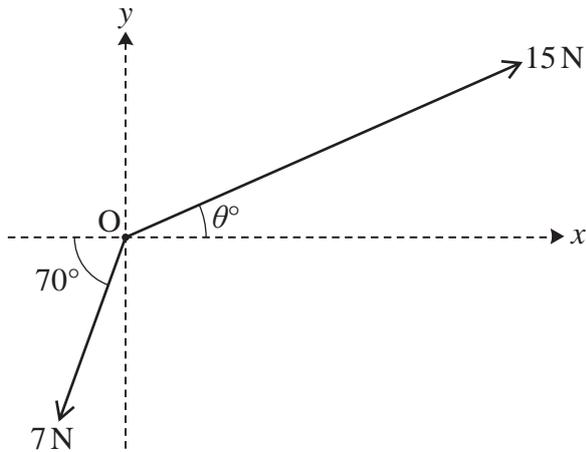


- 1 Two horizontal forces of magnitudes 7 N and 15 N act at a point O.
The 15 N force acts an angle of θ° above the positive x -axis.
The 7 N force acts at an angle of 70° below the negative x -axis (see diagram).



The resultant of the two forces acts only in the positive x -direction.

- (a) Calculate the value of θ . [2]
- (b) Calculate the magnitude of the resultant of the two forces. [2]

- 2 (a) Find the dimensions of energy. [1]

The moment of inertia, I , of a rigid body rotating about a fixed axis is measured in kg m^2 .

- (b) State the dimensions of I . [1]

The kinetic energy, E , of a rigid body rotating about a fixed axis is given by the formula

$$E = \frac{1}{2}I\omega^2,$$

where ω is the angular velocity (angle per unit time) of the rigid body.

- (c) Show that the formula for E is dimensionally consistent. [2]

When a rigid body is pivoted from one of its end points and allowed to swing freely, it forms a pendulum. The period, t , of the pendulum is the time taken for it to complete one oscillation. A student conjectures the formula

$$t = k(mg)^\alpha r^\beta I^\gamma,$$

where

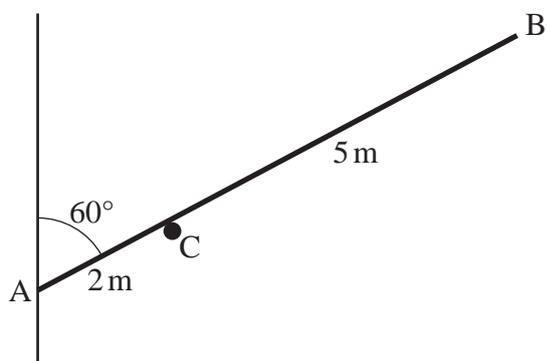
- k is a dimensionless constant,
- m is the mass of the rigid body,
- g is the acceleration due to gravity,
- r is the distance between the pivot point and the rigid body's centre of mass.

- (d) Use dimensional analysis to find the values of α , β and γ . [4]

The moment of inertia of a thin uniform rigid rod of mass 1.5 kg and length 0.8 m, rotating about one of its endpoints, is 0.32 kg m^2 . The student suspends such a rod from one of its endpoints and allows it to swing freely. The student measures the period of this pendulum and finds that it is 1.47 seconds.

- (e) Using the formula conjectured by the student, determine the value of k . [3]

- 3 The diagram shows a uniform beam AB, of weight 80 N and length 7 m, resting in equilibrium in a vertical plane. The end A is in contact with a rough vertical wall, and the angle between the beam and the upward vertical is 60° . The beam is supported by a smooth peg at a point C, where $AC = 2$ m.



- (a) Complete the diagram in the **Printed Answer Booklet** to show all the forces acting on the beam. [2]
- (b) (i) Show that the magnitude of the frictional force exerted on the beam by the wall is 25 N. [3]
- (ii) Hence determine the magnitude of the total contact force exerted on the beam by the wall. [3]
- (c) Determine the direction of the total contact force exerted on the beam by the wall. [2]

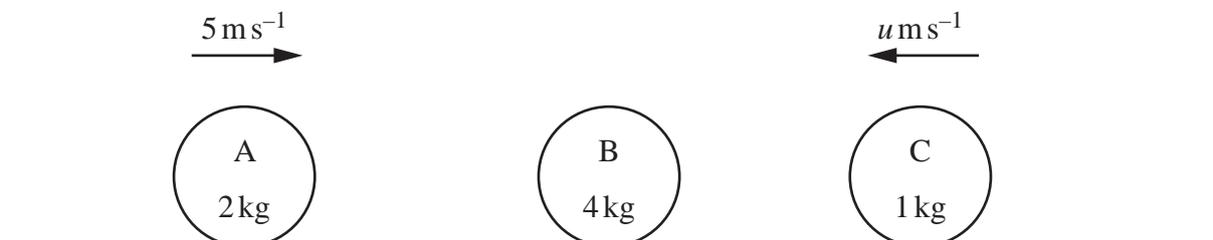
The coefficient of friction between the beam and the wall is μ .

- (d) Find the range of possible values for μ . [2]
- (e) Explain how your answer to part (b)(ii) would change if the peg were situated closer to A but the angle between the beam and the upward vertical remained at 60° . [1]

- 4 Three spheres A, B, and C, of equal radius are in the same straight line on a smooth horizontal surface. The masses of A, B and C are 2 kg, 4 kg and 1 kg respectively.

Initially the three spheres are at rest.

Spheres A and C are each given impulses so that A moves towards B with speed 5 m s^{-1} and C moves towards B with speed $u \text{ m s}^{-1}$ as shown in the diagram below.



The coefficient of restitution between A and B is $\frac{4}{5}$.

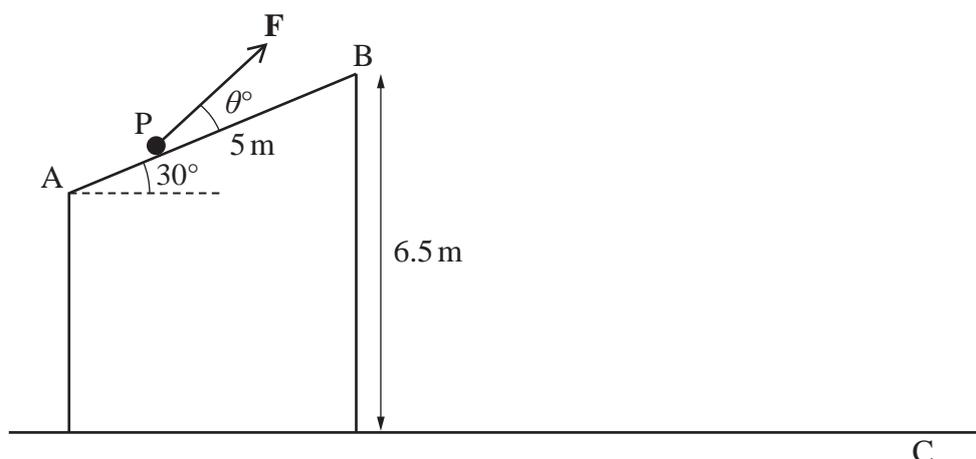
It is given that the first collision occurs between A and B.

- (a) State how you can tell from the information given above that kinetic energy is lost when A collides with B. [1]
- (b) Show that the combined kinetic energy of A and B decreases by 24% during their collision. [5]

Sphere B next collides with C. The coefficient of restitution between B and C is $\frac{2}{3}$.

- (c) Given that a third collision occurs, determine the range of possible values for u . [6]
- (d) State **one** limitation of the model used in this question. [1]

- 5 In the diagram below, points A, B and C lie in the same vertical plane. The slope AB is inclined at an angle of 30° to the horizontal and $AB = 5$ m. The point B is a vertical distance of 6.5 m above horizontal ground. The point C lies on the horizontal ground.



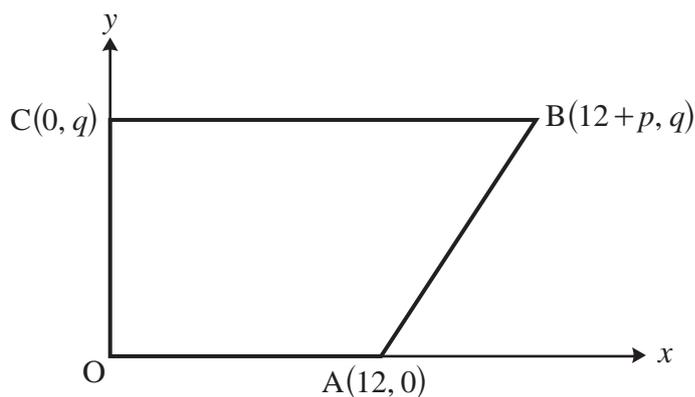
Starting at A, a particle P, of mass m kg, moves along the slope towards B, under the action of a constant force \mathbf{F} . The force \mathbf{F} has a magnitude of 50 N and acts at an angle of θ° to AB in the same vertical plane as A and B. When P reaches B, \mathbf{F} is removed, and P moves under gravity landing at C.

It is given that

- the speed of P at A is 3 m s^{-1} ,
- the speed of P at B is 6 m s^{-1} ,
- the speed of P at C is 12 m s^{-1} ,
- 58 J of work is done against non-gravitational resistances as P moves from A to B,
- 42 J of work is done against non-gravitational resistances as P moves from B to C.

- (a) By considering the motion from B to C, show that $m = 4.33$ correct to 3 significant figures. [3]
- (b) By considering the motion from A to B, determine the value of θ . [4]
- (c) Calculate the power of \mathbf{F} at the instant that P reaches B. [2]

- 6 A uniform lamina OABC is in the shape of a trapezium where O is the origin of the coordinate system in which the points A, B and C have coordinates $(12, 0)$, $(12+p, q)$ and $(0, q)$ respectively.



- (a) Determine, in terms of p and q , the coordinates of the centre of mass of OABC. [4]

The point D has coordinates $(7.6, q)$. When OABC is suspended from D, the lamina hangs in equilibrium with BC horizontal.

- (b) Determine the value of p . [3]

When OABC is suspended from C, the lamina hangs in equilibrium with BC at an angle of 35° to the downward vertical.

- (c) Determine the value of q , giving your answer correct to 3 significant figures. [3]

END OF QUESTION PAPER

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