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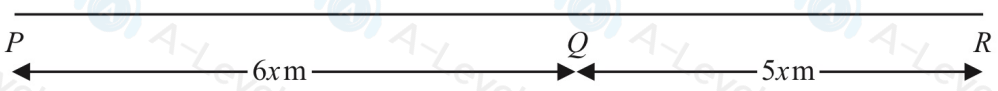

Figure 2

Three points P, Q and R are on a horizontal road where PQR is a straight line.

The point Q is between P and R, with $PQ = 6x$ metres and $QR = 5x$ metres, as shown in Figure 2.

A vehicle moves along the road from P to Q with constant acceleration.

The vehicle is modelled as a particle.

At time $t = 0$, the vehicle passes P with speed $u\,\text{m s}^{-1}$

At time $t = 12$ s, the vehicle passes Q with speed $2u\,\text{m s}^{-1}$

Using the model,

(a) show that $x = 3u$

(2)

As the vehicle passes Q, the acceleration of the vehicle changes instantaneously to $1.5\,\text{m s}^{-2}$

The vehicle continues to move with a constant acceleration of $1.5\,\text{m s}^{-2}$ and passes R with speed $3u\,\text{m s}^{-1}$

Using the model,

(b) find the value of u,

(3)

(c) find the distance travelled by the vehicle during the first 14 seconds after passing P

(4)

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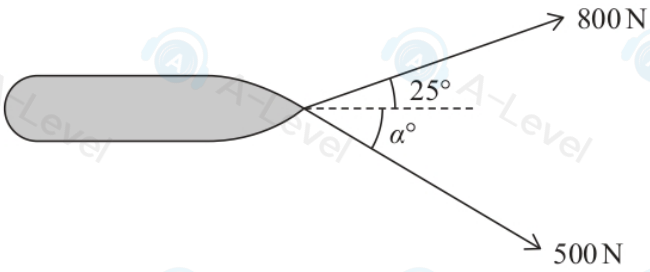

Figure 2

Two ropes are attached to a point on the front of a barge.
The barge is being pulled horizontally in a straight line along the centre of a long straight canal.

One rope makes an angle of 25° with the direction of motion of the barge and has a tension of 800 N.
The other rope makes an angle of $\alpha°$ with the direction of motion of the barge and has a tension of 500 N, as shown in Figure 2.

Both ropes are horizontal.

(a) Find the value of α

(3)

The mass of the barge is 15 tonnes and the resistance to the motion of the barge is a constant force of magnitude 750 N.

(b) Find the acceleration of the barge.

(4)

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4. Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on a particle. The force $\mathbf{F}_1$ has magnitude 8 N and acts due east. The resultant of $\mathbf{F}_1$ and $\mathbf{F}_2$ is a force of magnitude 14 N acting in a direction whose bearing is 120°.

Find

(i) the magnitude of $\mathbf{F}_2$,

(4)

(ii) the direction of $\mathbf{F}_2$, giving your answer as a bearing to the nearest degree.

(5)

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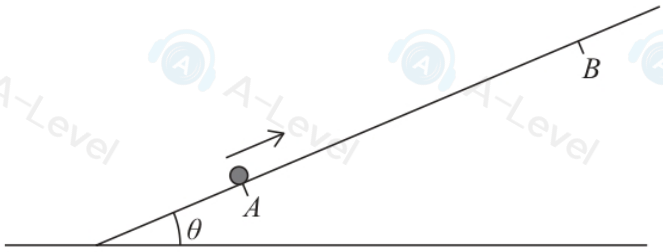

Figure 4

Figure 4 shows a rough plane inclined at an angle θ to the horizontal, where $\tan\theta = \frac{3}{4}$

The points A and B lie on a line of greatest slope of the plane, with B above A.

A package P of mass m is projected up the plane from A towards B.

The coefficient of friction between the plane and the package is $\frac{1}{4}$

The package P is modelled as a particle.

(a) Show that the **deceleration** of P, as it moves from A to B, is $\frac{4}{5}g$

(6)

The package P comes to rest at B.

Given that P is projected from A with speed $U\,\text{m s}^{-1}$ and that $AB = 1.5\,\text{m}$,

(b) find the value of U.

(2)

On reaching B, P is held at rest there by a force of magnitude X newtons acting up the plane in the direction AB.

Given that the mass of P is 2 kg,

(c) find the smallest possible value of X.

(3)

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8. Two trains, A and B, start together from rest, at time $t = 0$, at a station and move along parallel straight horizontal tracks. Both trains come to rest at the next station after 180 s.

Train A moves with constant acceleration $\frac{2}{3}$ m s^{-2} for 30 s, then moves at constant speed for 120 s and then moves with constant deceleration for the final 30 s. Train B moves with constant acceleration for 90 s and then moves with constant deceleration for the final 90 s.

(a) Sketch, on the same axes, the speed–time graphs for the motion of the two trains between the two stations.

(3)

(b) Find the acceleration of train B for the first half of its journey.

(5)

(c) Find the times when the two trains are moving at the same speed.

(4)

(d) Find the distance between the trains 96 s after they start.

(5)

3. A particle P is moving with constant acceleration $(-4\mathbf{i} + \mathbf{j})\,\text{m s}^{-2}$

At time $t = 0$, P has velocity $(14\mathbf{i} - 5\mathbf{j})\,\text{m s}^{-1}$

(a) Find the speed of P at time $t = 2$ seconds.

(3)

(b) Find the size of the angle between the direction of $\mathbf{i}$ and the direction of motion of P at time $t = 2$ seconds.

(3)

At time $t = T$ seconds, P is moving in the direction of vector $(2\mathbf{i} - 3\mathbf{j})$

(c) Find the value of T

(4)

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6. An athlete goes for a run along a straight horizontal road. Starting from rest, she accelerates at $0.6\,\text{m s}^{-2}$ up to a speed of $V\,\text{m s}^{-1}$. She then maintains this constant speed of $V\,\text{m s}^{-1}$ before finally decelerating at $0.2\,\text{m s}^{-2}$ back to rest. She covers a total distance of 1500 m in 270 s.

(a) Sketch a speed-time graph to represent the athlete's run.

(2)

(b) Show that she accelerates for $\frac{5V}{3}$ seconds.

(2)

(c) Show that $V^2 - kV + 450 = 0$, where k is a constant to be found.

(6)

(d) Find the value of V, justifying your answer.

(4)

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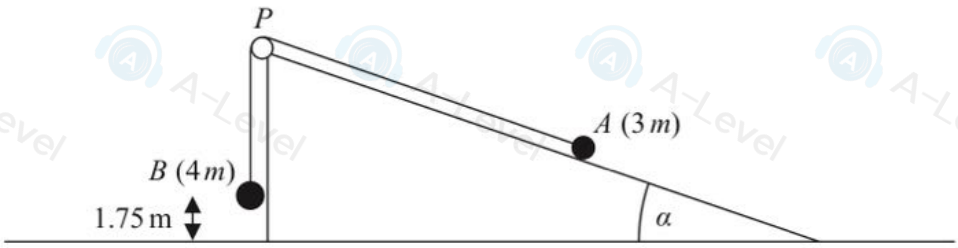

Figure 2

Figure 2 shows two particles A and B, of masses $3m$ and $4m$ respectively, attached to the ends of a light inextensible string. Initially A is held at rest on the surface of a fixed rough inclined plane. The plane is inclined to the horizontal at an angle α where $\tan\alpha = \frac{3}{4}$. The coefficient of friction between A and the plane is $\frac{1}{4}$. The string passes over a small smooth light pulley P which is fixed at the top of the plane. The part of the string from A to P is parallel to a line of greatest slope of the plane. The particle B hangs freely and is vertically below P. The system is released from rest with the string taut and with B at a height of 1.75 m above the ground. In the subsequent motion, A does not hit the pulley.

For the period before B hits the ground,

(a) write down an equation of motion for each particle.

(4)

(b) Hence show that the acceleration of B is $\frac{8}{35}g$.

(5)

(c) Explain how you have used the fact that the string is inextensible in your calculation.

(1)

When B hits the ground, B does not rebound and comes immediately to rest.

(d) Find the distance travelled by A from the instant when the system is released to the instant when A first comes to rest.

(7)

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

A boy B is running in a field with constant velocity $(3\mathbf{i} - 2\mathbf{j})$ m s^{-1}. At time $t = 0$, B is at the point with position vector $10\mathbf{j}$ m.

Find

(a) the speed of B,

(2)

(b) the direction in which B is running, giving your answer as a bearing.

(3)

At time $t = 0$, a girl G is at the point with position vector $(4\mathbf{i} - 2\mathbf{j})$ m. The girl is running with constant velocity $\left(\frac{5}{3}\mathbf{i} + 2\mathbf{j}\right)$ m s^{-1} and meets B at the point P.

(c) Find

(i) the value of t when they meet,

(ii) the position vector of P.

(6)

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6. Two cars A and B are moving in the same direction along a straight horizontal road. Car A is moving with uniform acceleration $0.4\,\text{m s}^{-2}$ and car B is moving with uniform acceleration $0.5\,\text{m s}^{-2}$. At the instant when B is 200 m behind A, the speed of A is $35\,\text{m s}^{-1}$ and the speed of B is $44\,\text{m s}^{-1}$. Find the speed of B when it overtakes A.

(9)

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7. A train travels along a straight horizontal track between two stations A and B. The train starts from rest at A and moves with constant acceleration until it reaches its maximum speed of 108 km h^{-1}. The train then travels at this speed before it moves with constant deceleration coming to rest at B. The journey from A to B takes 8 minutes.

(a) Change 108 km h^{-1} into m s^{-1}.

(2)

(b) Sketch a speed-time graph for the motion of the train between the two stations A and B.

(2)

Given that the distance between the two stations is 12 km and that the time spent decelerating is three times the time spent accelerating,

(c) find the acceleration, in m s^{-2}, of the train.

(6)