



eClassroom

A-LEVEL MATHEMATICS • MECHANICS 1

Forces and Friction

Worked Solutions

Pearson Edexcel International A Level (WME01) & A Level (9MA0) • Calculator and statistical tables allowed: take $g = 9.8 \text{ m s}^{-2}$ and give answers to 2 or 3 s.f.

Full worked solutions for the free Forces and Friction worksheet, A-Level and International A-Level Maths



Tap a section to jump straight to it

Full worked solutions for every question on the Mechanics 1 Forces and Friction 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 1 exam questions

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A**Your turn answers**

Compare each line of your working with the solution.

CORE

A1 $50 \cos 40^\circ, 50 \sin 40^\circ$: **38.3 N, 32.1 N**

A2 The push presses the box down: $R = 8g + 30 \sin 25^\circ$: **91.1 N**

A3 $\mu R = 0.25(6g) = 14.7 < 18$: **it moves**; $\frac{18 - 14.7}{6}$: **0.55 ms^{-2}**

STRETCH

A4 $9.8 \sin 20^\circ$: **3.35 ms^{-2}**

A5 $9.8(\sin 25^\circ - 0.15 \cos 25^\circ)$: **2.81 ms^{-2}**

A6 $\tan 35^\circ = 0.700 > 0.6$: **yes, it slides**

A7 $a = 0.25g = 2.45$; $0 = 100 - 4.9s$: **20.4 m**

B**Fluency solutions**

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

CORE

B1 (a) $98 - 40 \sin 30^\circ$: **78 N** (b) **15.6 N** (c) $\frac{40 \cos 30^\circ - 15.6}{10}$: **1.90 ms^{-2}** (d) $R = 118$: **1.10 ms^{-2}**

Pushing down increases R , so friction increases.

B2 (a) $2g \cos 25^\circ$: **17.8 N** (b) **4.14 ms^{-2}** (c) $2g \sin 25^\circ$: **8.28 N** (d) $2g \tan 25^\circ$: **9.14 N**

A horizontal force has a component into the plane, so it must be larger.

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B3 (a) 42.4 N (b) 10.6 N (c) $\frac{24.5 - 10.61}{5}$: 2.78 ms^{-2} (d) $\sqrt{2(2.778)(3)}$: 4.08 ms^{-1}

Friction opposes the motion, so it acts up the plane.

B4 (a) $0.1(0.5g)$: 0.49 N (b) 0.98 ms^{-2} (c) $\frac{64}{1.96}$: 32.7 m (d) $\frac{8}{0.98}$: 8.16 s

The deceleration μg does not depend on the mass.

CORE

B5 (a) $0.5(3g)$: 14.7 N (b) friction 10 N ; it stays at rest (c) $\frac{20 - 14.7}{3}$: 1.77 ms^{-2}

$F = \mu R$ only when limiting or moving.

B6 (a) 36.8 N (b) 11.1 N (c) $\frac{40 - 13.41 - 11.05}{4}$: 3.89 ms^{-2} (d) $13.41 + 11.05$: 24.5 N

Up the plane, both the weight component and friction oppose the pull.

STRETCH

B7 (a) 18.9 N (b) 7.57 N (c) 5.07 N (d) $7.57 - 5.07$: 2.50 N

The push only has to make up the difference.

B8 (a) $\tan 22^\circ$: 0.404 (b) $g(\sin 30^\circ - 0.404 \cos 30^\circ)$: 1.47 ms^{-2}
 (c) $3g(\sin 30^\circ + 0.404 \cos 30^\circ)$: 25.0 N (d) $\tan 15^\circ = 0.268 < 0.404$: yes

At constant speed down a plane, $\mu = \tan \alpha$

B9 (a) $5g \cos 30^\circ - 60 \sin 20^\circ$: 21.9 N (b) 6.57 N (c) $\frac{56.38 - 24.5 - 6.57}{5}$: 5.06 ms^{-2}
 (d) 4.55 ms^{-2}

Pulling at an angle reduces R and so reduces friction.

B10 (a) $0.2(5g)$: 9.8 N (b) $\frac{30 - 9.8}{5}$: 4.04 ms^{-2} (c) $2(4.04) + 3.92$: 12 N (d) 12 N

With the same μ for both, the tension is $\frac{2}{5}$ of the pull whatever μ is.



C**Reasoning solutions**

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

CORE

- C1** The pull has an upward component: $R = 5g - 20 \sin 30^\circ = \boxed{39 \text{ N}}$
- C2** Friction opposes the motion: $\boxed{\text{it acts up the plane}}$ while the particle slides down.
- C3** The block is not on the point of moving, so friction just balances the push: $\boxed{8 \text{ N}}$ (less than $\mu R = 19.6 \text{ N}$).
- C4** The string has a component perpendicular to the plane: $\boxed{R = mg \cos \alpha - T \sin 30^\circ}$

STRETCH

- C5** Constant speed means $a = 0$: $\boxed{\text{the resultant force is zero}}$, so the forces balance.
- C6** At rest, friction needed $\leq$ friction available: $\boxed{mg \sin \alpha \leq \mu R, \text{ so } \mu \geq \tan \alpha}$
- C7** R is a force, so the weight $5g$ is needed: $\boxed{\text{friction} = 5g\mu = 49\mu}$
- C8** (a) It slides if $mg \sin \alpha > \mu mg \cos \alpha$; divide by $mg \cos \alpha > 0$: $\boxed{\tan \alpha > \mu}$
(b) $\tan^{-1} 0.45$: $\boxed{24.2^\circ}$

D**Problem solving solutions**

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

CORE

- D1** (a) $a = g(\sin 30^\circ - 0.2 \cos 30^\circ)$: $\boxed{3.20 \text{ ms}^{-2}}$
(b) $4 = \frac{1}{2}(3.203)t^2$: $\boxed{1.58 \text{ s}}$



- D2** (a) $R = 12g - T \sin 25^\circ$; $T \cos 25^\circ = 0.4R$, so $T(\cos 25^\circ + 0.4 \sin 25^\circ) = 0.4(12g)$: **43.7 N**
(b) $43.74 \cos 25^\circ$: **39.6 N**

D3 $a = \frac{9-1}{4} = 2$; $mg \sin 20^\circ - \mu mg \cos 20^\circ = 2m$: **$\mu = 0.147$**

- D4** On the point of slipping down, friction acts up: $X = 3g(\sin 35^\circ - 0.3 \cos 35^\circ)$: **9.64 N**

STRETCH

- D5** (a) $120 - 20g \sin 15^\circ - 0.25(20g \cos 15^\circ) = 20a$: **1.10 ms^{-2}**
(b) $\sqrt{2(1.097)(5)}$: **3.31 ms^{-1}**

- D6** (a) $R = 4g \cos 20^\circ + H \sin 20^\circ$; $H \cos 20^\circ = 4g \sin 20^\circ + 0.3R$: **$H = 29.2$**
(b) $36.84 + 29.22 \sin 20^\circ$: **46.8 N**

- D7** (a) $A: 20 - 2g(0.6) - 0.5(2g)(0.8) = 2a$: **0.2 ms^{-2}**
(b) $B: Mg - 20 = 0.2M$: **$M = 2.08$**

- D8** (a) $R = 6g + P \sin 30^\circ$; at rest $P \cos 30^\circ \leq 0.5R$: $P(\cos 30^\circ - 0.25) \leq 29.4$: **$P = 47.7$**
(b) Moves only if $P \cos 30^\circ > \mu(6g + P \sin 30^\circ)$, i.e. $P(\cos 30^\circ - \mu \sin 30^\circ) > 6\mu g$. If $\mu > \sqrt{3}$ the bracket is negative, so **no P works**

E**Exam practice solutions**

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



CORE

Exam questions for everyone

- E1** (a) $\sin \alpha = \frac{7}{25}$, $\cos \alpha = \frac{24}{25}$; $\tan \alpha = 0.292 < 0.4$ M1
- friction can hold it: it stays at rest** A1
- (b) $P - 5g \left(\frac{7}{25} \right) - 0.4 \left(5g \cdot \frac{24}{25} \right) = 5(1.2)$ M1 A1
- $P = 38.5$** A1
- (c) $v = 3.6$; deceleration $g \left(\frac{7}{25} + 0.4 \cdot \frac{24}{25} \right) = 6.507$ M1 A1
- $\frac{3.6^2}{2(6.507)}$: **0.996 m** A1
- (d) At rest, needs $mg \sin \alpha \leq \mu mg \cos \alpha$: $0.28 < 0.384$ M1
- it stays at rest** A1

- E2** (a) $B: 4g - T = 4a$; $A: T - 3g \sin 30^\circ - 0.2(3g \cos 30^\circ) = 3a$ M1 A1 M1
- $a = 2.77 \text{ ms}^{-2}$** A1
- (b) $4(9.8 - 2.773)$: **28.1 N** B1
- (c) Angle between the two parts of the string is 60° : $2T \cos 30^\circ$ M1 A1
- 48.7 N** A1
- (d) Not moving up: $Mg \leq 3g \sin 30^\circ + 0.2(3g \cos 30^\circ)$; not moving down: $Mg \geq 3g \sin 30^\circ - 0.2(3g \cos 30^\circ)$ M1 M1
- $0.980 \leq M \leq 2.02$** A1

STRETCH

- E3** (a) $30g - 80 \sin 20^\circ$ M1
- 267 N** A1
- (b) $80 \cos 20^\circ - 0.15(266.6) = 30a$ M1 A1
- 1.17 ms^{-2}** A1
- (c) $v = 8(1.173) \approx 9.38$; deceleration $0.15g = 1.47$ M1 A1
- $\frac{9.38^2}{2.94}$: **29.9 m** A1
- (d) $T \cos 20^\circ = 0.15(30g - T \sin 20^\circ)$ M1 A1
- 44.5 N** A1
- (e) Horizontal: $0.15(30g) = 44.1 \text{ N}$, slightly less. B1
- Lifting cuts friction by $0.15T \sin 20^\circ$**
- but loses $T(1 - \cos 20^\circ)$ of pull** B1

