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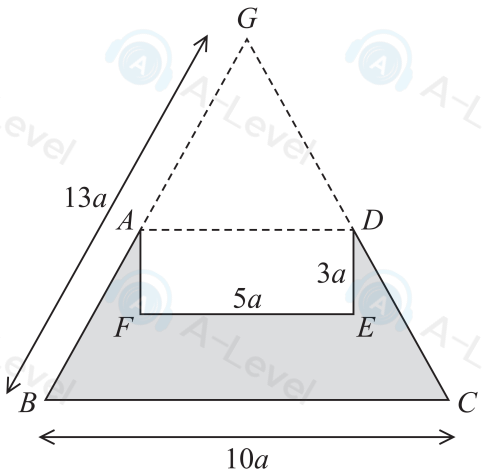

Figure 2

The uniform lamina GBC is in the shape of an isosceles triangle with $GB = GC = 13a$ and $BC = 10a$. The midpoint of GB is A and the midpoint of GC is D. The rectangle $AFED$ is such that $FE = 5a$ and $DE = 3a$.

The template, shown shaded in Figure 2, is formed by removing the triangle GAD and the rectangle $ADEF$ from the lamina GBC.

(a) Show that the centre of mass of the template is $\frac{7}{4}a$ from BC.

(5)

The template is freely suspended from A and hangs in equilibrium with AB at an angle of $\theta°$ to the downward vertical.

(b) Find the value of θ, giving your answer to the nearest whole number.

(5)

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3. [*In this question, the unit vectors* **i** *and* **j** *are in a vertical plane,* **i** *being horizontal and* **j** *being vertically upwards.*]

The point A is on horizontal ground.

A ball is projected from A with velocity $(8\mathbf{i} + 14\mathbf{j})\,\text{m s}^{-1}$

The motion of the ball is modelled as that of a particle moving freely under gravity.

(a) Find the maximum possible height of the ball above the ground.

(2)

(b) Find the speed of the ball 2.4 s after leaving A.

(3)

The point B is also on the horizontal ground.

The point C is 3 m vertically above B.

After the ball reaches its maximum height, the ball passes through the point C.

(c) Find the distance AB.

(5)

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5. [*In this question,* **i** *and* **j** *are horizontal perpendicular unit vectors.*]

A particle Q of mass 2 kg is moving on a smooth horizontal surface.

Particle Q is moving with velocity $4\mathbf{i}\ \text{m s}^{-1}$ when it receives a horizontal impulse $\mathbf{I}$ N s.

The magnitude of $\mathbf{I}$ is $4\sqrt{10}$ N s.

Immediately after receiving the impulse, the velocity of Q is $\lambda(\mathbf{i}+\mathbf{j})\ \text{m s}^{-1}$, where λ is a positive constant.

(a) Find the value of λ.

(5)

(b) Find $\mathbf{I}$ in terms of $\mathbf{i}$ and $\mathbf{j}$.

(1)

The angle between the direction of the impulse and the initial direction of motion of Q is $\theta°$

(c) Find the value of θ.

(2)

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2. A trailer of mass 250 kg is towed by a car of mass 1000 kg. The car and the trailer are travelling down a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{20}$

The resistance to motion of the car is modelled as a single force of magnitude 300 N acting parallel to the road. The resistance to motion of the trailer is modelled as a single force of magnitude 100 N acting parallel to the road. The towbar joining the car to the trailer is modelled as a light rod which is parallel to the direction of motion. At a given instant the car and the trailer are moving down the road with speed 25 m s^{-1} and acceleration 0.2 m s^{-2}.

(a) Find the power being developed by the car's engine at this instant.

(6)

(b) Find the tension in the towbar at this instant.

(4)

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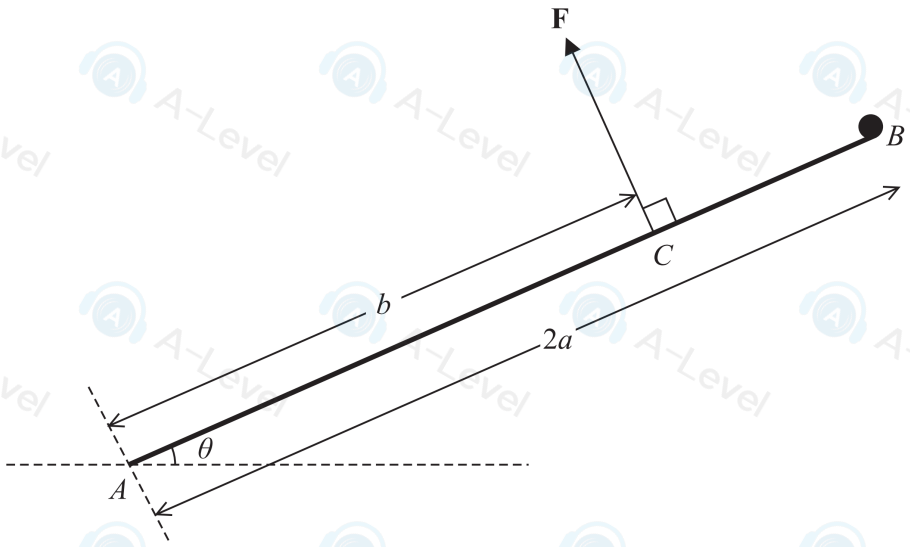

Figure 3

A uniform rod AB, of mass $3m$ and length $2a$, is freely hinged at A to a fixed point on horizontal ground. A particle of mass m is attached to the rod at the end B. The system is held in equilibrium by a force **F** acting at the point C, where $AC = b$. The rod makes an acute angle θ with the ground, as shown in Figure 3. The line of action of **F** is perpendicular to the rod and in the same vertical plane as the rod.

(a) Show that the magnitude of **F** is $\dfrac{5mga}{b}\cos\theta$

(4)

The force exerted on the rod by the hinge at A is **R**, which acts upwards at an angle ϕ above the horizontal, where $\phi > \theta$.

(b) Find

(i) the component of **R** parallel to the rod, in terms of m, g and θ,

(ii) the component of **R** perpendicular to the rod, in terms of a, b, m, g and θ.

(5)

(c) Hence, or otherwise, find the range of possible values of b, giving your answer in terms of a.

(2)

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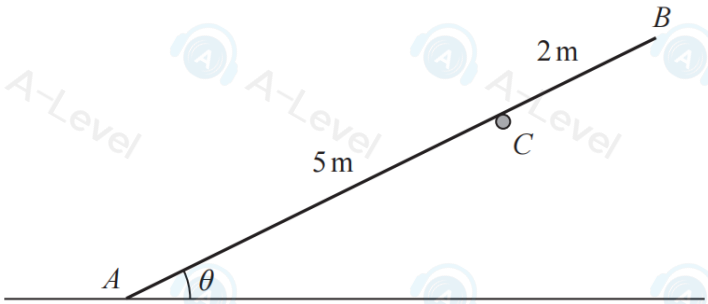

Figure 5

A uniform beam AB, of weight 40 N and length 7 m, rests with end A on rough horizontal ground.

The beam rests on a smooth horizontal peg at C, with $AC = 5$ m, as shown in Figure 5.

The beam is inclined at an angle θ to the ground, where $\sin\theta = \frac{3}{5}$

The beam is modelled as a rod that lies in a vertical plane perpendicular to the peg.

The normal reaction between the beam and the peg at C has magnitude P newtons.

Using the model,

(a) show that $P = 22.4$

(3)

(b) find the magnitude of the resultant force acting on the beam at A.

(6)

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3. A particle P of mass 4 kg moves from point A to point B down a line of greatest slope of a fixed rough plane. The plane is inclined at 40° to the horizontal and $AB = 12$ m. The coefficient of friction between P and the plane is 0.5

(a) Find the work done against friction as P moves from A to B.

(3)

Given that the speed of P at B is 24 m s^{-1}

(b) use the work-energy principle to find the speed of P at A.

(4)

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1. A particle P moves on the x-axis. The acceleration of P, in the positive x direction at time t seconds, is $(2t - 3)$ m s^{-2}. The velocity of P, in the positive x direction at time t seconds, is v m s^{-1}. When $t = 0$, $v = 2$

(a) Find v in terms of t.

(4)

The particle is instantaneously at rest at times t_1 seconds and t_2 seconds, where $t_1 < t_2$.

(b) Find the values t_1 and t_2.

(3)

(c) Find the distance travelled by P between $t = t_1$ and $t = t_2$.

(4)

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3. A cyclist and his bicycle, with a combined mass of 75 kg, move along a straight horizontal road. The cyclist is working at a constant rate of 180 W. There is a constant resistance to the motion of the cyclist and his bicycle of magnitude R newtons. At the instant when the speed of the cyclist is 4 m s^{-1}, his acceleration is 0.2 m s^{-2}.

(a) Find the value of R.

(4)

Later, the cyclist moves up a straight road with a constant speed v m s^{-1}. The road is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{21}$. The cyclist is working at a rate of 180 W and the resistance to the motion of the cyclist and his bicycle from non-gravitational forces is again the same constant force of magnitude R newtons.

(b) Find the value of v.

(4)

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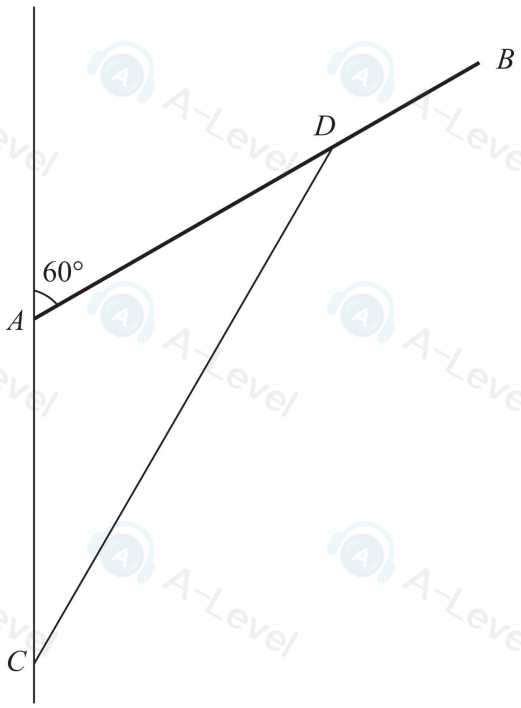

Figure 1

A uniform rod AB of weight W is freely hinged at end A to a vertical wall. The rod is supported in equilibrium at an angle of 60° to the wall by a light rigid strut CD. The strut is freely hinged to the rod at the point D and to the wall at the point C, which is vertically below A, as shown in Figure 1. The rod and the strut lie in the same vertical plane, which is perpendicular to the wall. The length of the rod is $4a$ and $AC = AD = 2.5a$.

(a) Show that the magnitude of the thrust in the strut is $\frac{4\sqrt{3}}{5}W$.

(3)

(b) Find the magnitude of the force acting on the rod at A.

(6)

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2. A car of mass 500 kg is moving at a constant speed of $20\,\text{m s}^{-1}$ up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{20}$. The resistance to motion from non-gravitational forces is modelled as a constant force of magnitude 150 N.

(a) Find the rate of working of the engine of the car.

(5)

When the car is travelling up the road at $20\,\text{m s}^{-1}$, the engine is switched off. The car then comes to instantaneous rest, without braking, having moved a distance d metres up the road from the point where the engine was switched off. The resistance to motion from non-gravitational forces is again modelled as a constant force of magnitude 150 N.

(b) Use the work-energy principle to find the value of d.

(4)