



eClassroom

A-LEVEL MATHEMATICS • MECHANICS 1

Statics of a Particle

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 Statics of a Particle 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 for a particle in equilibrium • solve problems with strings and smooth rings • use vector forces in equilibrium • use limiting friction • *Stretch:* ranges of forces for equilibrium, forces at angles to rough planes, and show-that inequalities.

Which questions are for me?

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

STRETCH Particles that stay put: strings, rings, rods, rough surfaces, and the range of forces that keeps them there.

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	17
Stretch marks	16	14	17	10
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: two strings

A 20 N weight hangs from two strings at 60° and 30° to the horizontal. Find each tension.

Resolve horizontally and vertically

$$T_1 \cos 60^\circ = T_2 \cos 30^\circ; \quad T_1 \sin 60^\circ + T_2 \sin 30^\circ = 20$$

$$T_1 = 17.3 \text{ N}, \quad T_2 = 10 \text{ N}$$

Your turn A1

A 50 N weight hangs from two strings at 50° and 40° to the horizontal. Find each tension.

Worked example A2: vector forces

Forces $(3\mathbf{i} + 5\mathbf{j}) \text{ N}$, $(-7\mathbf{i} + 2\mathbf{j}) \text{ N}$ and $\mathbf{F}$ keep a particle in equilibrium. Find $\mathbf{F}$ and $|\mathbf{F}|$

The forces add to zero

$$\mathbf{F} = 4\mathbf{i} - 7\mathbf{j}, \quad 8.06 \text{ N}$$

Your turn A2

Forces $(6\mathbf{i} - 2\mathbf{j}) \text{ N}$, $(-\mathbf{i} - 9\mathbf{j}) \text{ N}$ and $\mathbf{F}$ keep a particle in equilibrium. Find $\mathbf{F}$ and $|\mathbf{F}|$

Worked example A3: a smooth plane

A 3 kg particle is held at rest on a smooth plane at 30° by a horizontal force H . Find H and R

*Resolve horizontally and vertically: $R \sin \alpha = H$,
 $R \cos \alpha = mg$*

$$H = 17.0 \text{ N}, \quad R = 33.9 \text{ N}$$

Your turn A3

A 2 kg particle is held at rest on a smooth plane at 25° by a horizontal force H . Find H and R



STRETCH

Worked example A4: limiting friction

A 4 kg block is on the point of moving under a 15 N horizontal pull. Find μ

Limiting: $F = \mu R$

$$15 = \mu(4g)$$

$$\mu = 0.383$$

Your turn A4

A 7 kg block is on the point of moving under a 20 N horizontal pull. Find μ

Worked example A5: on the point of slipping

A particle on a rough plane at 25° is on the point of slipping. Find μ

$$mg \sin \alpha = \mu mg \cos \alpha$$

$$\mu = \tan 25^\circ = 0.466$$

Your turn A5

A particle on a rough plane at 32° is on the point of slipping. Find μ

Worked example A6: the least holding force

A 5 kg block on a rough plane at 35° ($\mu = 0.3$) is held by a force P up the slope. Find the least P

About to slip down: friction acts up the slope

$$P + 0.3(5g \cos 35^\circ) = 5g \sin 35^\circ$$

$$16.1 \text{ N}$$

Your turn A6

A 4 kg block on a rough plane at 40° ($\mu = 0.4$) is held by a force P up the slope. Find the least P

Worked example A7: a balancing force

Horizontal forces of 6 N due east and 8 N due north act on a particle. Find the third force that keeps it in equilibrium.

Equal and opposite to the resultant

Resultant 10 N on 037°

$$10 \text{ N on a bearing of } 217^\circ$$

Your turn A7

Horizontal forces of 5 N due east and 12 N due south act on a particle. Find the third force that keeps it in equilibrium.



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 An 8 kg mass hangs from two strings at 35° and 55° to the horizontal.

- (a) Find the tension in the 35° string (b) Find the tension in the 55° string
(c) Either string breaks at 100 N: find the greatest weight (d) Find the greatest mass

[4 marks]

B2 $(2\mathbf{i} + 3\mathbf{j})$, $(p\mathbf{i} - 5\mathbf{j})$ and $(-4\mathbf{i} + q\mathbf{j})$ N keep a particle in equilibrium.

- (a) Find p (b) Find q
(c) Find the magnitude of the third force (d) The first force is removed: find the resultant's magnitude

[4 marks]

B3 A 6 kg particle rests on a smooth plane at 20°

- (a) Find the force parallel to the slope that holds it (b) Find R then
(c) Find the horizontal force that holds it (d) Find R then

[4 marks]

B4 A 10 kg box is on the point of moving under a 30 N pull at 25° above the horizontal.

- (a) Find R (b) Find the friction
(c) Find μ (d) Find the friction if the pull is 20 N horizontally

[4 marks]



CORE

continued: rough planes

- B5** A 3 kg particle rests on a rough plane at 20° with $\mu = 0.5$
- (a) Find the friction acting.
 - (b) Find the greatest possible friction.
 - (c) Explain why the particle stays at rest. [3 marks]
- B6** A 2 kg particle is on a rough plane at 30° with $\mu = 0.25$, held by a force P up the slope.
- (a) Find R
 - (b) Find the greatest friction
 - (c) Find the least P for equilibrium
 - (d) Find the greatest P for equilibrium [4 marks]

STRETCH

- B7** A 30 N weight hangs at P from strings $AP = 3$ m and $BP = 4$ m, where A and B are 5 m apart on a horizontal ceiling.
- (a) Find the angle AP makes with the ceiling
 - (b) Find the tension in AP
 - (c) Find the tension in BP
 - (d) Find the depth of P below the ceiling [4 marks]
- B8** A 5 kg particle is on a rough plane at 25° with $\mu = 0.2$, held by a horizontal force H
- (a) Find the least H
 - (b) Find the greatest H
 - (c) Find R at the greatest H
 - (d) Find the friction when $H = 20$ N [4 marks]
- B9** Horizontal forces of 10 N due north and 6 N due east act on a particle, together with a third force that keeps it in equilibrium.
- (a) Find the third force's magnitude
 - (b) Find its bearing
 - (c) The east force becomes 12 N: find the resultant
 - (d) The particle has mass 0.5 kg: find a [4 marks]
- B10** A 4 kg particle rests on a smooth plane at 30° , held by a string parallel to the slope that passes over a smooth pulley to a hanging mass M
- (a) Find the tension
 - (b) Find M
 - (c) Find R
 - (d) Find the force on the pulley [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 particle on a horizontal floor is held by a string pulling upwards at an angle. Ama writes $R = mg$
Explain her error. [2 marks]
- C2** For a particle in equilibrium, Ben writes “resultant force = ma ”.
Explain his error. [2 marks]
- C3** A block rests on a rough plane and is not on the point of slipping. Cal writes $F = \mu R$
Explain his error. [3 marks]
- C4** To find the greatest force P up a rough plane for equilibrium, Dee takes friction acting up the plane.
Explain her error. [3 marks]

STRETCH

- C5** A particle remains at rest on a rough floor. Eli writes $P \cos \alpha \geq \mu R$
Explain his error, and write the correct condition. [3 marks]
- C6** For a 2 kg particle, Faye writes the weight component down a 30° plane as $2 \sin 30^\circ$
Explain her error, and give the correct value. [3 marks]
- C7** A 10 N force acts at 30° above the horizontal. Gus writes its vertical component as $10 \cos 30^\circ$
Explain his error, and give the correct value. [3 marks]
- C8** A particle of weight W hangs from two perpendicular strings, one at θ to the horizontal.
(a) Show that the tension in that string is $W \sin \theta$ and in the other is $W \cos \theta$ (3)
(b) Hence explain which string has the greater tension when $\theta > 45^\circ$ (2)
[5 marks]



D

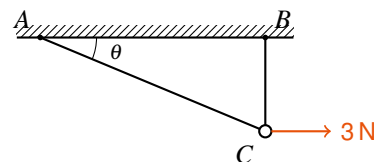
Problem solving

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

CORE

Secure the method

- D1** A small smooth ring C is threaded on a light inextensible string whose ends are fixed at points A and B on a horizontal ceiling. A horizontal force of 3 N holds the ring at rest vertically below B , with the string taut. The string AC makes an angle θ with the ceiling, where $\tan \theta = \frac{5}{12}$. Find the tension in the string and the mass of the ring.



[3 marks]

- D2** In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal perpendicular unit vectors.

A particle rests in equilibrium on a smooth horizontal plane under forces $(2c\mathbf{i} - c\mathbf{j})\text{ N}$, $(-9\mathbf{i} + 13\mathbf{j})\text{ N}$ and $\mathbf{F}_3\text{ N}$

- (a) Find $\mathbf{F}_3$ in terms of c , $\mathbf{i}$ and $\mathbf{j}$

(2)

- (b) The force $\mathbf{F}_3$ is removed and $c = 3$. Find the magnitude of the resultant force and the angle it makes with $\mathbf{i}$

(2)

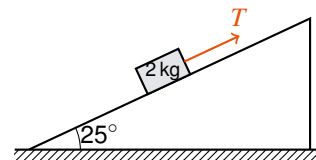
[4 marks]

- D3** A block of mass 2 kg rests on a rough plane inclined at 25° to the horizontal. The coefficient of friction is 0.3 . The block is held by a light string parallel to the line of greatest slope.
- (a) Find the least tension for which the block stays at rest.

(2)

- (b) Explain why the block cannot stay at rest with no string.

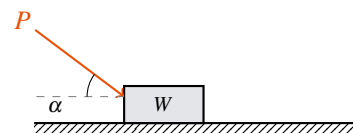
(1)



[3 marks]

- D4** A particle of weight W newtons rests on a rough horizontal floor. A force of magnitude P newtons pushes the particle at an angle α below the horizontal, where $\tan \alpha = \frac{3}{4}$. The coefficient of friction is $\frac{1}{3}$

Given that the particle does not move, show that $P \leq \frac{5}{9}W$

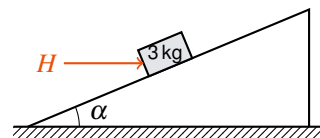


[3 marks]



STRETCH

- D5** A particle of mass 3 kg rests on a rough plane inclined at α to the horizontal, where $\tan \alpha = \frac{5}{12}$. The coefficient of friction is 0.2. It is held by a horizontal force H newtons in the vertical plane containing a line of greatest slope.



(a) Find the least value of H

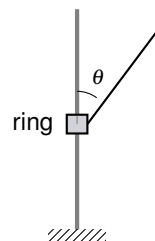
(3)

(b) Find the normal reaction for this value of H

(1)

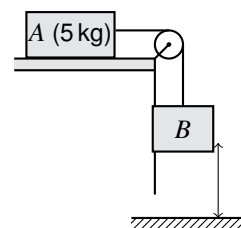
[4 marks]

- D6** A ring of mass 0.5 kg is threaded on a fixed rough vertical rod. A light string attached to the ring pulls upwards at an angle θ to the rod, where $\tan \theta = \frac{3}{4}$. The coefficient of friction between the ring and the rod is 0.5. Find the range of values of the tension T for which the ring stays at rest.



[4 marks]

- D7** A block A of mass 5 kg rests on a rough horizontal table, with $\mu = 0.35$. A light string from A passes over a smooth pulley at the edge of the table to a particle B of mass m kg hanging freely.



(a) Find the value of m for which A is on the point of slipping.

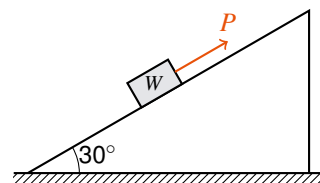
(2)

(b) Find the friction on A when $m = 1$

(2)

[4 marks]

- D8** A particle of weight W rests on a rough plane inclined at 30° , with $\mu = 0.4$. A force P acts on it up the plane, parallel to a line of greatest slope.



(a) Find, in terms of W , the range of values of P for which the particle stays at rest.

(3)

(b) Find the value of P for which there is no friction.

(2)

[5 marks]



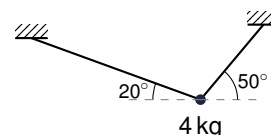
E**Exam practice**

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 particle P of mass 4 kg hangs in equilibrium, attached to two light inextensible strings whose other ends are fixed. One string makes an angle of 20° with the horizontal and the other makes an angle of 50° with the horizontal, as shown. The strings and the particle lie in the same vertical plane.



- (a) Find the tension in each string.

(5)

The 20° string will break if its tension exceeds 30 N , and the 50° string will break if its tension exceeds 50 N

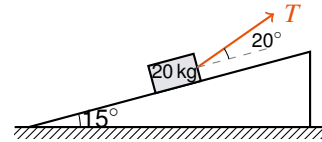
- (b) Find the greatest mass that can hang at P , with both strings in the same positions, without either string breaking.

(3)

(Total for Question E1 is 8 marks)



- E2** A crate of mass 20 kg rests on a rough plane inclined at 15° to the horizontal. The coefficient of friction between the crate and the plane is 0.4. The crate is modelled as a particle and the plane is fixed.



- (a) Show that the crate remains at rest on the plane when no other force acts.

(2)

A light rope is attached to the crate and pulls it at an angle of 20° above the line of greatest slope, in the vertical plane containing that line.

- (b) Find the least tension in the rope that will make the crate start to move up the plane. You must show your working clearly.

(5)

- (c) Find the normal reaction between the crate and the plane when the tension takes this least value.

(2)

(Total for Question E2 is 9 marks)



STRETCH

E3 In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal perpendicular unit vectors.

A particle of mass 2 kg rests in equilibrium on a smooth horizontal surface under the action of three horizontal forces, and no other horizontal forces act on it. The three forces are $\mathbf{F}_1 = (4\mathbf{i} + 3\mathbf{j})$ N, $\mathbf{F}_2 = (-2\mathbf{i} + 6\mathbf{j})$ N and $\mathbf{F}_3$ N

(a) Find $\mathbf{F}_3$

(2)

(b) Find the magnitude of $\mathbf{F}_3$, and the angle it makes with the direction of $-\mathbf{j}$

(2)

The force $\mathbf{F}_2$ is removed and the particle starts to move from rest.

(c) Find the magnitude of the acceleration of the particle.

(2)

(d) Find the time taken for the particle to reach a speed of 10 ms^{-1}

(2)

(e) Find the distance travelled by the particle in the first 4 seconds of its motion after $\mathbf{F}_2$ is removed.

(2)

(Total for Question E3 is 10 marks)

Want more exam practice? The **Exam Questions by Topic** booklets have 10 more full exam questions on Mechanics 1 Chapter 7, Statics of a Particle, 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**.



Join students already acing their exams.

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