1. Two chess pieces are placed on a uniform straight ruler. The ruler balances horizontally on a pivot.

- The ruler AB is of length 30 cm.
- The pivot P is at the centre of the ruler.
- The first chess piece, of mass 20 grams, is at A.
- The second chess piece, of mass 50 grams, is x cm from B.

This is shown in Fig. 5.

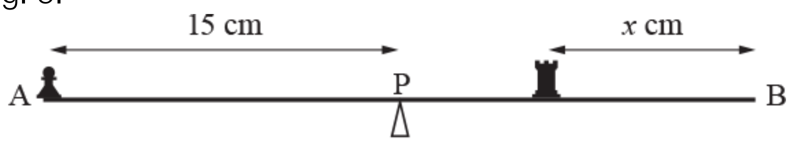


Fig. 5

Calculate the value of x. [4]

2. Fig. 1 shows a block of mass 5 kg on a rough plane inclined at an angle α to the horizontal.

The block is in equilibrium.

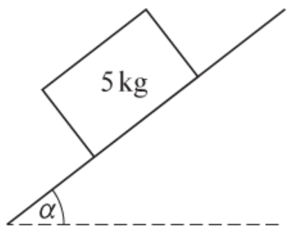
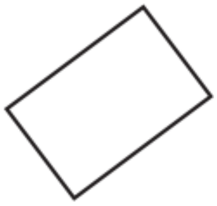


Fig. 1

(i) Draw a force diagram showing all the forces acting on the block. [3]



(ii) The normal reaction of the plane on the block is 37.5 N.

Find α, giving your answer to the nearest degree.

Find also the frictional force acting on the block. [3]

3. Olga and Petya are using light ropes to pull a sledge across rough snow.

- The surface of the snow is horizontal.

- The mass of the sledge and its load is 430 kg.
- Both ropes are horizontal.
- Olga pulls with a force of 120 N at an angle of 20° to the line of motion of the sledge.
- Petya also pulls with a force of 120 N at an angle of 20° to the line of motion of the sledge.

This is illustrated in a plan view in Fig. 2.

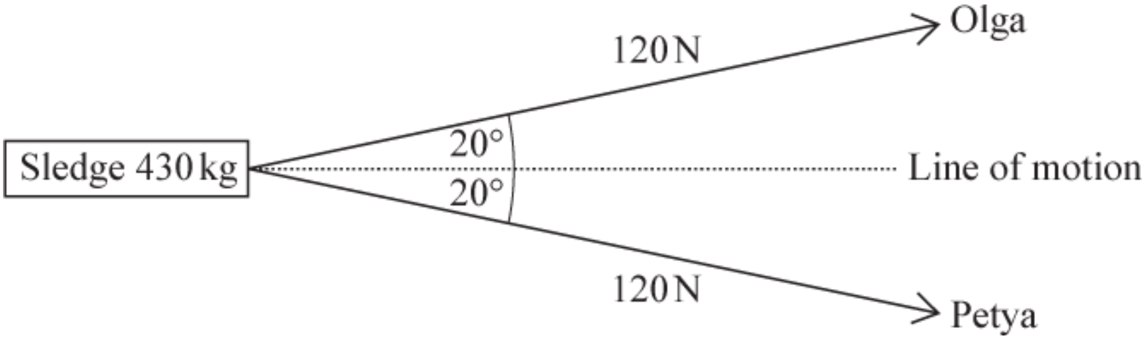


Fig. 2

(i) The sledge has acceleration 0.05 m s^{-2} in the direction of its line of motion.

Find the frictional force acting on the sledge. [3]

Olga and Petya then change to walking side by side. Their ropes, which are still horizontal, are now along the line of motion of the sledge. They maintain the forces on their ropes at 120 N and the frictional force remains the same.

(ii) Find the percentage increase in the acceleration of the sledge. [4]

4. Fig. 11 shows two blocks at rest, connected by a light inextensible string which passes over a smooth pulley. Block A of mass 4.7 kg rests on a smooth plane inclined at 60° to the

horizontal. Block B of mass 4 kg rests on a rough plane inclined at 25° to the horizontal. On either side of the pulley, the string is parallel to a line of greatest slope of the plane. Block B is on the point of sliding up the plane.

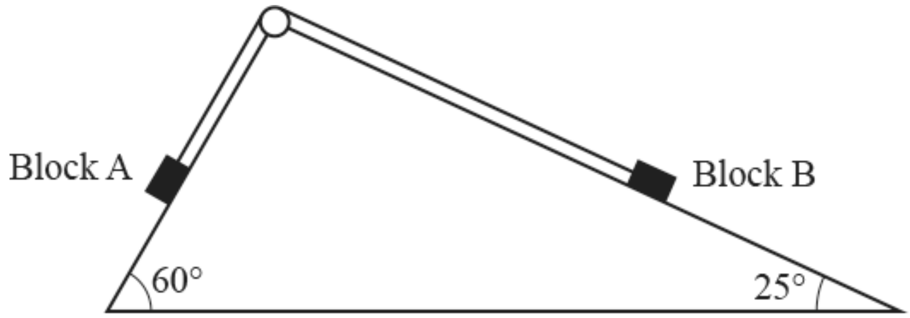


Fig.11

(a) Show that the tension in the string is 39.9 N correct to 3 significant figures. [2]

(b) Find the coefficient of friction between the rough plane and Block B. [5]

5. Zoe tries to push a box of mass 5 kg along a rough horizontal floor. When she applies a horizontal force of P N the box is on the point of sliding. When she applies a horizontal force of $3P$ N the box has an acceleration of 2 m s^{-2}. Find the value of P.

[3]

6. A block of mass 5 kg is placed on a rough horizontal table. The coefficient of friction between the table and the block is 0.3. A horizontal force P N is applied to the block but the block does not move.
Find the greatest possible value of P. [4]

7. A block of mass 2.7 kg is placed on a rough plane inclined at 25° to the horizontal. The coefficient of friction between the block and the plane is 0.4. A force of 24 N parallel to a line of greatest slope of the plane pulls the block up the plane from rest.

(a) Calculate the acceleration of the block. [5]

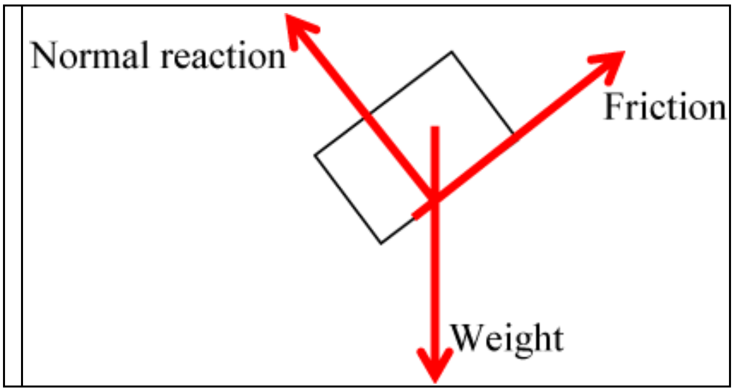
After 5 s the 24 N force is removed.

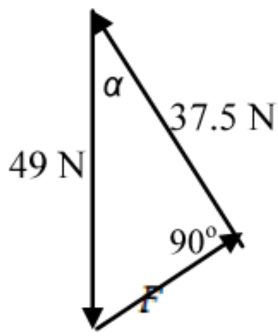
(b) Calculate the distance that the block travels after the force is removed before coming instantaneously to rest.

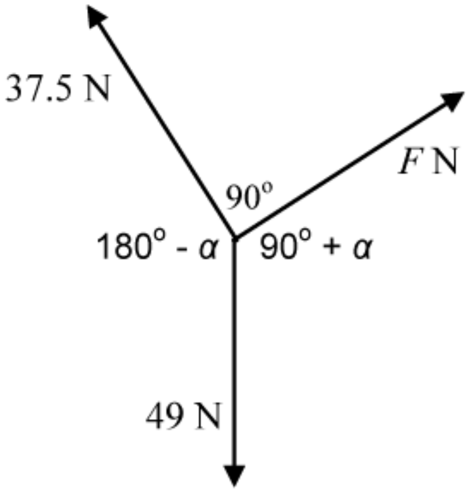
[6]

END OF QUESTION paper

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			Distance of 50 g piece from pivot is (15 – *x*) cm Moments about pivot: 20 × 15 = 50 × (15 – *x*) oe *x* = 9	B1(AO 3.3) M1(AO 3.1b) A1(AO 2.1) A1(AO 1.1b) [4]	soi; may be on the diagram Allow any consistent units of weight (or mass) and length mass) and length — Condone e.g. 20*g* with no units for *g* stated Correct (unsimplified) equation
			Total	4	
2		i		B1 B1 B1	**Forces**: 3 correct forces. **Labels**: Accept 5*g* and *mg* for weight. **Arrows** Missing force(s) If at least one of the 3 forces is missing, allow **SC1** for each fully correct force (ie including label and arrow) and ignore any additional forces that may be present. Extra force(s) Allow **B0** for **Forces** and up to **B1** for each of **Labels** and **Arrows** based on the correct forces and ignoring any extra(s). Components of weight Allow weight resolved into components parallel and perpendicular to the slope Accept **both** the weight and its components if the components are shown to be clearly different from

				[3]	the other forces (eg drawn with broken lines). Do not accept both the weight and its components if they all look the same; mark this as detailed under **Extra force(s)**. **Examiner's Comments** Part (i) of this question involved drawing a diagram for the forces acting on a block in equilibrium on a rough slope. While on the whole this was well answered, there were some surprising errors, such as showing the weight acting perpendicular to the slope or the normal reaction acting vertically. Some candidates showed the components of the weight as well as the weight itself; this is accepted if the components are presented differently from the other forces, for example using broken lines, but not if they all look the same.
		ii	$N = 5g\cos\alpha$ (or $37.5 = 5g\cos\alpha$)	M1	Do not allow sin-cos interchange
			$\cos\alpha = \frac{37.5}{49}$ $\alpha = 40.065...°$ so 40° to the nearest degree	A1	Must be rounded to 40°
			Frictional force = component of weight down the slope $= 5g\sin 40.065...°$ (= 31.539…) so 31.5 N	B1 [3]	Allow any answer that rounds to 31.5 N Allow answer 31.5 N following two consistent sin-cos interchanges.
			Alternative Using a triangle of forces 	M1	Condone no arrows. Do not allow sin-cos interchange
			$\cos\alpha = \frac{37.5}{49} \Rightarrow \alpha = 40°$	A1	Must be rounded to 40°
			$= 5g\sin 40.065...°$ (= 31.539…) so 31.5 N	B1	Allow any answer that rounds to 31.5 N Allow answer 31.5 N following two consistent sin-cos interchanges.
			Alternative Using Lami's theorem		

			 $$\frac{F}{\sin(180°-\alpha)}=\frac{37.5}{\sin(90°+\alpha)}=\frac{49}{\sin 90°}$$ $\alpha = 40°$ $F = 31.5$N	M1 A1 B1	Must be rounded to 40° Allow any answer that rounds to 31.5 N **Examiner's Comments** In part (ii) candidates were required to use the given information to find the angle of the slope and the frictional force. Most did this successfully. However, the question asked for the angle to be given to the nearest degree and many lost a mark by giving it to some other level of accuracy.
			Total	6	
3		i	$2\times120\times\cos 20° - F = 430\times0.05$ $F = 204(.206\ldots)$	M1 A1 A1 [3]	Newton's 2nd law, including *ma* term, friction and resolved force(s); allow sin-cos interchange for this mark only. All terms and signs correct **Examiner's Comments** In part (i) the forces acting on a sledge and its acceleration were given and the question asked for the force of resistance. This was answered correctly by nearly everyone.
		ii	$430\times a = -240.026\ldots$ $a = 0.08366\ldots$ Percentage increase is	M1 A1 M1	Apply FT from their *F* from part (i) throughout this part. All forces present Condone 0.08 for this mark There must be evidence of a complete method for finding percentage change. The denominator must

			$\frac{0.0836...-0.05}{0.05}\times 100 \quad (=67.32...)$ Percentage increase is 67.3% (to nearest 0.1)	A1 [4]	be the original acceleration and the original value must be subtracted from the new value at some stage. To allow for rounding and truncation, allow answers between 66% and 68% inclusive following otherwise correct working. Examiner's Comments In part (ii) candidates were asked to find the new acceleration and the percentage increase when the forces were applied in a different manner. Almost all found the new acceleration correctly but there were quite a lot of errors working out the percentage, for example using the wrong denominator and forgetting to subtract the original value. Teachers using this question in the classroom may like to compare the percentage increases in the forward force on the sledge (6.4%) and the acceleration (67.3%) and consider why there is such a large difference between them.
			Total	7	
4		a	Component of weight down the plane $4.7g \sin 60^\circ$ Equilibrium equation $T = 4.7g \sin 60^\circ$ $= 39.889...$ so $T = 39.9$ to 3 sf	B1 (AO 2.1) E1 (AO 3.3) [2]	AG Award if seen Must be clear that 39.9 N is the tension and not just component of weight Examiner's Comments This was generally well answered but some candidates lost a mark as all they had written was a component of weight and it was not clear that they had equated that to the tension. Since the answer was given in the question, the response needed to be a full mathematical justification to show the given answer.

					AfL Make sure that you set up an equilibrium equation even if there are only two terms.
		b	Resolve perpendicular to the slope N is the normal reaction between plane and block B $N = 4g\cos 25^\circ$ Resolve up the slope $T - F - 4g\sin 25^\circ = 0$ On the point of sliding so $F = \mu N = \mu \times 4g\cos 25^\circ$ $$\mu = \frac{4.7g\sin 60^\circ - 4g\sin 25^\circ}{4g\cos 25^\circ} = 0.656 \text{ to 3sf}$$	B1 (AO 1.1a) M1 (AO 3.3) A1 (AO 1.1b) M1 (AO 3.1b) A1 (AO 1.1b) [5]	Need not be evaluated here [≈35.5] Allow only sign errors F need not be evaluated here [≈23.3] Do not allow for $F \le \mu N$ unless = used subsequently. FT their values. FT (notice this answer is 0.657 if 39.9 used for T) If only values are seen used, it must be clear that the values used are friction and normal reaction. **Examiner's Comments** The problem solving element of this question stems from the lack of help that candidates were given in structuring their answer. They had to realise that they had to calculate the normal reaction and the frictional force before they could calculate the coefficient of friction. Some answers were very fragmented with very little help given by candidates to the examiner who were not always able to tell whether finding the normal reaction and the frictional forces had been attempted.
			Total	7	

5			Equilibrium when P applied: $P - F = 0$ $\Rightarrow F = P$ Newton II when $3P$ applied: $3P - F = 5 \times 2$ So $2P = 10$, giving $P = 5$	B1 (AO 3.1b) M1 (AO 3.1b) A1 (AO 1.1) [3]	Friction force may appear as μR oe F in terms of P not needed here
			Total	3	
6			Vertical equilibrium $N = 5g$ $F = P$ On the point of sliding $P_{max} = F[= \mu N] = 0.3 \times 5g$ $P_{max} = 14.7$	B1 (AO 1.1a) M1 (AO 1.1a) M1 (AO 3.3) A1 (AO 3.4) [4]	Must be seen – may be on a diagram May be implied Allow for 0.3 × $5g$ even if B1 not awarded cao
			Total	4	
7		a	Resolve perpendicular to plane: $R = 2.7g \cos 25°$ so $F = \mu R$ gives $F = 0.4 \times 2.7g \cos 25°$ (= 9.59…) Newton II ∥ to plane: $24 - F - 2.7g \sin 25° = 2.7a$	B1 (AO 3.3) M1 (AO 3.4) A1 (AO 1.1) M1 (AO 3.3)	Allow sin/cos interchange if consistent error elsewhere For 0.4 × their R, but not if $R = 2.7g$ For correct expression for F; evaluation not needed here

			$a = 1.1945\ldots$ so acceleration is 1.19 m s^{-2} (3sf)	A1 (AO 1.1) [5]	All forces needed and the 'weight' term must be a component; allow sign errors awrt 1.19
		b	After 5 s, $v = 0 + 1.1945 \times 5$ $v = 5.9725$ Newton II ∥ to plane: $-F - 2.7\,g\sin 25° = 2.7a$ $a = -7.6943$ $v = 0$ at distance s where $0 = 5.9725^2 - 2 \times 7.6943 \times s$ $s = 2.3179\ldots$ so distance travelled is 2.32 m (3sf)	M1 (AO 3.1b) A1 (AO 1.1) M1 (AO 3.3) A1 (AO 1.1) M1 (AO 1.1a) A1 (AO 1.1) [6]	Use of *suvat* leading to a value for v Both forces, with weight resolved Use of *suvat* leading to a value for s cao
			Total	11	