

Applications of Forces and Moments A level Edexcel Past Papers Questions

01.

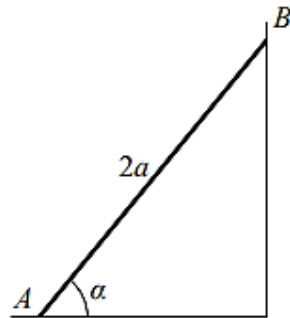


Figure 1

A uniform ladder  $AB$ , of length  $2a$  and weight  $W$ , has its end  $A$  on rough horizontal ground.

The coefficient of friction between the ladder and the ground is  $\frac{1}{4}$ .

The end  $B$  of the ladder is resting against a smooth vertical wall, as shown in Figure 1.

A builder of weight  $7W$  stands at the top of the ladder.

To stop the ladder from slipping, the builder's assistant applies a horizontal force of magnitude  $P$  to the ladder at  $A$ , towards the wall.

The force acts in a direction which is perpendicular to the wall.

The ladder rests in equilibrium in a vertical plane perpendicular to the wall and makes an angle  $\alpha$  with the horizontal ground, where  $\tan \alpha = \frac{5}{2}$ .

The builder is modelled as a particle and the ladder is modelled as a uniform rod.

(a) Show that the reaction of the wall on the ladder at  $B$  has magnitude  $3W$ . (5)

(b) Find, in terms of  $W$ , the range of possible values of  $P$  for which the ladder remains in equilibrium. (5)

Often in practice, the builder's assistant will simply stand on the bottom of the ladder.

(c) Explain briefly how this helps to stop the ladder from slipping. (3)

02.

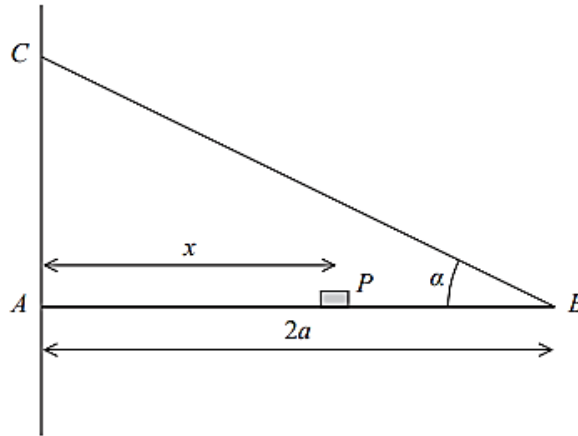


Figure 3

A plank,  $AB$ , of mass  $M$  and length  $2a$ , rests with its end  $A$  against a rough vertical wall. The plank is held in a horizontal position by a rope. One end of the rope is attached to the plank at  $B$  and the other end is attached to the wall at the point  $C$ , which is vertically above  $A$ .

A small block of mass  $3M$  is placed on the plank at the point  $P$ , where  $AP = x$ . The plank is in equilibrium in a vertical plane which is perpendicular to the wall.

The angle between the rope and the plank is  $\alpha$ , where  $\tan \alpha = \frac{3}{4}$ , as shown in Figure 3.

The plank is modelled as a uniform rod, the block is modelled as a particle and the rope is modelled as a light inextensible string.

(a) Using the model, show that the tension in the rope is  $\frac{5Mg(3x + a)}{6a}$  (3)

The magnitude of the horizontal component of the force exerted on the plank at  $A$  by the wall is  $2Mg$ .

(b) Find  $x$  in terms of  $a$ . (2)

The force exerted on the plank at  $A$  by the wall acts in a direction which makes an angle  $\beta$  with the horizontal.

(c) Find the value of  $\tan \beta$  (5)

The rope will break if the tension in it exceeds  $5Mg$ .

(d) Explain how this will restrict the possible positions of  $P$ . You must justify your answer carefully. (3)

03.

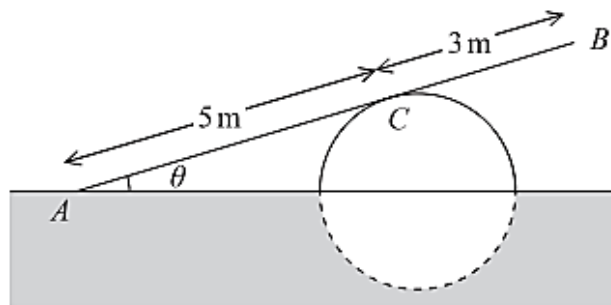


Figure 2

A ramp,  $AB$ , of length 8 m and mass 20 kg, rests in equilibrium with the end  $A$  on rough horizontal ground.

The ramp rests on a smooth solid cylindrical drum which is partly under the ground. The drum is fixed with its axis at the same horizontal level as  $A$ .

The point of contact between the ramp and the drum is  $C$ , where  $AC = 5$  m, as shown in Figure 2.

The ramp is resting in a vertical plane which is perpendicular to the axis of the drum, at an angle  $\theta$  to the horizontal, where  $\tan \theta = \frac{7}{24}$

The ramp is modelled as a uniform rod.

- (a) Explain why the reaction from the drum on the ramp at point  $C$  acts in a direction which is perpendicular to the ramp. (1)
- (b) Find the magnitude of the resultant force acting on the ramp at  $A$ . (9)

The ramp is still in equilibrium in the position shown in Figure 2 but the ramp is not now modelled as being uniform.

Given that the centre of mass of the ramp is assumed to be closer to  $A$  than to  $B$ ,

- (c) state how this would affect the magnitude of the normal reaction between the ramp and the drum at  $C$ . (1)

04.

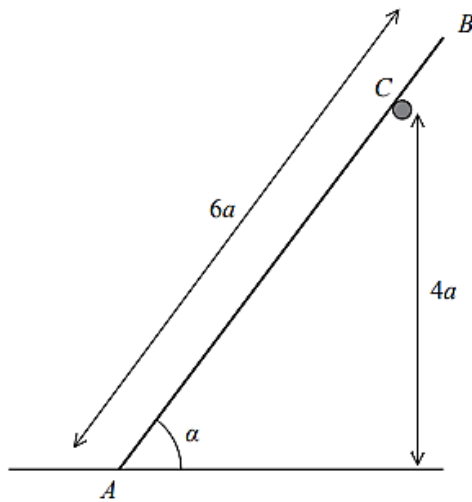


Figure 1

A ladder  $AB$  has mass  $M$  and length  $6a$ .

The end  $A$  of the ladder is on rough horizontal ground.

The ladder rests against a fixed smooth horizontal rail at the point  $C$ .

The point  $C$  is at a vertical height  $4a$  above the ground.

The vertical plane containing  $AB$  is perpendicular to the rail.

The ladder is inclined to the horizontal at an angle  $\alpha$ , where  $\sin \alpha = \frac{4}{5}$ , as shown in Figure 1.

The coefficient of friction between the ladder and the ground is  $\mu$ .

The ladder rests in limiting equilibrium.

The ladder is modelled as a uniform rod.

Using the model,

(a) show that the magnitude of the force exerted on the ladder by the rail at  $C$  is  $\frac{9Mg}{25}$  (3)

(b) Hence, or otherwise, find the value of  $\mu$ . (7)

05.

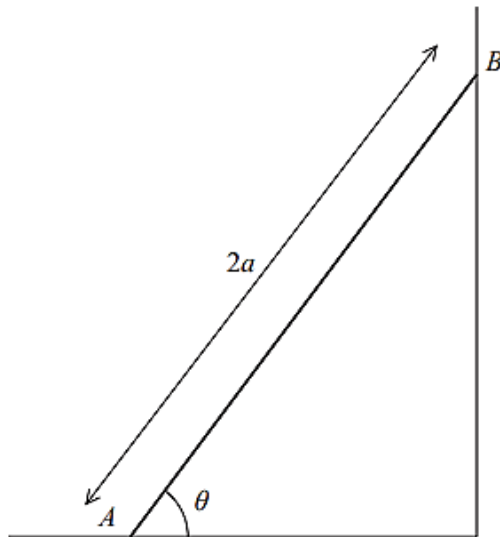


Figure 2

A beam  $AB$  has mass  $m$  and length  $2a$ .

The beam rests in equilibrium with  $A$  on rough horizontal ground and with  $B$  against a smooth vertical wall.

The beam is inclined to the horizontal at an angle  $\theta$ , as shown in Figure 2.

The coefficient of friction between the beam and the ground is  $\mu$

The beam is modelled as a uniform rod resting in a vertical plane that is perpendicular to the wall.

Using the model,

(a) show that  $\mu \geq \frac{1}{2} \cot \theta$  (5)

A horizontal force of magnitude  $kmg$ , where  $k$  is a constant, is now applied to the beam at  $A$ .

This force acts in a direction that is perpendicular to the wall and towards the wall.

Given that  $\tan \theta = \frac{5}{4}$ ,  $\mu = \frac{1}{2}$  and the beam is now in limiting equilibrium,

(b) use the model to find the value of  $k$ . (5)

06.

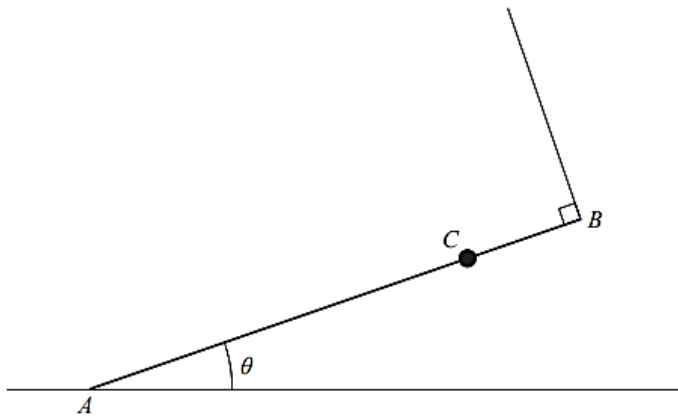


Figure 2

A uniform rod  $AB$  has mass  $M$  and length  $2a$

A particle of mass  $2M$  is attached to the rod at the point  $C$ , where  $AC = 1.5a$

The rod rests with its end  $A$  on rough horizontal ground.

The rod is held in equilibrium at an angle  $\theta$  to the ground by a light string that is attached to the end  $B$  of the rod.

The string is perpendicular to the rod, as shown in Figure 2.

- (a) Explain why the frictional force acting on the rod at  $A$  acts horizontally to the right on the diagram. (1)

The tension in the string is  $T$

- (b) Show that  $T = 2Mg \cos \theta$  (3)

Given that  $\cos \theta = \frac{3}{5}$

- (c) show that the magnitude of the vertical force exerted by the ground on the rod at  $A$  is  $\frac{57Mg}{25}$  (3)

The coefficient of friction between the rod and the ground is  $\mu$

Given that the rod is in limiting equilibrium,

- (d) show that  $\mu = \frac{8}{19}$  (4)

07.

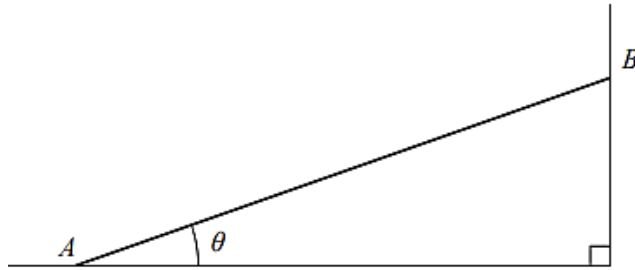


Figure 3

A rod  $AB$  has mass  $M$  and length  $2a$ .

The rod has its end  $A$  on rough horizontal ground and its end  $B$  against a smooth vertical wall.

The rod makes an angle  $\theta$  with the ground, as shown in Figure 3.

The rod is at rest in limiting equilibrium.

- (a) State the direction (left or right on Figure 3 above) of the frictional force acting on the rod at  $A$ . Give a reason for your answer.

(1)

The magnitude of the normal reaction of the wall on the rod at  $B$  is  $S$ .

In an initial model, the rod is modelled as being **uniform**.

Use this initial model to answer parts (b), (c) and (d).

- (b) By taking moments about  $A$ , show that

$$S = \frac{1}{2} Mg \cot \theta \quad (3)$$

The coefficient of friction between the rod and the ground is  $\mu$

Given that  $\tan \theta = \frac{3}{4}$

- (c) find the value of  $\mu$

(5)

- (d) find, in terms of  $M$  and  $g$ , the magnitude of the resultant force acting on the rod at  $A$ .

(3)

In a new model, the rod is modelled as being **non-uniform**, with its centre of mass closer to  $B$  than it is to  $A$ .

A new value for  $S$  is calculated using this new model, with  $\tan \theta = \frac{3}{4}$

- (e) State whether this new value for  $S$  is larger, smaller or equal to the value that  $S$  would take using the initial model. Give a reason for your answer.

(1)