

Topic Test

Summer 2022

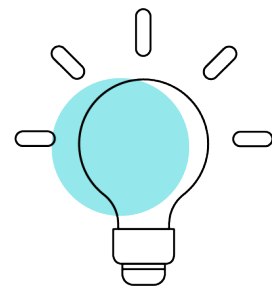
Pearson Edexcel GCE Mathematics (9MA0)

Paper 3 – Mechanics

Topic 4: Forces and Newton's laws

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General guidance to Topic Tests

Context

- Topic Tests have come from past papers both [published](#) (those materials available publicly) and unpublished (those currently under padlock to our centres) presented in a different format to allow teachers to adapt them for use with candidates.

Purpose

- The purpose of this resource is to provide qualification-specific sets/groups of questions covering the knowledge, skills and understanding relevant to this Pearson qualification.
- This document should be used in conjunction with the advance information for the subject as well as general marking guidance for the qualification (available in published mark schemes).

Revise Revision Guide content coverage

The questions in this topic test have been taken from past papers, and have been selected as they cover the topic(s) most closely aligned to the [A level](#) advance information for summer 2022:

- Topic 4: Forces and Newton's laws and Quantities and units in mechanics
 - o Newton's 2nd law in 2-D using vectors
 - o Dynamics, resolving forces, friction, equilibrium

The focus of content in this topic test can be found in the Revise Pearson Edexcel A level Mathematics Revision Guide. Free access to this Revise Guide is available for front of class use, to support your students' revision.

Contents	Revise Guide page reference	Level
Pure Mathematics	1-111	A level
Statistics	112-147	A level
Mechanics	148-181	A level

Content on other pages may also be useful, including for synoptic questions which bring together learning from across the specification.

Questions

Question T4_Q1

7.

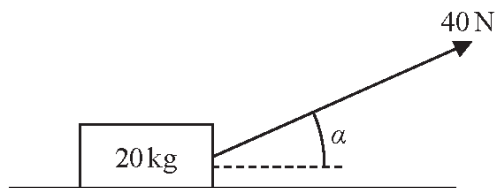


Figure 1

A wooden crate of mass 20 kg is pulled in a straight line along a rough horizontal floor using a handle attached to the crate.

The handle is inclined at an angle α to the floor, as shown in Figure 1, where $\tan \alpha = \frac{3}{4}$

The tension in the handle is 40 N.

The coefficient of friction between the crate and the floor is 0.14

The crate is modelled as a particle and the handle is modelled as a light rod.

Using the model,

(a) find the acceleration of the crate.

(6)

The crate is now pushed along the same floor using the handle. The handle is again inclined at the same angle α to the floor, and the thrust in the handle is 40 N as shown in Figure 2 below.

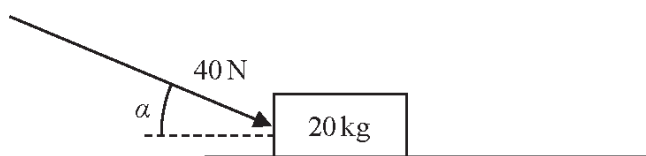


Figure 2

(b) Explain briefly why the acceleration of the crate would now be less than the acceleration of the crate found in part (a).

(2)

Question T4_Q2

8. [In this question \mathbf{i} and \mathbf{j} are horizontal unit vectors due east and due north respectively and position vectors are given relative to the fixed point O .]

A particle P moves with constant acceleration.

At time $t = 0$, the particle is at O and is moving with velocity $(2\mathbf{i} - 3\mathbf{j})\text{ms}^{-1}$

At time $t = 2$ seconds, P is at the point A with position vector $(7\mathbf{i} - 10\mathbf{j})\text{m}$.

- (a) Show that the magnitude of the acceleration of P is 2.5ms^{-2}

(4)

Question T4_Q3

3.

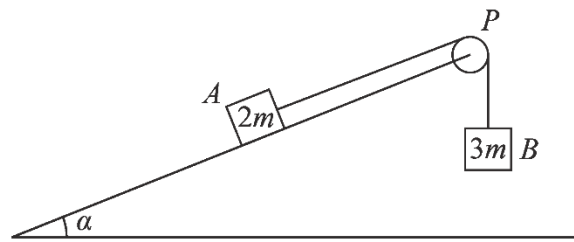


Figure 1

Two blocks, A and B , of masses $2m$ and $3m$ respectively, are attached to the ends of a light string.

Initially A is held at rest on a fixed rough plane.

The plane is inclined at angle α to the horizontal ground, where $\tan \alpha = \frac{5}{12}$

The string passes over a small smooth pulley, P , fixed at the top of the plane.

The part of the string from A to P is parallel to a line of greatest slope of the plane. Block B hangs freely below P , as shown in Figure 1.

The coefficient of friction between A and the plane is $\frac{2}{3}$

The blocks are released from rest with the string taut and A moves up the plane.

The tension in the string immediately after the blocks are released is T .

The blocks are modelled as particles and the string is modelled as being inextensible.

(a) Show that $T = \frac{12mg}{5}$ (8)

After B reaches the ground, A continues to move up the plane until it comes to rest before reaching P .

(b) Determine whether A will remain at rest, carefully justifying your answer. (2)

(c) Suggest two refinements to the model that would make it more realistic. (2)

Question T4_Q4

1. A rough plane is inclined to the horizontal at an angle α , where $\tan \alpha = \frac{3}{4}$

A brick P of mass m is placed on the plane.

The coefficient of friction between P and the plane is μ

Brick P is in equilibrium and on the point of sliding down the plane.

Brick P is modelled as a particle.

Using the model,

- (a) find, in terms of m and g , the magnitude of the normal reaction of the plane on brick P (2)

- (b) show that $\mu = \frac{3}{4}$ (4)

For parts (c) and (d), you are not required to do any further calculations.

Brick P is now removed from the plane and a much heavier brick Q is placed on the plane.

The coefficient of friction between Q and the plane is also $\frac{3}{4}$

- (c) Explain briefly why brick Q will remain at rest on the plane. (1)

Brick Q is now projected with speed 0.5 m s^{-1} down a line of greatest slope of the plane.

Brick Q is modelled as a particle.

Using the model,

- (d) describe the motion of brick Q , giving a reason for your answer. (2)

Question T4_Q5

2.

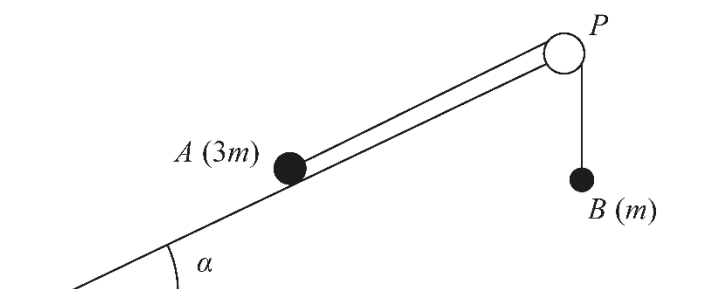


Figure 1

A small stone A of mass $3m$ is attached to one end of a string.

A small stone B of mass m is attached to the other end of the string.

Initially A is held at rest on a fixed rough plane.

The plane is inclined to the horizontal at an angle α , where $\tan \alpha = \frac{3}{4}$

The string passes over a pulley P that is fixed at the top of the plane.

The part of the string from A to P is parallel to a line of greatest slope of the plane.

Stone B hangs freely below P , as shown in Figure 1.

The coefficient of friction between A and the plane is $\frac{1}{6}$

Stone A is released from rest and begins to move down the plane.

The stones are modelled as particles.

The pulley is modelled as being small and smooth.

The string is modelled as being light and inextensible.

Using the model for the motion of the system before B reaches the pulley,

(a) write down an equation of motion for A (2)

(b) show that the acceleration of A is $\frac{1}{10}g$ (7)

(c) sketch a velocity-time graph for the motion of B , from the instant when A is released from rest to the instant just before B reaches the pulley, explaining your answer. (2)

In reality, the string is not light.

(d) State how this would affect the working in part (b). (1)

Mark Scheme

Question T4_Q1

Question	Scheme	Marks	AOs
7(a)	Resolve vertically	M1	3.1b
	$R + 40 \sin \alpha = 20g$	A1	1.1b
	Resolve horizontally	M1	3.1b
	$40 \cos \alpha - F = 20a$	A1	1.1b
	$F = 0.14R$	B1	1.2
	$a = 0.396$ or 0.40 (m s^{-2})	A1	2.2a
		(6)	
(b)	Pushing will increase R which will increase available F	B1	2.4
	Increasing F will <u>decrease</u> a * GIVEN ANSWER	B1*	2.4
		(2)	
			(8 marks)
Notes:			
<p>(a)</p> <p>M1: Resolve vertically with usual rules applying</p> <p>A1: Correct equation. Neither g nor $\sin \alpha$ need to be substituted</p> <p>M1: Apply $F = ma$ horizontally, with usual rules</p> <p>A1: Neither F nor $\cos \alpha$ need to be substituted</p> <p>B1: $F = 0.14R$ seen (e.g. on a diagram)</p> <p>A1: Either answer</p>			
<p>(b)</p> <p>B1: Pushing increases R which produces an increase in available (limiting) friction</p> <p>B1: F increase produces an <u>decrease</u> (need to see this)</p> <p>N.B. It is possible to score B0 B1 but for the B1, some “explanation” is needed to say why friction is increased e.g. by pushing into the ground.</p>			

Question T4_Q2

Question	Scheme	Marks	AOs
8(a)	Use of $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$: $(7\mathbf{i} - 10\mathbf{j}) = 2(2\mathbf{i} - 3\mathbf{j}) + \frac{1}{2}\mathbf{a}2^2$	M1	3.1b
	$\mathbf{a} = (1.5\mathbf{i} - 2\mathbf{j})$	A1	1.1b
	$ \mathbf{a} = \sqrt{1.5^2 + (-2)^2}$	M1	1.1b
	$= 2.5 \text{ m s}^{-2}$ * GIVEN ANSWER	A1*	2.1
		(4)	

Question	Scheme	Marks	AOs
8(a)	Use of $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$: $(7\mathbf{i} - 10\mathbf{j}) = 2(2\mathbf{i} - 3\mathbf{j}) + \frac{1}{2}\mathbf{a}2^2$	M1	3.1b
	$\mathbf{a} = (1.5\mathbf{i} - 2\mathbf{j})$	A1	1.1b
	$ \mathbf{a} = \sqrt{1.5^2 + (-2)^2}$	M1	1.1b
	$= 2.5 \text{ m s}^{-2}$ * GIVEN ANSWER	A1*	2.1
		(4)	

Question T4_Q3

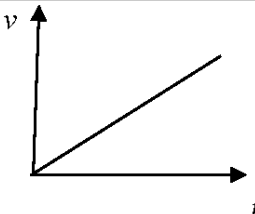
Question	Scheme	Marks	AO
3(a)			
	$R = 2mg \cos \alpha$	B1	3.4
	$F = \frac{2}{3}R$	B1	1.2
	Equation of motion for A:	M1	3.3
	$T - F - 2mg \sin \alpha = 2ma$	A1	1.1b
	Equation of motion for B:	M1	3.3
	$3mg - T = 3ma$	A1	1.1b
	Complete strategy to find an equation in T , m and g only.	M1	3.1b
	$T = \frac{12mg}{5}$ *	A1*	2.2a
	(8)		
(b)	$(F_{\max} =) \frac{16mg}{13} > \frac{10mg}{13}$	M1	2.1
 so A will not move.	A1	2.2a
		(2)	
(c)	<ul style="list-style-type: none"> • Extensible string • Weight of string • Friction at pulley e.g. rough pulley • Allow for the dimensions of the blocks e.g. "Do not model blocks as particles"; "(include) air resistance"; "include rotational effects of forces on blocks i.e. spin" 	B1 B1	3.5c 3.5c
		(2)	
		(12)	

Marks		Notes
3a	B1	Normal reaction between A and the plane seen or implied, $\cos \alpha$ does not need to be substituted.
	B1	$F = \frac{2}{3}R$ seen or implied anywhere, including part (b)
	M1	Form an equation of motion for A . Must include all relevant terms. Must be the correct mass but condone consistent missing m 's. Condone sign errors and sin/cos confusion
	A1	Correct unsimplified equation (F does not need to be substituted). Allow consistent use of $(-a)$ N.B. If $T - 2mg = 2ma$ is seen with no working, M0A0 unless both B1 marks have been scored.
	M1	Form an equation of motion for B . Must be the correct mass on RHS but condone consistent missing m 's. Condone sign errors and sin/cos confusion.
	A1	Correct unsimplified equation (F does not need to be substituted). Allow consistent use of $(-a)$
		N.B. Allow the 'whole system' equation to replace the equation for A or B . $3mg - F - 2mg \sin \alpha = 5ma$ Must be the correct mass on RHS but condone consistent missing m 's. Condone sign errors and sin/cos confusion.
	M1	Complete method to give an equation in T , m and g only. N.B. Allow θ in the equation if they have defined what θ is: e.g. $\theta = \tan^{-1}(\frac{5}{12})$ This is an <u>independent</u> mark but they must have two simultaneous equations in T and a unless one of the equations is the whole system equation in which case one equation will be in T and a and the other equation will be in a only.
	A1* Obtain the given answer from correct working using EXACT trig ratios. (not available if using a decimal angle)	
3b	M1	Comparison of their F_{\max} ($\frac{2}{3}R$) and their component of weight down the slope, must be comparing numerical values. oe e.g. if they consider the difference N.B. Allow comparison of μ and $\tan \alpha$ with numerical values
	A1	Correctly justified conclusion and no errors seen N.B. If they equate their difference to an ' ma ' term then A0
	B1 B1	Deduct 1 mark for each extra (more than 2) incorrect answer up to a maximum of 2 incorrect answers. Ignore extra correct answers. e.g. two correct, one incorrect B1 B0 one correct, one incorrect B1 B0 one correct, two incorrect B0 B0 Ignore incorrect reasons or consequences. Ignore any mention of wind or a general reference to friction.

Question T4_Q4

Question	Scheme	Marks	AOs
1.(a)	Resolve perpendicular to the plane	M1	3.4
	$R = mg \cos \alpha = \frac{4}{5} mg$	A1	1.1b
		(2)	
1(b)	Resolve parallel to the plane or horizontally or vertically	M1	3.4
	$F = mg \sin \alpha$ or $R \sin \alpha = F \cos \alpha$	A1	1.1b
	Use $F = \mu R$ and solve for μ	M1	2.1
	$\mu = \frac{3}{4}$ *	A1*	2.2a
		(4)	
1(c)	The forces acting on Q will still balance as the m 's cancel oe Other possibilities: e.g. the <u>friction</u> will increase <u>in the same proportion</u> as <u>the weight component</u> or <u>force down the plane</u> . The <u>force pulling the brick down the plane</u> increases <u>by the same amount</u> as the <u>friction</u> oe This mark can be scored if they do the calculation.	B1	2.4
		(1)	
1(d)	Brick Q slides down the plane with constant speed.	B1	2.4
	No resultant force down the plane (so no acceleration) oe	B1	2.4
	These marks can be scored if they do the calculation.	(2)	
			(9 marks)
Notes:			
1a	M1	Correct no. of terms, condone sin/cos confusion	
	A1	cao with no wrong working seen. $mg \cos 36.86$ is A0	
1b	M1	Correct no. of terms, condone sin/cos confusion	
	A1	Correct equation	
	M1	Must use $F = \mu R$ (not merely state it) to obtain a numerical value for μ . This is an independent M mark.	
	A1*	Given answer correctly obtained	
1c	B1	Must have the 3 underlined phrases/word oe	
1d	B1	Must say constant speed.	
	B1	Any appropriate equivalent statement	

Question T4_Q5

Question	Scheme	Marks	AOs
	Mark parts (a) and (b) together		
2(a)	Equation of motion for A	M1	3.3
	$3mg \sin \alpha - F - T = 3ma$	A1	1.1b
		(2)	
2(b)	Resolve perpendicular to the plane	M1	3.4
	$R = 3mg \cos \alpha$	A1	1.1b
	$F = \frac{1}{6}R$	B1	1.2
	Equation of motion for B OR for whole system	M1	3.3
	$T - mg = ma$ OR $3mg \sin \alpha - F - mg = 3ma + ma$	A1	1.1b
	Complete method to solve for a	DM1	3.1b
	$a = \frac{1}{10}g$ *	A1*	2.2a
		(7)	
2(c)		B1	1.1b
	e.g. acceleration (of B) is constant; dependent on first B1	DB1	2.4
		(2)	
2(d)	e.g. the tensions in the two equations of motion would be different. Tension on A would be different to tension on B	B1	3.5a
		(1)	
(12 marks)			
Notes: N.B. If m's are consistently missing treat as a MR, so max (a) M1A0 (b) M1A0B0M1A1M1A1 (c) B1B1 (d) B1			
For (a) and (b), allow verification, but must see full equations of motion.			
2a	M1	Equation in T and a with correct no. of terms, condone sign errors and sin/cos confusion (If one of the 3's is missing, allow M1) N.B. Treat sin(3/5) etc as an A error but allow recovery	
	A1	Correct equation (allow $(-a)$ instead of a in <u>both</u> equations)	

2b	M1	Correct no. of terms, condone sign errors and sin/cos confusion Allow if appears in (a)
	A1	Correct equation
	B1	Seen anywhere in (a) or (b), including on a diagram
	M1	Equation (for B) in T and a with correct no. of terms, condone sign errors and sin/cos confusion OR Whole system equation with correct no. of terms, condone sign errors and sin/cos confusion
	A1	Correct equation
	DM1	Complete method (trig may not be substituted), dependent on M1 in (a) and second M1 in (b) if they use two equations, or second M1 in (b) if they use one equation.
	A1*	Correct answer correctly obtained.
2c	B1	Straight line starting at the origin (could be reflected in the t -axis). B0 if continuous vertical line at the end.
	DB1	Dependent on first B1, for any equivalent statement
2d	B1	B0 if incorrect extras