Past paper questions
4.1 Forces and equilibrium

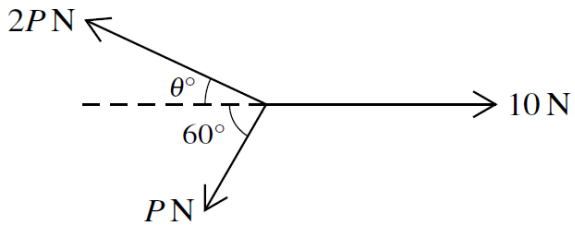
The questions in this document have been compiled from a number of past papers, as indicated in the table below. Use these questions to formatively assess your learners' understanding of this topic.

Question	Year	Series	Paper number
2	2018	March	42
4	2018	March	42
3	2013	June	42
6	2013	June	43
3	2014	June	41
1	2014	June	43
5	2015	June	43
4	2016	June	41
1	2013	November	42
4	2013	November	42
2	2013	November	43

The mark scheme for each question is provided at the end of the document.

You can find the complete question papers and the complete mark schemes (with additional notes where available) on the School Support Hub www.cambridgeinternational.org/support.

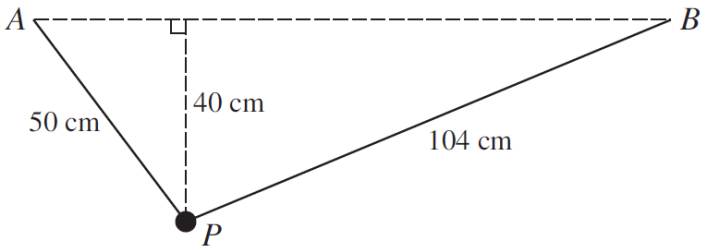
2



The three coplanar forces shown in the diagram are in equilibrium. Find the values of θ and P. [4]

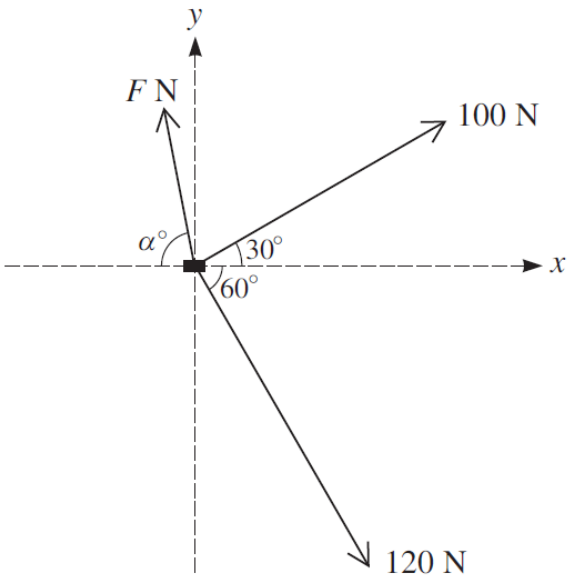
4 A particle of mass 12 kg is on a rough plane inclined at an angle of 25° to the horizontal. A force of magnitude P N acts on the particle. This force is horizontal and the particle is on the point of moving up a line of greatest slope of the plane. The coefficient of friction between the particle and the plane is 0.8. Find the value of P. [6]

3



A particle P of mass 2.1 kg is attached to one end of each of two light inextensible strings. The other ends of the strings are attached to points A and B which are at the same horizontal level. P hangs in equilibrium at a point 40 cm below the level of A and B, and the strings PA and PB have lengths 50 cm and 104 cm respectively (see diagram). Show that the tension in the string PA is 20 N, and find the tension in the string PB. [5]

6

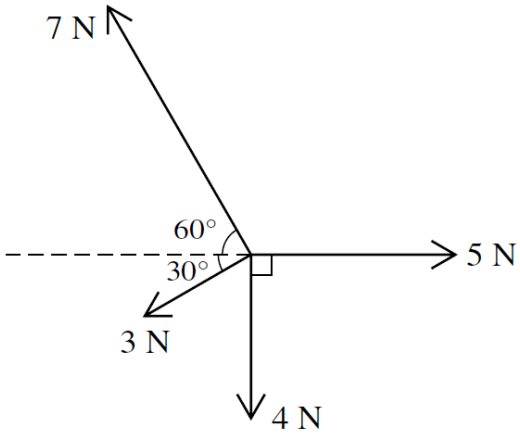


A small box of mass 40 kg is moved along a rough horizontal floor by three men. Two of the men apply horizontal forces of magnitudes 100 N and 120 N, making angles of 30° and 60° respectively with the positive x-direction. The third man applies a horizontal force of magnitude F N making an angle of $\alpha°$ with the negative x-direction (see diagram). The resultant of the three horizontal forces acting on the box is in the positive x-direction and has magnitude 136 N.

(i) Find the values of F and α. [6]

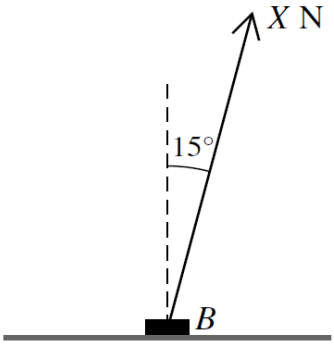
(ii) Given that the box is moving with constant speed, state the magnitude of the frictional force acting on the box and hence find the coefficient of friction between the box and the floor. [3]

3



Four coplanar forces act at a point. The magnitudes of the forces are 5 N, 4 N, 3 N and 7 N, and the directions in which the forces act are shown in the diagram. Find the magnitude and direction of the resultant of the four forces. [6]

1



A block B of mass 7 kg is at rest on rough horizontal ground. A force of magnitude X N acts on B at an angle of 15° to the upward vertical (see diagram).

(i) Given that B is in equilibrium find, in terms of X, the normal component of the force exerted on B by the ground. [2]

(ii) The coefficient of friction between B and the ground is 0.4. Find the value of X for which B is in limiting equilibrium. [3]

5

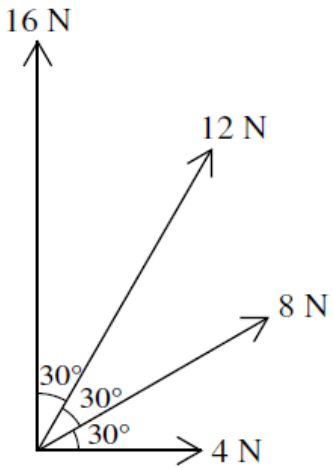


Fig. 1

Four coplanar forces of magnitudes 4 N, 8 N, 12 N and 16 N act at a point. The directions in which the forces act are shown in Fig. 1.

(i) Find the magnitude and direction of the resultant of the four forces. [5]

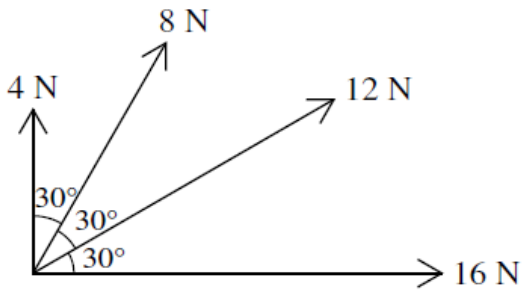
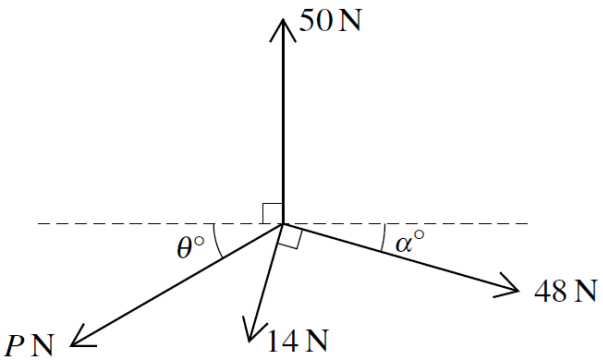


Fig. 2

The forces of magnitudes 4 N and 16 N exchange their directions and the forces of magnitudes 8 N and 12 N also exchange their directions (see Fig. 2).

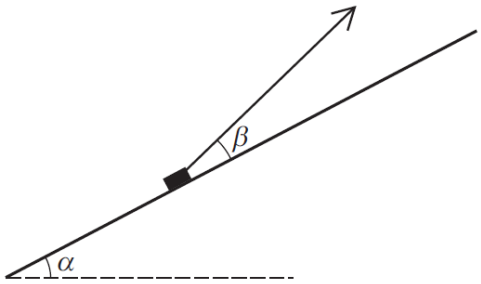
(ii) State the magnitude and direction of the resultant of the four forces in Fig. 2. [2]

4



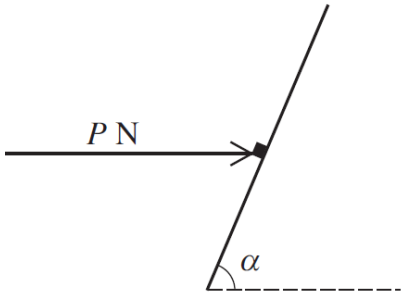
Coplanar forces of magnitudes 50 N, 48 N, 14 N and P N act at a point in the directions shown in the diagram. The system is in equilibrium. Given that $\tan\alpha = \frac{7}{24}$, find the values of P and θ. [6]

1



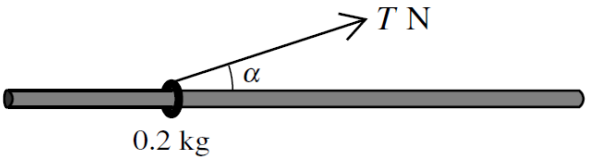
A small block of weight 5.1 N rests on a smooth plane inclined at an angle α to the horizontal, where $\sin\alpha = \frac{8}{17}$. The block is held in equilibrium by means of a light inextensible string. The string makes an angle β above the line of greatest slope on which the block rests, where $\sin\beta = \frac{7}{25}$ (see diagram). Find the tension in the string. [3]

4



A rough plane is inclined at an angle α to the horizontal, where $\tan\alpha = 2.4$. A small block of mass 0.6 kg is held at rest on the plane by a horizontal force of magnitude P N. This force acts in a vertical plane through a line of greatest slope (see diagram). The coefficient of friction between the block and the plane is 0.4. The block is on the point of slipping down the plane. By resolving forces parallel to and perpendicular to the inclined plane, or otherwise, find the value of P. [8]

2



A ring of mass 0.2 kg is threaded on a fixed rough horizontal rod and a light inextensible string is attached to the ring at an angle α above the horizontal, where $\cos\alpha = 0.96$. The ring is in limiting equilibrium with the tension in the string T N (see diagram). Given that the coefficient of friction between the ring and the rod is 0.25, find the value of T. [5]

Mark schemes

Mark Scheme Notes

Marks are of the following three types:

M Method mark, awarded for a valid method applied to the problem. Method marks are not lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. Correct application of a formula without the formula being quoted obviously earns the M mark and in some cases an M mark can be implied from a correct answer.

A Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated method mark is earned (or implied).

B Mark for a correct result or statement independent of method marks.

- When a part of a question has two or more "method" steps, the M marks are generally independent unless the scheme specifically says otherwise; and similarly when there are several B marks allocated. The notation DM or DB (or dep*) is used to indicate that a particular M or B mark is dependent on an earlier M or B (asterisked) mark in the scheme. When two or more steps are run together by the candidate, the earlier marks are implied and full credit is given.

- The symbol √ or FT implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A or B marks are given for correct work only. A and B marks are not given for fortuitously "correct" answers or results obtained from incorrect working.

  - Note: B2 or A2 means that the candidate can earn 2 or 0.
    B2/1/0 means that the candidate can earn anything from 0 to 2.

The marks indicated in the scheme may not be subdivided. If there is genuine doubt whether a candidate has earned a mark, allow the candidate the benefit of the doubt. Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored.

- Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise.

- For a numerical answer, allow the A or B mark if a value is obtained which is correct to 3 s.f., or which would be correct to 3 s.f. if rounded (1 d.p. in the case of an angle). As stated above, an A or B mark is not given if a correct numerical answer arises fortuitously from incorrect working. For Mechanics questions, allow A or B marks for correct answers which arise from taking g equal to 9.8 or 9.81 instead of 10.

The following abbreviations may be used in a mark scheme or used on the scripts:

AEF/OE Any Equivalent Form (of answer is equally acceptable) / Or equivalent

AG Answer Given on the question paper (so extra checking is needed to ensure that the detailed working leading to the result is valid)

BOD Benefit of Doubt (allowed when the validity of a solution may not be absolutely clear)

CAO Correct Answer Only (emphasising that no "follow through" from a previous error is allowed)

CWO Correct Working Only – often written by a 'fortuitous' answer

ISW Ignore Subsequent Working

MR Misread

PA Premature Approximation (resulting in basically correct work that is insufficiently accurate)

SOI Seen or implied

SOS See Other Solution (the candidate makes a better attempt at the same question)

SR Special Ruling (detailing the mark to be given for a specific wrong solution, or a case where some standard marking practice is to be varied in the light of a particular circumstance)

Penalties

MR –1 A penalty of MR –1 is deducted from A or B marks when the data of a question or part question are genuinely misread and the object and difficulty of the question remain unaltered. In this case all A and B marks then become "follow through √" marks. MR is not applied when the candidate misreads his own figures – this is regarded as an error in accuracy. An MR –2 penalty may be applied in particular cases if agreed at the coordination meeting.

PA –1 This is deducted from A or B marks in the case of premature approximation. The PA –1 penalty is usually discussed at the meeting.

March 2018 Paper 42

2	*EITHER:* $2P \sin\theta = P \sin 60$	**(M1**	Resolve vertically (2 terms)
	$\theta = 25.7$	**A1**	
	$2P \cos\theta + P \cos 60 = 10$	**M1**	Resolve horizontally (3 terms)
	$P = 4.34$	**A1)**	
	OR1: $\left[\frac{2P}{\sin 120} = \frac{P}{\sin(180-\theta)} = \frac{10}{\sin(60+\theta)}\right]$	**(M1**	Attempt Lami's theorem using one pair of terms
	$\theta = 25.7$	**A1**	Solve for θ
	Use a second Lami equation	**M1**	
	$P = 4.34$	**A1)**	
	OR2: Use sine or cosine rule with triangle of forces using forces P, $2P$ and 10 and with angles 60, θ and $120 - \theta$ between	**(M1**	
	$\theta = 25.7$	**A1**	
	Use a second relationship from the triangle of forces	**M1**	
	$P = 4.34$	**A1)**	
		4	

March 2018 Paper 42

4	$[R = 12g \cos 25 + P \sin 25$ $P \cos 25 = F + 12g \sin 25]$ or $[P = F \cos 25 + R \sin 25$ $R \cos 25 = F \sin 25 + 12g]$	**M1**	Attempt resolving of forces in any one direction, parallel to, perpendicular to plane or horizontally, vertically
		A1	Any one correct equation
		A1	Any second correct equation
	$F = 0.8R$	**M1**	Use of $F = \mu R$
	Complete method to find P from 2 equations(3 terms each)	**M1**	
	$P = 242$	**A1**	
		6	

May/June 2013 Paper 42

3		M1		For using Lami's Rule
	$21/\sin 104.3 = T_A/\sin 112.6$ (or $T_B/\sin 143.1$)	A1		
	$21/\sin 104.3 = T_B/\sin 143.1$ (or $T_A/\sin 112.6$) or $T_B/\sin 143.1 = 20/\sin 112.6$ or $T_A/\sin 112.6 = 13/\sin 143.1$	B1		
	Solve for T_A and T_B	M1		For using the equations to find T_A and T_B
	Tension in AP is 20 N and tension in BP is 13 N	A1	[5]	Both $T_A = 20$ and $T_B = 13$

May/June 2013 Paper 43

6	**(i)**	M1		For resolving the applied forces on the box in the x-direction or the y-direction.
	$100 \cos 30^\circ + 120 \cos 60^\circ - F \cos\alpha = 136$ ($F \cos \alpha = 10.6025 \ldots$) or $100 \sin 30^\circ - 120 \sin 60^\circ + F \sin \alpha = 0$ ($F \sin \alpha = 53.9230 \ldots$)	A1		
	$100 \sin 30^\circ - 120 \sin 60^\circ + F \sin \alpha = 0$ ($F \sin \alpha = 53.9230 \ldots$) or $100 \cos 30^\circ + 120 \cos 60^\circ - F \cos \alpha = 136$ ($F \cos \alpha = 10.6025 \ldots$)	B1		
		M1		for using $F^2 = (F \cos \alpha)^2 + (F \sin \alpha)$ or $\tan \alpha = F \sin \alpha \div F \cos \alpha$
	$F = 55.0$ or $\alpha = 78.9$	A1		
	$\alpha = 78.9$ or $F = 55.0$	B1	[6]	
	(ii) Magnitude is 136 N	B1		
	$R = 40$ g	B1		
	Coefficient is 0.34	B1	[3]	

May/June 2014 Paper 41

3		M1		For finding the component of the forces in the x direction
	$X = 5 - 7\cos 60^\circ - 3\cos 30^\circ \quad (= -1.098)$	A1		
		M1		For finding the component of the forces in the y direction
	$Y = 7\sin 60^\circ - 3\sin 30^\circ - 4 \quad (= 0.5622)$	A1		
		M1		For using $R^2 = X^2 + Y^2$ and $\tan\theta = Y/X$
	Resultant is 1.23 N and Direction is 152.9° anticlockwise from +ve x-axis oe	A1	[6]	

May/June 2014 Paper 43

1 (i)	[N + component of X = Weight of B]	M1		For resolving forces acting on the block vertically (3 terms required)
	Normal component is $(70 - X\cos 15^\circ)$ N	A1	[2]	
(ii)	$F = X\sin 15^\circ$	B1		
	$[X\sin 15^\circ = 0.4(70 - X\cos 15^\circ)]$	M1		For using $F = \mu R$
	Value of X is 43.4	A1	[3]	

May/June 2015 Paper 43

5 (i)	x-component $= 4+8\cos 30°+12\cos 60°$ $[= 10 + 4\sqrt{3}]$	B1		16.928
	y-component $= 8\sin 30°+12\sin 60°+16$ $[= 20 + 6\sqrt{3}]$	B1		30.392
		M1		For using $R^2 = X^2 + Y^2$ or $\tan\theta = Y \div X$
	$R = 34.8$ or $\theta = 60.9°$ with the 4N force	A1		
	$\theta = 60.9°$ with the 4N force or $R = 34.8$	B1	5	
(ii)	$R = 34.8$	B1√		ft R from **(i)**
	$\theta = 29.1°$ with the 16N force	B1√	2	ft $90 - \theta$ from **(i)**

May/June 2016 Paper 41

4	$P\cos\theta = 48\cos\alpha - 14\sin\alpha$ and/or $P\sin\theta = 50 - 48\sin\alpha - 14\cos\alpha$	**M1**		For resolving forces horizontally and/or vertically
	$P\cos\theta = 48(24/25) - 14(7/25)$ $= 42.16$	**A1**		Allow $\alpha = 16.3$ used throughout
	$P\sin\theta = 50 - 48(7/25) - 14(24/25)$ $= 23.12$	**A1**		
		M1		For attempting to find P or θ
	$P = \sqrt{42.16^2 + 23.12^2} = 48.1$	**A1**		Allow $P = 34\sqrt{2}$
	$\tan\theta = \dfrac{23.12}{42.16}$ $\theta = 28.7$	**B1**	[6]	

October/November 2013 Paper 42

1		M1		For resolving forces parallel to the line of greatest slope
	Applying T cos β = W sin α	A1		T (24/25) = 5.1 (8/17) or T cos 16.26 = 5.1 sin 28.07
	Tension is 2.5 N	A1	3	
First Alternative Marking Scheme				
		M1		For resolving forces vertically or horizontally
	Applying R cos α + T sin (α + β) = W and R sin α = T cos (α + β)	A1		R cos 28.07 + T sin 44.33 = 5.1 and R sin 28.07 = T cos 44.33
	Tension is 2.5 N	A1	3	
Second Alternative Marking Scheme				
		M1		Using Triangle of forces
	Applying T / sin α = 5.1 / sin (90 + β)	A1		T / sin 28.07 = 5.1 / sin 106.26
	Tension is 2.5 N	A1	3	

October/November 2013 Paper 42

4		M1		For resolving three forces parallel to the plane
	$0.6g \sin \alpha = F + P \cos \alpha$	A1		Value of α used or values of $\sin \alpha$ and $\cos \alpha$ used
		M1		For resolving three forces perpendicular to the plane
	$R = 0.6g \cos \alpha + P \sin \alpha$	A1		Value of α used or values of $\sin \alpha$ and $\cos \alpha$ used
		M1		For using $F = \mu R$
	$0.6g \sin \alpha - P \cos \alpha =$ $0.4\,(0.6g \cos \alpha + P \sin \alpha)$	A1		Value of α used or values of $\sin \alpha$ and $\cos \alpha$ used
	$6(12/13) - P(5/13) =$ $2.4(5/13) + 0.4P(12/13)$	M1		For solving the resultant equation for P
	$P = 6.12$	A1	8	

October/November 2013 Paper 43

2		M1		For using $a = (M - m)g/(M+m)$ or for applying Newton's 2nd law to A and to B and solving for a.
	$a = 5$	A1		
	When B reaches the floor $v^2 = 2 \times 5 \times 1.6$; speed is $4 ms^{-1}$	B1ft		ft a $a \neq g$ $v = \sqrt{(3.2a)}$
		M1		For using $0 = u^2 - 2gs$ or for using PE gain = KE loss
	$0 = 16 - 20s$ $(s = 0.8)$	A1ft		ft speed
	$h + 1.6 + 0.8 = 3 \rightarrow h = 0.6$	B1	6	