eClassroom

A-LEVEL MATHEMATICS • MECHANICS 2

Work and Energy

Worked Solutions

Pearson Edexcel International A Level (WME02) • Calculator allowed: take $g = 9.8\,\text{m}\,\text{s}^{-2}$ and give answers to 2 or 3 s.f.

Full worked solutions for the free Work and Energy worksheet, A-Level and International A-Level Maths

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Tap a section to jump straight to it

Full worked solutions for every question on the Mechanics 2 Work and Energy worksheet, in the same order and with the same question numbers.

How to mark your work. Tick each step you got right, not just the final answer. At A-level most marks are for method, so a wrong final answer can still earn most of the marks. If you lost marks, find the *first* line where your working is different from ours. That is the thing to fix.

In Section E: **M** = method mark, **dM** = method mark that depends on the previous M mark, **A** = accuracy mark (needs the M mark before it), **B** = independent mark.

Question sheet | Exam questions by topic | Mechanics 2 exam questions | More worksheets

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A Your turn answers

Compare each line of your working with the solution.

CORE

A1 $60\cos 25° \times 15$: **816 J**

A2 $\frac{1}{2}(3)v^2 = 3(9.8)(2.5)$: $7\,\text{m s}^{-1}$

A3 $F = \dfrac{30000}{20} = 1500$; $1500 - 900 = 1500a$: **1500 N,** $0.4\,\text{m s}^{-2}$

STRETCH

A4 $F = 0.25(5)(9.8) = 12.25$; $12.25d = \frac{1}{2}(5)(8^2)$: **13.1 m**

A5 PE lost $3(9.8)(4)\left(\frac{5}{13}\right) \approx 45.23$; work against friction $0.2(3)(9.8)\left(\frac{12}{13}\right)(4) \approx 21.71$

$\frac{1}{2}(3)v^2 \approx 23.52$: $3.96\,\text{m s}^{-1}$

A6 $\dfrac{45000}{1800}$: $25\,\text{m s}^{-1}$; $\dfrac{45000}{1800+784}$: $17.4\,\text{m s}^{-1}$

A7 $F = \dfrac{50000}{20} = 2500$; down the hill: $2500 + 980 - 3000 = 2500a$: $0.192\,\text{m s}^{-2}$

B Fluency solutions

One mark for each correct part. The notes in italics explain why each sequence was chosen.

CORE

B1 **(a)** **300 J** **(b)** $50\cos 60° \times 6$: **150 J** **(c)** **120 J** **(d)** $5(9.8)(6)$: **294 J**

Work = force component along the motion × distance.

B2 **(a)** **12 J** **(b)** **48 J** **(c)** $1.5(9.8)(3)$: **44.1 J** **(d)** $v^2 = 2(9.8)(3)$: $7.67\,\text{m s}^{-1}$

Double the speed, four times the kinetic energy.

B3 **(a)** **9 kW** **(b)** $\frac{12000}{20}$: **600 N** **(c)** $\frac{20000}{800}$: $25\,\text{m s}^{-1}$ **(d)** $\frac{20000}{16}$: **1250 N**

At a fixed power, a lower speed gives a larger driving force.

B4 **(a)** $0.25(2)(9.8)$: **4.9 N** **(b)** **9.8 J** **(c)** $\frac{1}{2}(2)v^2 = 36 - 9.8$: $5.12\,\text{m s}^{-1}$ **(d)** $\frac{36}{4.9}$: **7.35 m**

KE at the start = work against friction + KE left.

B5 **(a)** $\frac{40000}{800}$: $50\,\text{m s}^{-1}$ **(b)** $\frac{40000}{800+200}$: $40\,\text{m s}^{-1}$ **(c)** $\frac{40000}{800-200}$: $66.7\,\text{m s}^{-1}$

The weight component $mg\sin\alpha = 200$ N adds to or subtracts from the resistance.

B6 **(a)** $\frac{3000-1000}{1500}$: $1.33\,\text{m s}^{-2}$ **(b)** $0.333\,\text{m s}^{-2}$

(c) **0 (maximum speed)** **(d)** $\frac{1200-1000}{1500}$: $0.133\,\text{m s}^{-2}$

As the speed rises the driving force falls, until it equals the resistance.

STRETCH

B7 **(a)** $4(9.8)\cos 30°$: **33.9 N** **(b)** $0.4R$: **13.6 N**

(c) $13.58(3) + 4(9.8)(1.5)$: **99.5 J** **(d)** $\frac{1}{2}(4)u^2 = 99.5$: $7.05\,\text{m s}^{-1}$

Count the weight once: as PE gained (mgh, $h = 3\sin 30°$), not again as a force.

B8 **(a)** $\frac{1}{2}(70)(10^2 - 4^2) + 30(50)$: **4440 J** **(b)** $\frac{4440}{8}$: **555 W**

(c) $4440 + 70(9.8)(5)$: **7870 J** **(d)** $\frac{7870}{8}$: **984 W**

Work done = gain in KE + gain in PE + work against resistance.

B9 **(a)** $v^2 = 2(9.8)(5)$: $9.90\,\text{m s}^{-1}$ **(b)** $v^2 = 2(9.8)(3.2)$: $7.92\,\text{m s}^{-1}$

(c) $v^2 = 9 + 98$: $10.3\,\text{m s}^{-1}$ **(d)** $98 - 64$: **34 J**

On a smooth ramp the shape does not matter, only the drop in height.

B10 **(a)** $\frac{24000}{15}$: **1600 N** **(b)** $\frac{1600-600}{1200}$: $0.833\,\text{m s}^{-2}$

(c) $T - 200 = 300(0.833)$: **450 N** **(d)** $\frac{24000}{600}$: $40\,\text{m s}^{-1}$

Whole system for a, then the trailer alone for T

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C Reasoning solutions

Your wording can be different. Check that your reason makes the same point.

CORE

C1 The gain is $\frac{1}{2}mv^2 - \frac{1}{2}mu^2$, not $\frac{1}{2}m(v-u)^2$: $\frac{1}{2}(2)(25-9)$: **16 J**

C2 The power must be in watts, 30 000 W: $\frac{30000}{15}$: **2000 N**

C3 He has counted the weight twice: mgh already is the work against $mg\sin 30°$ over 6 m

$5(9.8)(3) + 10(6)$: **207 J**

C4 2000 N is the *driving force*; it equals the resistance only at constant speed

$2000 - R = 1000(0.3)$: $R = 1700$ **N**

STRETCH

C5 The normal reaction is perpendicular to the plane: $R = 2g\cos\alpha = 2(9.8)(0.8)$

$0.5(15.68)$: **7.84 N**

C6 Both particles move at speed v, so both have kinetic energy: total mass 5 kg

$\frac{1}{2}(5)v^2 = 2(9.8)(1.5)$: $3.43\,\text{m s}^{-1}$

C7 The engine does work against the resistance and the weight component; the KE is constant, not the work

30000×40: **1.2 MJ**

C8 **(a)** At maximum speed $a = 0$: $\frac{P}{v} = R + mg\sin\alpha$: $v = \frac{P}{R + mg\sin\alpha}$

(b) On the level at speed v: driving force $\frac{P}{v} = R + mg\sin\alpha$

$(R + mg\sin\alpha) - R = ma$: $a = g\sin\alpha$

D Problem solving solutions

There is often more than one correct method. Any complete, correct method scores full marks.

CORE

D1 $R = 3(9.8)\left(\frac{4}{5}\right) = 23.52$, friction $\frac{1}{4}R = 5.88$; weight component $3(9.8)\left(\frac{3}{5}\right) = 17.64$

$(17.64 + 5.88) \times 8$: **188 J**

D2 **(a)** $\frac{40000}{16} - R = 2000(0.5)$: $R = 1500$

(b) $\frac{40000}{v} = 1500 + \frac{2000(9.8)}{14} = 2900$: $13.8\,\text{m s}^{-1}$

D3 **(a)** $R = 2(9.8)(0.96)$; $0.15R \times 5$: **14.1 J**

(b) PE lost $2(9.8)(5)(0.28) = 27.44$; $\frac{1}{2}(2)v^2 = 27.44 - 14.112$: $3.65\,\text{m s}^{-1}$

D4 $F = \frac{10000}{25} = 400$; $400 - 600 - 1200(9.8)\left(\frac{1}{12}\right) = 1200a$

$a \approx -0.983$: **deceleration** $0.983\,\text{m s}^{-2}$

STRETCH

D5 **(a)** $F = \frac{18000}{12} = 1500$; whole system: $1500 - 450 - 1500(9.8)\left(\frac{1}{20}\right) = 1500a$: $0.21\,\text{m s}^{-2}$

(b) Trailer: $T - 150 - 400(9.8)\left(\frac{1}{20}\right) = 400(0.21)$: **430 N**

D6 **(a)** $\frac{1}{2}(75)(6^2) + 75(9.8)(40) + 25(2000)$: **80 800 J** (80.75 kJ)

(b) $\frac{80750}{400}$: **202 W**

D7 **(a)** Height lost $200 \times \frac{1}{20} = 10$ m; $\frac{1}{2}(800)v^2 = \frac{1}{2}(800)(10^2) + 800(9.8)(10) - 300(200)$

$400v^2 = 58400$: $12.1\,\text{m s}^{-1}$

(b) $800(9.8)\left(\frac{1}{20}\right)$: **392 N**

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D8 **(a)** $\sin\theta = \frac{7}{25}$, $\cos\theta = \frac{24}{25}$; friction $0.25(1.2)(9.8)(0.96) = 2.8224$; $\times 3$: **8.47 J**

(b) $\frac{1}{2}(1.2)U^2 = 8.4672 + 1.2(9.8)(3)(0.28)$: $U = 5.53$

(c) Weight component $1.2(9.8)(0.28) = 3.2928 > 2.8224$, the greatest friction, so it slides back

$\frac{1}{2}(1.2)v^2 = 9.8784 - 8.4672$: $1.53\,\text{m s}^{-1}$

E Exam practice solutions

Mark-scheme notes are shown on the right of each line.

CORE *Exam questions for everyone*

E1 **(a)** $\frac{15000}{v} = 300 + 900(9.8)\left(\frac{1}{18}\right)$ *M1 A1*

$\frac{15000}{790}$: $19.0\,\text{m s}^{-1}$ *A1*

(b) $\frac{15000}{12} - 300 - 490 = 900a$ *M1 A1*

$0.511\,\text{m s}^{-2}$ *A1*

(c) KE lost = PE gained + work against resistance *M1*

$\frac{1}{2}(900)(12^2) = 900(9.8)\left(\frac{d}{18}\right) + 300d$ *A1 A1*

$64800 = 790d$: **82.0 m** *A1*

E2 **(a)** $\frac{1}{2}(60)v^2 = 60(9.8)(20)$ *M1*

$19.8\,\text{m s}^{-1}$ *A1*

(b) $60(9.8)(20) - \frac{1}{2}(60)(15^2)$ *M1*

5010 J *A1*

(c) Friction $0.1(60)(9.8) = 58.8$ *B1*

$58.8d = 6750$ *M1*

115 m *A1*

(d) $50F = 5010$ *M1*

100 N *A1*

STRETCH

E3 **(a)** $\frac{12000}{v} = 500(9.8) + 300$ *M1*

$\boxed{2.31\,\text{m s}^{-1}}$ *A1*

(b) $\frac{12000}{1.5} = 8000;\ 8000 - 4900 - 300 = 500a$ *M1 A1*

$\boxed{5.6\,\text{m s}^{-2}}$ *A1*

(c) Work $= 500(9.8)(10) + \frac{1}{2}(500)(2^2) + 300(10) = 53000$ *M1 A1 A1*

$\frac{53000}{6}$: $\boxed{\textbf{8.83 kW}}$ *A1*

(d) $\frac{1}{2}(500)(2^2) = 500(9.8)h + 300h$ *M1 A1*

$\boxed{\textbf{0.192 m}}$ *A1*

(e) Falling: $(4900 - 300)h = \frac{1}{2}(500)v^2$ with $h = \frac{1000}{5200}$ *M1*

$\boxed{1.88\,\text{m s}^{-1}}$ *A1*