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4. A small stone is projected vertically upwards from the point O and moves freely under gravity. The point A is 3.6 m vertically above O. When the stone first reaches A, the stone is moving upwards with speed 11.2 m s^{-1}. The stone is modelled as a particle.

(a) Find the maximum height above O reached by the stone.

(4)

(b) Find the total time between the instant when the stone was projected from O and the instant when it returns to O.

(5)

(c) Sketch a velocity-time graph to represent the motion of the stone from the instant when it passes through A moving upwards to the instant when it returns to O. Show, on the axes, the coordinates of the points where your graph meets the axes.

(4)

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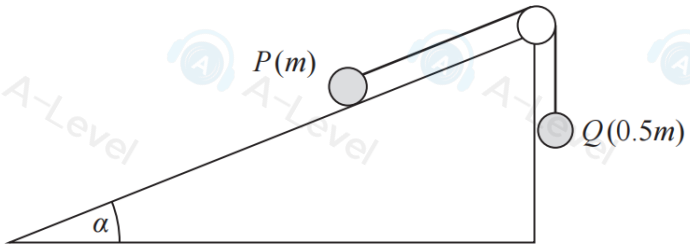

Figure 5

A fixed rough plane is inclined at an angle α to the horizontal, where $\tan\alpha = \frac{5}{12}$

A small smooth pulley is fixed at the top of the plane.

One end of a light inextensible string is attached to a particle P which is at rest on the plane. The string passes over the pulley and the other end of the string is attached to a particle Q which hangs vertically below the pulley, as shown in Figure 5.

Particle P has mass m and particle Q has mass $0.5m$

The string from P to the pulley lies along a line of greatest slope of the plane.

The coefficient of friction between P and the plane is μ.

The system is in **limiting equilibrium** with the string taut and P is on the point of slipping **up** the plane.

(a) Find the value of μ.

(8)

The string breaks and P begins to move down the plane.

When particle P has travelled a distance of $0.8\,\text{m}$ down the plane, the speed of P is $V\,\text{m s}^{-1}$

(b) Find the value of V.

(4)

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7. [*In this question* **i** *and* **j** *are horizontal unit vectors due east and due north respectively and position vectors are given relative to a fixed origin O.*]

A ship A is moving with constant velocity $(2\mathbf{i} - 14\mathbf{j})\,\text{km h}^{-1}$. At 2 pm the position vector of ship A is $(8\mathbf{i} + 7\mathbf{j})\,\text{km}$.

A ship B is moving with constant velocity $(12\mathbf{i} - 4\mathbf{j})\,\text{km h}^{-1}$. At 2 pm the position vector of ship B is $(\mathbf{i} + 2\mathbf{j})\,\text{km}$.

(a) Show that at time t hours after 2 pm,

$$\overrightarrow{BA} = [(7 - 10t)\mathbf{i} + (5 - 10t)\mathbf{j}]\,\text{km}$$

(5)

(b) Hence find the length of time for which the ships are within 2 km of each other.

(7)

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5. Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on a particle. The resultant of the two forces is $\mathbf{R}$.

Given that $\mathbf{R}$ has the same direction as the vector $(3\mathbf{i} - 2\mathbf{j})$,

(a) find the size of the angle between $\mathbf{R}$ and the vector $\mathbf{j}$.

(2)

Given that $\mathbf{F}_1 = (a\mathbf{i} + 3\mathbf{j})$ N and $\mathbf{F}_2 = (-4\mathbf{i} + b\mathbf{j})$ N,

(b) show that $2a + 3b + 1 = 0$

(4)

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5. [*In this question* **i** *and* **j** *are perpendicular horizontal unit vectors and position vectors are given relative to a fixed origin O.*]

A particle P is moving in a straight line with constant velocity. At 9 am, the position vector of P is $(7\mathbf{i} + 5\mathbf{j})$ km and at 9.20 am, the position vector of P is $6\mathbf{i}$ km. At time t hours after 9 am, the position vector of P is $\mathbf{r}_P$ km.

(a) Find, in km h^{-1}, the speed of P.

(4)

(b) Show that $\mathbf{r}_P = (7 - 3t)\,\mathbf{i} + (5 - 15t)\,\mathbf{j}$.

(2)

(c) Find the value of t when $\mathbf{r}_P$ is parallel to $16\mathbf{i} + 5\mathbf{j}$.

(4)

The position vector of another particle Q, at time t hours after 9 am, is $\mathbf{r}_Q$ km, where $\mathbf{r}_Q = (5 + 2t)\,\mathbf{i} + (-3 + 5t)\,\mathbf{j}$

(d) Show that P and Q will collide and find the position vector of the point of collision.

(5)

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3. A block A of mass 9 kg is released from rest from a point P which is a height h metres above horizontal soft ground. The block falls and strikes another block B of mass 1.5 kg which is on the ground vertically below P. The speed of A immediately before it strikes B is 7 m s^{-1}. The blocks are modelled as particles.

(a) Find the value of h.

(2)

Immediately after the impact the blocks move downwards together with the same speed and both come to rest after sinking a vertical distance of 12 cm into the ground. Assuming that the resistance offered by the ground has constant magnitude R newtons,

(b) find the value of R.

(8)

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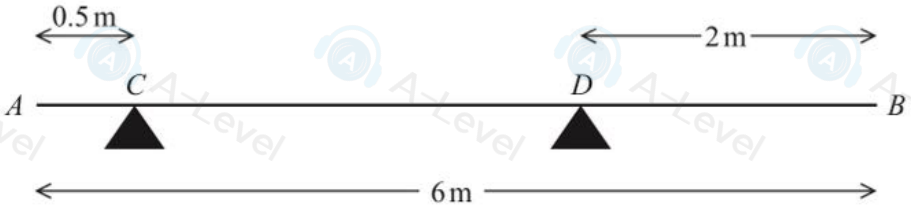

Figure 1

A metal girder AB, of weight 1080 N and length 6 m, rests in equilibrium in a horizontal position on two supports, one at C and one at D, where $AC = 0.5$ m and $BD = 2$ m, as shown in Figure 1. A boy of weight 400 N stands on the girder at B and the girder remains horizontal and in equilibrium. The boy is modelled as a particle and the girder is modelled as a uniform rod.

(a) Find

(i) the magnitude of the reaction on the girder at C,

(ii) the magnitude of the reaction on the girder at D.

(6)

The boy now stands at a point E on the girder, where $AE = x$ metres, and the girder remains horizontal and in equilibrium. Given that the magnitude of the reaction on the girder at D is now 520 N greater than the magnitude of the reaction on the girder at C,

(b) find the value of x.

(5)

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6.

Figure 3

A box of mass m lies on a rough horizontal plane. The box is pulled along the plane in a straight line at **constant speed** by a light rope. The rope is inclined at an angle θ to the plane, as shown in Figure 3.

The coefficient of friction between the box and the plane is $\frac{1}{3}$

The box is modelled as a particle.

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

(a) find, in terms of m and g, the tension in the rope.

(7)

The rope is now removed and the box is placed at rest on the plane.
The box is then projected horizontally along the plane with speed u.

The box is again modelled as a particle.

When the box has moved a distance d along the plane, the speed of the box is $\frac{1}{2}u$.

(b) Find d in terms of u and g.

(5)