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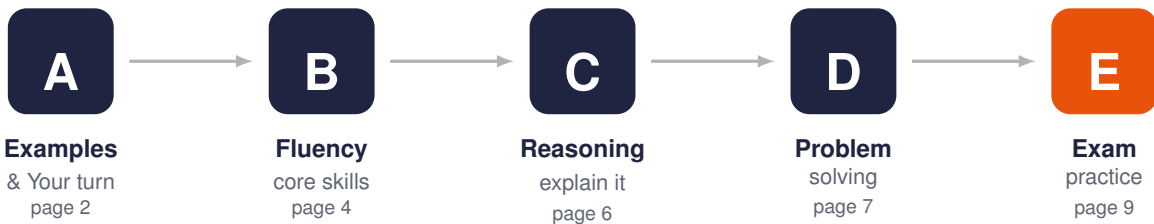
A-LEVEL MATHEMATICS • MECHANICS 1

Dynamics 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 Dynamics 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: use $F = ma$ with force diagrams • solve vertical motion, lifts and forces as vectors • model connected particles and towing • *Stretch:* pulleys, Newton's third law, and motion after a string breaks or goes slack.

Which questions are for me?

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

STRETCH One equation of motion per particle, pulleys and lifts, and what changes when a string breaks.

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				

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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: Newton's second law**

A 5 kg box is pulled along a floor by a 40 N force against a resistance of 15 N. Find its acceleration.

Resultant force = ma

$$40 - 15 = 5a$$

$$a = 5 \text{ m s}^{-2}$$

Your turn A1

An 8 kg box is pulled along a floor by a 50 N force against a resistance of 18 N. Find its acceleration.

Worked example A2: vertical motion

A 3 kg bucket is raised by a rope with acceleration 2 m s^{-2} upwards. Find the tension.

Upwards: $T - mg = ma$

$$T = 3(9.8 + 2)$$

$$T = 35.4 \text{ N}$$

Your turn A2

A 5 kg bucket is lowered by a rope with acceleration 1.5 m s^{-2} downwards. Find the tension.

Worked example A3: forces as vectors

Forces $(6\mathbf{i} - 2\mathbf{j}) \text{ N}$ and $(2\mathbf{i} + 8\mathbf{j}) \text{ N}$ act on a 2 kg particle. Find the magnitude of its acceleration.

Add the forces, divide by m , then find the magnitude

$$\mathbf{a} = \frac{1}{2}(8\mathbf{i} + 6\mathbf{j}) = 4\mathbf{i} + 3\mathbf{j}$$

$$5 \text{ m s}^{-2}$$

Your turn A3

Forces $(3\mathbf{i} + 7\mathbf{j}) \text{ N}$ and $(9\mathbf{i} - 2\mathbf{j}) \text{ N}$ act on a 4 kg particle. Find the magnitude of its acceleration.



STRETCH

Worked example A4: towing

A 900 kg car tows a 300 kg trailer. The driving force is 1800 N; the resistances are 200 N on the car and 100 N on the trailer. Find a and the towbar tension.

Whole system for a ; then the trailer alone for T

$$1500 = 1200a; \quad T - 100 = 300a$$

$$a = 1.25 \text{ ms}^{-2}, \quad T = 475 \text{ N}$$

Your turn A4

A 1100 kg car tows a 400 kg trailer. The driving force is 2000 N; the resistances are 250 N on the car and 50 N on the trailer. Find a and the towbar tension.

Worked example A5: a pulley

Particles of mass 3 kg and 5 kg hang over a smooth pulley. Find a and T

Heavier: $5g - T = 5a$; lighter: $T - 3g = 3a$

$$\text{Add: } 2g = 8a$$

$$a = 2.45 \text{ ms}^{-2}, \quad T = 36.75 \text{ N}$$

Your turn A5

Particles of mass 2 kg and 6 kg hang over a smooth pulley. Find a and T

Worked example A6: a table and pulley

A 4 kg particle on a smooth table is joined over a pulley at the edge to a 1 kg hanging particle. Find a and T

Table: $T = 4a$; hanging: $g - T = a$

$$g = 5a$$

$$a = 1.96 \text{ ms}^{-2}, \quad T = 7.84 \text{ N}$$

Your turn A6

A 6 kg particle on a smooth table is joined over a pulley at the edge to a 2 kg hanging particle. Find a and T

Worked example A7: a lift

A 70 kg man stands in a lift accelerating upwards at 1.2 ms^{-2} . Find the force of the floor on him.

Forces on the man only: $R - mg = ma$

$$R = 70(9.8 + 1.2)$$

$$770 \text{ N}$$

Your turn A7

An 80 kg man stands in a lift accelerating downwards at 0.8 ms^{-2} . Find the force of the floor on him.



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 2.5 kg particle on a horizontal surface is pulled by a horizontal force against a constant resistance.
- (a) The force is 20 N and the resistance 5 N: find a (b) Find the speed after 3 s from rest
- (c) Find the force for $a = 10 \text{ ms}^{-2}$ (d) The force is 20 N and $a = 4 \text{ ms}^{-2}$: find the resistance
- [4 marks]
- B2** A 50 kg crate hangs from a rope. Find the tension when the crate
- (a) is at rest (b) accelerates upwards at 0.6 ms^{-2}
- (c) accelerates downwards at 0.6 ms^{-2} (d) Find a when the tension is 600 N
- [4 marks]
- B3** Forces $(4\mathbf{i} - 3\mathbf{j}) \text{ N}$ and $(p\mathbf{i} + q\mathbf{j}) \text{ N}$ act on a 2 kg particle, which accelerates at $(3\mathbf{i} + 2\mathbf{j}) \text{ ms}^{-2}$
- (a) Find the resultant force (b) Find p and q
- (c) Find the magnitude of the acceleration (d) Find the angle between $\mathbf{a}$ and $\mathbf{i}$
- [4 marks]
- B4** A 1000 kg car tows a 600 kg caravan. The resistances are 300 N on the car and 180 N on the caravan.
- (a) The driving force is 2800 N: find a (b) Find the towbar tension
- (c) Find the driving force for constant speed (d) Find the towbar tension then
- [4 marks]



CORE

continued: pulleys and lifts

- B5** Particles of mass 4 kg and 5 kg hang over a smooth fixed pulley and are released from rest.
- (a) Find the acceleration.
 - (b) Find the tension.
 - (c) Find the force on the pulley. [3 marks]
- B6** A lift of mass 400 kg carries a woman of mass 60 kg.
- (a) Accelerating up at 0.5 ms^{-2} : find the cable tension
 - (b) Find the force of the floor on the woman
 - (c) Find this force at constant speed
 - (d) Find it when rising but slowing at 0.5 ms^{-2} [4 marks]

STRETCH

- B7** A 5 kg particle *A* on a horizontal table has a constant resistance of 4.9 N. It is joined over a smooth pulley at the edge to a 3 kg particle *B*, which hangs 0.8 m above the floor.
- (a) Find the acceleration
 - (b) Find the tension
 - (c) Find the speed of *B* as it lands
 - (d) Find how far *A* then moves [4 marks]
- B8** Particles of mass 2 kg and 3 kg hang over a smooth pulley and are released from rest. After 2 s the string breaks.
- (a) Find the acceleration before the break
 - (b) Find the speed at the break
 - (c) Find how much higher the 2 kg particle rises
 - (d) Find the acceleration of the 3 kg particle after [4 marks]
- B9** On a smooth table, *P* (2 kg) is pulled by a force of 18 N and drags *Q* (4 kg) behind it on a light string.
- (a) The force is horizontal: find *a*
 - (b) Find the tension
 - (c) The force acts at 30° above the horizontal: find *a*
 - (d) Find the tension now [4 marks]
- B10** A horizontal force pushes box *A* (2 kg), which pushes box *B* (3 kg) in front of it. The resistances are 2 N on *A* and 3 N on *B*
- (a) The push is 30 N: find *a*
 - (b) Find the force of *A* on *B*
 - (c) Find the force of *B* on *A*
 - (d) The push is 40 N: find the force of *A* on *B* [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 4 kg particle is pulled upwards by a 50 N force. Ama writes $50 - 4g = 4ga$
Explain her error, and find a [2 marks]
- C2** A 2 kg and a 3 kg particle hang over a smooth pulley. Ben writes, for the 3 kg particle, $3g - T = 5a$
Explain his error, and write the correct equation. [2 marks]
- C3** A 2 kg and a 3 kg particle hang over a smooth pulley. Cal says the heavier particle falls with acceleration g
Explain why this is wrong, and find the acceleration. [3 marks]
- C4** Forces on a 2 kg particle give $\mathbf{a} = (-6\mathbf{i} + 8\mathbf{j}) \text{ ms}^{-2}$. Asked for the magnitude of the acceleration, Dee gives $(-6\mathbf{i} + 8\mathbf{j})$
Explain her error, and give the answer. [3 marks]

STRETCH

- C5** Over a smooth fixed pulley, the tension in the string is 36 N and both hanging parts are vertical. Eli says the force on the pulley is 36 N
Explain his error, and find the force. [3 marks]
- C6** A car and trailer are braking. Faye writes the trailer's equation as $T - 150 = 400(-2)$ and gets $T = -650$, so "the towbar is broken".
Explain what her answer actually means. [3 marks]
- C7** Two particles hang over a pulley with acceleration 1.96 ms^{-2} . When the string breaks, Gus says the lighter particle continues to rise with acceleration 1.96 ms^{-2}
Explain his error. [3 marks]
- C8** Particles of mass m_1 and m_2 , where $m_2 > m_1$, hang over a smooth fixed pulley.
- (a) Show that the acceleration is $\frac{(m_2 - m_1)g}{m_1 + m_2}$ (3)
- (b) Hence show that the tension is $\frac{2m_1m_2g}{m_1 + m_2}$ (2)
- [5 marks]



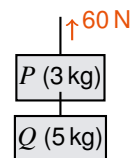
D**Problem solving**

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

CORE

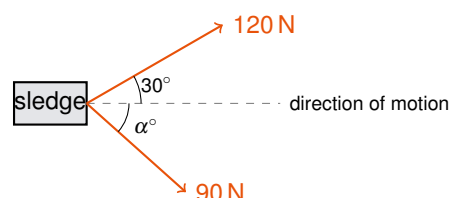
Secure the method

- D1** A particle P of mass 3 kg and a particle Q of mass 5 kg are connected by a light inextensible string, with Q hanging below P . A second light inextensible string, attached to P , is held vertically above P , as shown. The tension in the upper string is 60 N, and both strings are taut and vertical. Find the acceleration of the particles, stating its direction, and find the tension in the lower string.



[3 marks]

- D2** A sledge of mass 80 kg is pulled across horizontal ice by two horizontal ropes. One rope has tension 120 N and makes an angle of 30° with the direction of motion; the other has tension 90 N and makes an angle α° with it, on the other side, as shown. The resistance to motion is 50 N
- (a) Find the value of α



(2)

- (b) Find the acceleration of the sledge.

(2)

[4 marks]

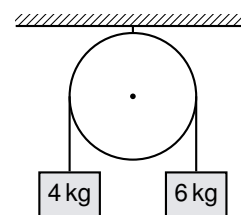
- D3** A lorry of mass 3000 kg moves along a straight horizontal road with constant acceleration. It passes a point A at 8 ms^{-1} and, 30 seconds later, passes a point B at 20 ms^{-1} . The resistance to motion is a constant 1500 N

Find the driving force of the engine.

[3 marks]

- D4** Particles of mass 4 kg and 6 kg are attached to the ends of a light inextensible string that passes over a small smooth fixed pulley. They are released from rest with the hanging parts of the string vertical.

Find the acceleration of the particles, the tension in the string, and the magnitude of the force exerted on the pulley by the string.



[3 marks]



STRETCH

- D5** A particle A (3 kg) on a smooth horizontal table is joined by a light inextensible string over a smooth pulley at the edge to a particle B (2 kg), hanging 0.6 m above the floor. The system is released from rest.

(a) Find the acceleration and the tension.

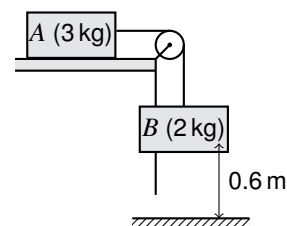
(2)

(b) Find the speed of B as it reaches the floor.

(1)

(c) A is then 1.2 m from the pulley. Find the time it takes to reach the pulley.

(1)



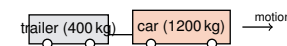
[4 marks]

- D6** A car of mass 1200 kg tows a 400 kg trailer along a straight horizontal road by a light horizontal towbar. The driving force is 2400 N; the resistances are 300 N on the car and 100 N on the trailer. (a) Find the acceleration.

(2)

(b) Find the tension in the towbar.

(2)



[4 marks]

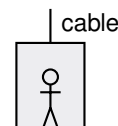
- D7** A lift of mass 500 kg, carrying a man of mass 75 kg, is raised by a vertical cable with tension 6100 N

(a) Find the acceleration of the lift.

(2)

(b) Find the magnitude of the force exerted on the man by the floor of the lift.

(2)



[4 marks]

- D8** Particles P (2 kg) and Q (3 kg) are attached to the ends of a light inextensible string over a smooth fixed pulley and released from rest. After 1.2 seconds the string breaks; P does not reach the pulley.

(a) Find the acceleration before the string breaks.

(1)

(b) Find the speed of P when the string breaks.

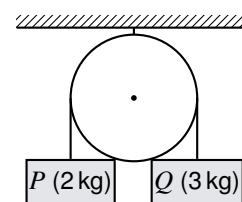
(1)

(c) Find how much further P rises.

(1)

(d) Find the time from the break until P is back at the height where the string broke.

(2)



[5 marks]



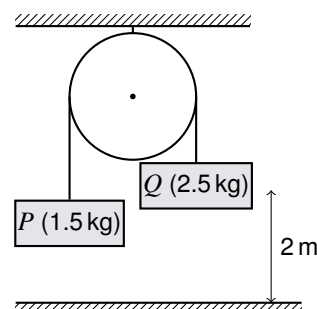
E**Exam practice**

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** Two particles, P and Q , have masses 1.5 kg and 2.5 kg respectively. The particles are attached to the ends of a light inextensible string which passes over a small smooth fixed pulley. The particles are released from rest with the string taut and the hanging parts of the string vertical. Q is initially 2 m above horizontal ground, and P is well below the pulley. The particles are modelled as particles moving freely.



- (a) Write down an equation of motion for P

(2)

- (b) Find the acceleration of the particles and the tension in the string.

(3)

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

(1)

When Q has descended 1.25 m , the string breaks.

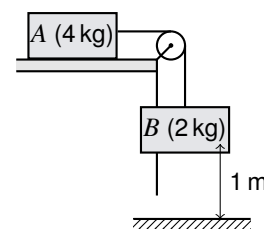
- (d) Find the speed of Q at the instant it hits the ground.

(4)

(Total for Question E1 is 10 marks)



E2 A particle A of mass 4 kg lies on a horizontal table. It is attached to one end of a light inextensible string, which passes over a small smooth pulley fixed at the edge of the table. The other end of the string is attached to a particle B of mass 2 kg , which hangs freely, 1 m above the floor. The motion of A is opposed by a constant resistance of 7.84 N . Initially A is 2.5 m from the pulley, and the system is released from rest with the string taut. Both particles are modelled as particles and the string lies in a vertical plane.



(a) Find the acceleration of the system.

(3)

(b) Find the tension in the string.

(1)

(c) Find the speed of B as it reaches the floor.

(2)

B does not rebound.

(d) Show that A comes to rest before it reaches the pulley.

(3)

(e) Find the total time from the instant of release until the instant at which A comes to rest.

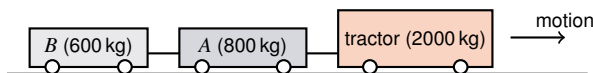
(2)

(Total for Question E2 is 11 marks)



STRETCH

- E3** A tractor of mass 2000 kg pulls two trailers along a straight horizontal road. Trailer *A*, of mass 800 kg, is attached to the tractor, and trailer *B*, of mass 600 kg, is attached behind *A*. The couplings are light and horizontal. The resistances to motion are 400 N on the tractor, 250 N on *A* and 150 N on *B*



The tractor's engine produces a driving force of 4200 N

- (a) Find the acceleration.

(2)

- (b) Find the tension in each coupling.

(3)

When the speed is 12 ms^{-1} , the engine is switched off and the tractor's brakes apply a constant braking force to the tractor only. The system then decelerates at 1.5 ms^{-2}

- (c) Find the braking force.

(2)

- (d) Find the force in the coupling between *A* and *B*, stating whether it is a tension or a thrust.

(2)

- (e) Find the distance travelled while braking to rest.

(2)

- (f) State two modelling assumptions that you have made in this question about the couplings or about the resistances to motion.

(2)

(Total for Question E3 is 13 marks)

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