



eClassroom

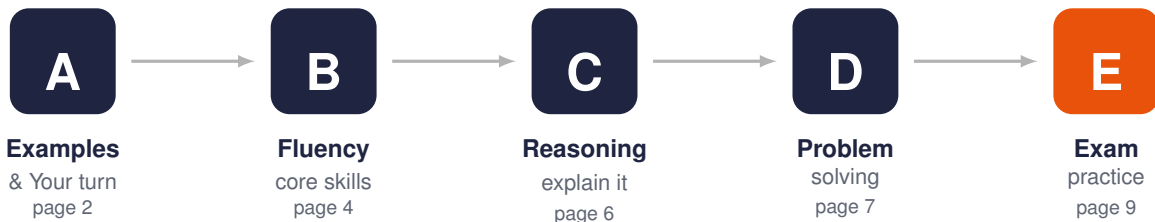
A-LEVEL MATHEMATICS • MECHANICS 1

Forces and Friction

Worksheet

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.

Free Forces and Friction worksheet for A-Level and International A-Level Maths, with full worked solutions



Tap a section to jump straight to it

By the end of this worksheet you can: resolve forces and find normal reactions • use $F \leq \mu R$ • solve motion on rough horizontal surfaces • solve motion on rough inclined planes • *Stretch:* forces at angles to a plane, pulleys on rough planes, and deciding whether motion starts.

Which questions are for me?

CORE The methods every A-level student must secure. Start here.

STRETCH Normal reactions that are not mg , friction that changes direction, and whether anything moves at all.

Every section has both, clearly labelled. Questions get harder as you go, and every skill in Sections A to D is needed in Section E.

Track your progress

Section	B	C	D	E
Core marks	23	10	13	21
Stretch marks	16	14	17	13
My score				

Full worked solutions

Exam questions by topic

Mechanics 1 exam questions

Formula sheet builder

Name

Class

Date



Join students already acing their exams.

Book your FREE lesson at www.eclassroom.org.uk

A**Worked examples & Your turn**

Read each example carefully. Cover it up, then answer the question beside it using the same method.

CORE*Secure the method***Worked example A1: resolving a force**

Resolve a 20 N force at 30° above the horizontal into horizontal and vertical components.

$P \cos \theta$ along, $P \sin \theta$ perpendicular

17.3 N, 10 N

Your turn A1

Resolve a 50 N force at 40° above the horizontal into horizontal and vertical components.

Worked example A2: the normal reaction

A 5 kg box on a floor is pulled by 20 N at 30° above the horizontal. Find R

Resolve vertically: the pull lifts the box

$$R + 20 \sin 30^\circ = 5g$$

$R = 39 \text{ N}$

Your turn A2

An 8 kg box on a floor is pushed by 30 N at 25° below the horizontal. Find R

Worked example A3: does it move?

A 4 kg block on a rough floor ($\mu = 0.3$) is pushed horizontally with 10 N. Does it move?

Compare the push with the greatest friction μR

$$\mu R = 0.3(4g) = 11.76 > 10$$

no; friction is 10 N

Your turn A3

A 6 kg block on a rough floor ($\mu = 0.25$) is pushed horizontally with 18 N. Does it move? If so, find a



STRETCH

Worked example A4: a smooth plane

Find the acceleration of a particle sliding down a smooth plane at 30°

Along the plane: $mg \sin \alpha = ma$

$$4.9 \text{ m s}^{-2}$$

Your turn A4

Find the acceleration of a particle sliding down a smooth plane at 20°

Worked example A5: a rough plane

A particle slides down a rough plane at 40° with $\mu = 0.3$. Find its acceleration.

$R = mg \cos \alpha$; friction acts up the plane

$$ma = mg \sin 40^\circ - 0.3mg \cos 40^\circ$$

$$4.05 \text{ m s}^{-2}$$

Your turn A5

A particle slides down a rough plane at 25° with $\mu = 0.15$. Find its acceleration.

Worked example A6: will it slide?

A particle rests on a rough plane at 20° with $\mu = 0.4$. Will it slide?

Slides if $mg \sin \alpha > \mu mg \cos \alpha$, i.e. $\tan \alpha > \mu$

$$\tan 20^\circ = 0.364 < 0.4$$

no

Your turn A6

A particle rests on a rough plane at 35° with $\mu = 0.6$. Will it slide?

Worked example A7: stopping on a floor

A puck slides at 6 m s^{-1} on a rough floor with $\mu = 0.3$. How far does it travel?

Deceleration μg ; then $v^2 = u^2 + 2as$

$$a = 2.94; 0 = 36 - 5.88s$$

$$6.12 \text{ m}$$

Your turn A7

A puck slides at 10 m s^{-1} on a rough floor with $\mu = 0.25$. How far does it travel?



B**Fluency**

Each question is a designed sequence. From one part to the next, ask yourself: what changed, and what did it do to the answer?

CORE*Secure the method*

- B1** A 10 kg box on a rough floor ($\mu = 0.2$) is pulled by a 40 N force at 30° above the horizontal.
- (a) Find R (b) Find the greatest friction
- (c) Find the acceleration (d) Find a if it is pushed at 30° below the horizontal
- [4 marks]
- B2** A 2 kg particle is on a smooth plane at 25°
- (a) Find R (b) Find its acceleration if released
- (c) Find the force up the slope to hold it (d) Find the horizontal force to hold it
- [4 marks]
- B3** A 5 kg particle slides down a rough plane at 30° with $\mu = 0.25$
- (a) Find R (b) Find the friction
- (c) Find the acceleration (d) Find its speed after 3 m from rest
- [4 marks]
- B4** A 0.5 kg puck slides across a rough floor from 8 m s^{-1} ; $\mu = 0.1$
- (a) Find the friction (b) Find the deceleration
- (c) Find the distance to stop (d) Find the time to stop
- [4 marks]



CORE

continued: limits and slopes

- B5** A 3 kg block is on a rough floor with $\mu = 0.5$, and a horizontal force P acts on it.
- (a) Find the greatest friction.
 - (b) $P = 10$ N: state the friction and whether it moves.
 - (c) $P = 20$ N: find the acceleration. [3 marks]
- B6** A 4 kg block is pulled up a rough plane at 20° by a 40 N force parallel to the slope; $\mu = 0.3$
- (a) Find R
 - (b) Find the friction
 - (c) Find the acceleration
 - (d) Find the force for constant speed [4 marks]

STRETCH

- B7** A 2 kg block rests on a rough plane at 15° with $\mu = 0.4$
- (a) Find R
 - (b) Find the greatest friction
 - (c) Find the weight component down the plane
 - (d) Find the least push down the slope to move it [4 marks]
- B8** A block slides down a rough plane at 22° at constant speed.
- (a) Find μ
 - (b) Find its acceleration down a 30° plane
 - (c) Find the force to push 3 kg up the 30° plane at constant speed
 - (d) Would it stay at rest on a 15° plane? [4 marks]
- B9** A 5 kg block on a rough plane at 30° ($\mu = 0.3$) is pulled up the slope by 60 N at 20° above the line of greatest slope.
- (a) Find R
 - (b) Find the friction
 - (c) Find the acceleration
 - (d) Find a if the 60 N acts along the slope [4 marks]
- B10** A (3 kg) and B (2 kg) are joined by a light string on a rough floor; A is pulled by 30 N horizontally, $\mu = 0.2$ for both.
- (a) Find the total friction
 - (b) Find a
 - (c) Find the tension
 - (d) Find the tension if $\mu = 0.4$ [4 marks]



C**Reasoning**

Show your working and explain your thinking. A correct answer without a reason does not score full marks.

CORE*Secure the method*

- C1** A 5 kg box is pulled by 20 N at 30° above the horizontal on a rough floor. Ama writes $R = 5g$
Explain her error, and find R [2 marks]
- C2** A particle slides down a rough plane. Ben draws the friction acting down the plane.
Explain his error. [2 marks]
- C3** A 4 kg block on a floor with $\mu = 0.5$ is pushed with 8 N and does not move. Cal writes the friction as $\mu R = 19.6$ N
Explain his error, and give the friction. [3 marks]
- C4** A particle on a rough plane at α is held by a string at 30° to the plane. Dee writes $R = mg \cos \alpha$
Explain her error. [3 marks]

STRETCH

- C5** A sledge is pulled at constant speed. Eli writes “the resultant force is ma , so I need the acceleration first”.
Explain his error. [3 marks]
- C6** A particle remains at rest on a rough plane. Faye writes $\mu R \leq mg \sin \alpha$ to find the possible values of μ
Explain her error, and write the correct condition. [3 marks]
- C7** For a 5 kg block on a floor, Gus writes the friction as $\mu \times 5$
Explain his error, and give the correct expression. [3 marks]
- C8** A particle is placed at rest on a rough plane inclined at α , where the coefficient of friction is μ
(a) Show that it slides if and only if $\tan \alpha > \mu$ (3)
(b) Find the least angle at which it slides when $\mu = 0.45$ (2)
[5 marks]



D**Problem solving**

You decide the method. Read the whole question first, and show every step.

CORE

Secure the method

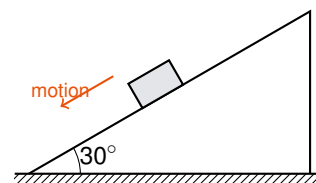
- D1** A particle is released from rest on a rough plane inclined at 30° to the horizontal. The coefficient of friction between the particle and the plane is 0.2

(a) Find the acceleration of the particle.

(2)

(b) Find the time it takes to slide 4 m down the plane.

(1)



[3 marks]

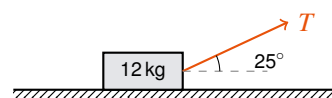
- D2** A box of mass 12 kg is pulled at constant speed across a rough horizontal floor by a light rope inclined at 25° above the horizontal. The coefficient of friction between the box and the floor is 0.4

(a) Find the tension in the rope.

(3)

(b) Find the magnitude of the frictional force.

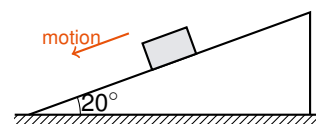
(1)



[4 marks]

- D3** A parcel slides down a straight rough ramp inclined at 20° to the horizontal. Its speed increases from 1 m s^{-1} to 3 m s^{-1} as it slides 2 m down the ramp.

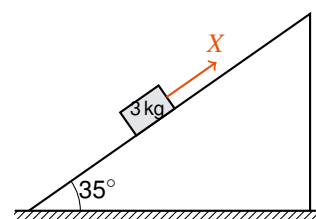
Find the coefficient of friction between the parcel and the ramp.



[3 marks]

- D4** A block of mass 3 kg rests on a rough plane inclined at 35° to the horizontal. The coefficient of friction is 0.3. The block is held at rest by a force X newtons acting up the slope, parallel to a line of greatest slope.

Find the least possible value of X



[3 marks]



STRETCH

- D5** A crate of mass 20 kg is pulled up a rough slope inclined at 15° to the horizontal by a rope parallel to the slope. The tension in the rope is 120 N and the coefficient of friction is 0.25

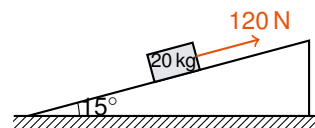
(a) Find the acceleration of the crate.

(3)

(b) The crate starts from rest. Find its speed after it has moved 5 m.

(1)

[4 marks]



- D6** A block of mass 4 kg is pushed up a rough plane inclined at 20° to the horizontal by a horizontal force of magnitude H newtons, in a vertical plane containing a line of greatest slope. The block moves at constant speed and $\mu = 0.3$

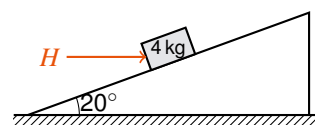
(a) Find the value of H

(3)

(b) Find the normal reaction.

(1)

[4 marks]



- D7** A particle A of mass 2 kg is on a rough plane inclined at α , where $\tan \alpha = \frac{3}{4}$, with $\mu = 0.5$. A light string from A passes over a smooth pulley at the top of the plane to a particle B of mass M kg hanging freely. When released, A moves up the plane and the tension in the string is 20 N

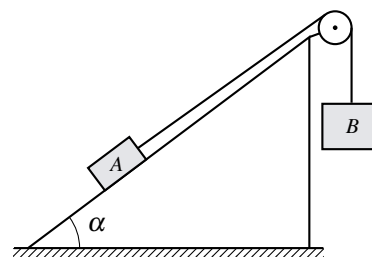
(a) Find the acceleration of A

(2)

(b) Find the value of M

(2)

[4 marks]



- D8** A block of mass 6 kg rests on a rough horizontal floor. A force P newtons pushes on it at 30° below the horizontal. The coefficient of friction is μ

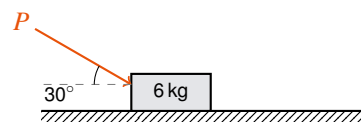
(a) Given that $\mu = 0.5$, find the greatest P for which the block stays at rest.

(3)

(b) Show that if $\mu > \sqrt{3}$, the block cannot be moved however large P is.

(2)

[5 marks]



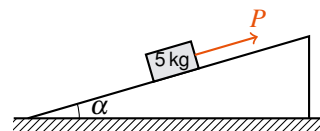
E**Exam practice**

Full-size exam questions in the style of WME01. Write your answers in the spaces, and show every step.

CORE

Exam questions for everyone

- E1** A block of mass 5 kg is placed on a rough plane inclined at an angle α to the horizontal, where $\tan \alpha = \frac{7}{24}$. The coefficient of friction between the block and the plane is 0.4. The block is modelled as a particle and air resistance is ignored.



- (a) Show that the block remains at rest when it is placed on the plane and released.

(2)

A force of magnitude P newtons, acting up the plane parallel to a line of greatest slope, now pulls the block up the plane from rest with acceleration 1.2 m s^{-2}

- (b) Find the value of P

(3)

After 3 seconds the force is removed.

- (c) Find the further distance the block moves up the plane.

(3)

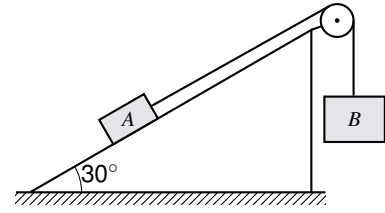
- (d) Determine whether the block then slides back down the plane after it comes to instantaneous rest. You must justify your answer.

(2)

(Total for Question E1 is 10 marks)



- E2** A particle A of mass 3 kg lies on a rough plane inclined at 30° to the horizontal. The coefficient of friction between A and the plane is 0.2 . A light inextensible string attached to A passes over a small smooth pulley at the top of the plane and is attached to a particle B of mass 4 kg , which hangs vertically. The string from A to the pulley lies along a line of greatest slope. The system is released from rest with the string taut, and the particles are modelled as particles.



- (a) Find the acceleration of the particles.

(4)

- (b) Find the tension in the string.

(1)

- (c) Find the magnitude of the force exerted on the pulley by the string.

(3)

Particle B is now replaced by a particle of mass $M\text{ kg}$, and the system is again released from rest with the string taut.

- (d) Find the range of values of M for which the system remains at rest.

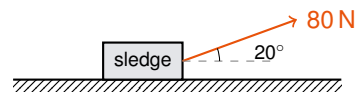
(3)

(Total for Question E2 is 11 marks)



STRETCH

- E3** A child sits on a sledge on horizontal snow; the child and sledge have total mass 30 kg and are modelled as a particle. The sledge is pulled from rest by a light rope inclined at 20° above the horizontal. The tension in the rope is 80 N and the coefficient of friction between the sledge and the snow is 0.15



- (a) Find the normal reaction between the sledge and the snow.

(2)

- (b) Find the acceleration of the sledge.

(3)

After 8 seconds the rope is released.

- (c) Find the distance the sledge travels after the rope is released, before it comes to rest.

(3)

On another day, with the same snow conditions, the sledge is pulled at constant speed with the rope again at 20° above the horizontal.

- (d) Find the tension in the rope.

(3)

- (e) Compare your answer to part (d) with the force needed to pull the sledge at constant speed if the rope were horizontal, and explain the result.

(2)

(Total for Question E3 is 13 marks)

Want more exam practice? The **Exam Questions by Topic** booklets have 10 more full exam questions on Mechanics 1 Chapter 5, Forces and Friction, with a full mark scheme.

[Open the booklet](#)

Finished? Mark your work with the **full worked solutions**, fill in your scores on the front page, then practise real exam questions on the **Mechanics 1 exam questions page**.

