skill	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Marks	6	6	6	6	6	11	10	10	10	11
1 Work done	●				●	●	●	●		●
2 Work against gravity	●			●		●	●	●		
3 Energy			●	●	●	●	●	●		●
4 Work–energy principle				●	●	●	●	●		●
5 Conservation			●					●		
6 Friction	●			●	●		●	●		
7 Power	●	●				●			●	●
8 Greatest speed		●				●			●	
9 Varying resistance									●	
Interleaved: $F = ma$, friction and connected particles (M1)		●			●	●	●		●	●
Interleaved: projectiles (Chapter 1)			●					●		
Interleaved: quadratics and simultaneous equations (P1)						●		●	●	

Exam difficulty. Questions 1 to 5 check each skill on its own. Questions 6 to 10 are multi-step questions built like the last questions on a real WME02 paper, where one part leads into the next and skills from different topics are combined.

Must learn. When a question says “use the work–energy principle”, suvat earns no marks. Write one equation with every energy and work term, counting gravity once. Convert kW to W and give answers to 2 or 3 significant figures.

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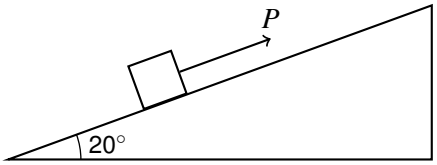


Figure 1

A package of mass 5 kg is pushed at constant speed for 4 m up a line of greatest slope of a rough plane inclined at 20° to the horizontal, by a force acting up the slope parallel to the line of greatest slope, as shown in Figure 1. The coefficient of friction between the package and the plane is 0.3. The package is modelled as a particle.

(a) Find the work done against friction.

(3)

(b) Find the total work done by the pushing force.

(2)

(c) The package takes 8 s to move the 4 m. Find the average rate at which the pushing force does work.

(1)

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Question 1 continued

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(Total for Question 1 is 6 marks)

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2. A cyclist and her bicycle have a combined mass of 80 kg. She rides along a straight road, working at a constant rate of 240 W. The resistance to her motion is modelled as a constant force of magnitude 30 N.

(a) Find her greatest possible speed on horizontal ground.

(2)

(b) Find her acceleration on horizontal ground at the instant when her speed is $5\,\mathrm{m\,s^{-1}}$

(2)

She later rides up a hill inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{40}$, at a constant speed of $4\,\mathrm{m\,s^{-1}}$. The resistance is unchanged.

(c) Find the rate at which she is now working.

(2)

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Question 2 continued

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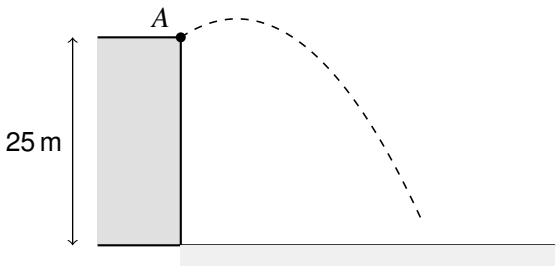


Figure 2

A stone is thrown from a point A at the top of a vertical cliff, 25 m above the sea, with speed $12\,\text{m}\,\text{s}^{-1}$, as shown in Figure 2. The stone moves freely under gravity.

(a) Use the principle of conservation of mechanical energy to find the speed of the stone as it hits the sea.

(3)

(b) Find the speed of the stone when it is 10 m above the sea.

(2)

(c) Explain why the angle at which the stone is thrown was not needed.

(1)

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Question 3 continued

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4. A particle of mass 2 kg is projected with speed $12\,\text{m}\,\text{s}^{-1}$ from the point A, up a line of greatest slope of a rough plane inclined at an angle α to the horizontal, where $\tan\alpha = \frac{3}{4}$. The coefficient of friction between the particle and the plane is 0.25. The particle comes to instantaneous rest at the point B.

(a) Use the work–energy principle to find the distance AB.

(5)

(b) Find the work done against friction as the particle moves from A to B.

(1)

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Question 4 continued

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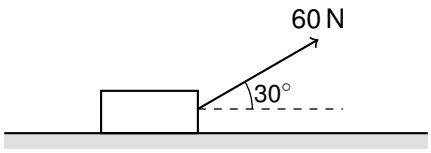


Figure 3

A sledge of mass 15 kg is pulled from rest across rough horizontal snow by a rope inclined at 30° above the horizontal, as shown in Figure 3. The tension in the rope is 60 N and the coefficient of friction between the sledge and the snow is 0.2. The sledge is modelled as a particle and the rope as light.

(a) Find the work done by the tension in the rope as the sledge moves 20 m.

(2)

(b) Use the work–energy principle to find the speed of the sledge after it has moved 20 m.

(4)

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6. A car of mass 1200 kg moves along a straight road. The resistance to motion is modelled as a constant force of magnitude R newtons, and the engine works at a constant rate of P watts. On a horizontal road the greatest possible speed of the car is $40\,\text{m s}^{-1}$. When the car moves up a road inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{20}$, its greatest possible speed is $25\,\text{m s}^{-1}$

(a) Show that $R = 980$ and find the value of P.

(5)

(b) Find the acceleration of the car on the horizontal road at the instant when its speed is $28\,\text{m s}^{-1}$

(3)

The car later moves down the inclined road with the engine switched off. The resistance is unchanged.

(c) Use the work–energy principle to find the distance the car travels while its speed falls from $25\,\text{m s}^{-1}$ to $15\,\text{m s}^{-1}$

(3)

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Question 6 continued

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Question 6 continued

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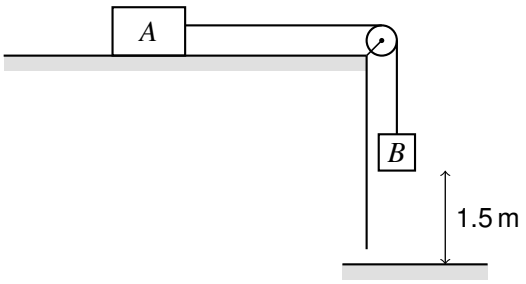


Figure 4

A particle A of mass 3 kg rests on a rough horizontal table. It is attached to a light inextensible string which passes over a small smooth pulley at the edge of the table. The other end of the string is attached to a particle B of mass 2 kg, which hangs 1.5 m above the floor, as shown in Figure 4. The coefficient of friction between A and the table is 0.4. The system is released from rest with the string taut, and A does not reach the pulley.

(a) Find the work done against friction as B falls 1.5 m.

(2)

(b) Use the work–energy principle to find the speed of B at the instant it reaches the floor.

(4)

B does not rebound.

(c) Use the work–energy principle to find the further distance moved by A before it comes to rest.

(3)

(d) State how you have used the fact that the pulley is smooth.

(1)

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Question 7 continued

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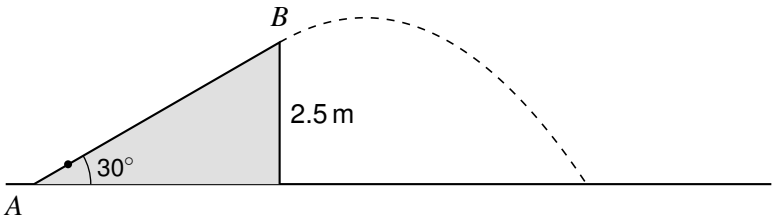


Figure 5

A ramp AB is a rough plane of length 5 m inclined at 30° to the horizontal, with A on horizontal ground and B 2.5 m above the ground. A particle P of mass 0.5 kg is projected from A with speed $10\,\text{m}\,\text{s}^{-1}$ up the line of greatest slope AB. The coefficient of friction between P and the ramp is 0.2. After leaving the ramp at B, P moves freely under gravity until it hits the ground, as shown in Figure 5.

(a) Find the work done against friction as P moves from A to B.

(2)

(b) Use the work–energy principle to find the speed of P at B.

(3)

(c) Use the principle of conservation of mechanical energy to find the speed of P as it hits the ground.

(2)

(d) Find the time taken by P to travel from B to the ground.

(3)

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Question 8 continued

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Question 8 continued

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9. A car of mass 800 kg moves along a straight road. The engine of the car works at a constant rate of 30 kW. The resistance to motion of the car is modelled as a force of magnitude kv newtons, where $v\,\text{m s}^{-1}$ is the speed of the car and k is a constant. The greatest possible speed of the car on a horizontal road is $50\,\text{m s}^{-1}$

(a) Find the value of k.

(2)

(b) Find the acceleration of the car on a horizontal road when its speed is $20\,\text{m s}^{-1}$

(3)

The car moves up a road inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{16}$, with the engine working at the same rate.

(c) Find the greatest possible speed of the car up this road.

(4)

(d) Suggest one reason why the model of the resistance may need refining.

(1)

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Question 9 continued

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Question 9 continued

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10. A van of mass 1500 kg tows a trailer of mass 500 kg up a straight road inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{14}$. The trailer is attached to the van by a light rigid towbar parallel to the road. The resistances to the motion of the van and of the trailer are constant forces of magnitude 400 N and 200 N respectively. The engine of the van works at a constant rate of 45 kW.

(a) Find the acceleration of the van and trailer at the instant when their speed is $15\,\text{m}\,\text{s}^{-1}$

(3)

(b) Find the tension in the towbar at this instant.

(2)

At this instant the towbar breaks.

(c) Use the work–energy principle to find the distance the trailer travels up the road before coming to rest.

(3)

(d) Find the acceleration of the van immediately after the towbar breaks.

(2)

(e) Explain why the van's acceleration in part (d) does not remain constant.

(1)

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Question 10 continued

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Question 10 continued

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TOTAL FOR CHAPTER 4 IS 82 MARKS

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