



Oxford Cambridge and RSA

Thursday 15 October 2020 – Afternoon

AS Level Further Mathematics A

Y533/01 Mechanics

Time allowed: 1 hour 15 minutes



You must have:

- the Printed Answer Booklet
- the Formulae Booklet for AS Level Further Mathematics A
- a scientific or graphical calculator

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided in the **Printed Answer Booklet**. If you need extra space use the lined pages at the end of the Printed Answer Booklet. The question numbers must be clearly shown.
- Fill in the boxes on the front of the Printed Answer Booklet.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.
- Give non-exact numerical answers correct to 3 significant figures unless a different degree of accuracy is specified in the question.
- The acceleration due to gravity is denoted by $g \text{ m s}^{-2}$. When a numerical value is needed use $g = 9.8$ unless a different value is specified in the question.
- Do **not** send this Question Paper for marking. Keep it in the centre or recycle it.

INFORMATION

- The total mark for this paper is **60**.
- The marks for each question are shown in brackets [].
- This document has **8** pages.

ADVICE

- Read each question carefully before you start your answer.

Answer **all** the questions.

- 1 A car of mass 1200 kg is driven on a long straight horizontal road. There is a constant force of 250 N resisting the motion of the car. The engine of the car is working at a constant power of 10 kW.

(a) The car can travel at constant speed $v \text{ m s}^{-1}$ along the road. Find v . [2]

(b) Find the acceleration of the car at an instant when its speed is 30 m s^{-1} . [3]

- 2 A particle P of mass 4.5 kg is moving in a straight line on a smooth horizontal surface at a speed of 2.4 m s^{-1} when it strikes a vertical wall directly. It rebounds at a speed of 1.6 m s^{-1} .

(a) Find the coefficient of restitution between P and the wall. [1]

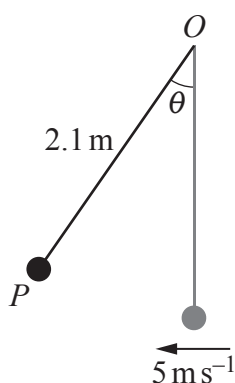
(b) Determine the impulse applied to P by the wall, stating its direction. [3]

(c) Find the loss of kinetic energy of P as a result of the collision. [2]

(d) State, with a reason, whether the collision is perfectly elastic. [1]

- 3 A particle P of mass 5.6 kg is attached to one end of a light rod of length 2.1 m. The other end of the rod is freely hinged to a fixed point O .

The particle is initially at rest directly below O . It is then projected horizontally with speed 5 m s^{-1} . In the subsequent motion, the angle between the rod and the downward vertical at O is denoted by θ radians, as shown in the diagram.



(a) Find the speed of P when $\theta = \frac{1}{4}\pi$. [4]

(b) Find the value of θ when P first comes to instantaneous rest. [2]

- 4 A particle P of mass 2.4 kg is moving in a straight line OA on a horizontal plane. P is acted on by a force of magnitude 30 N in the direction of motion. The distance OA is 10 m .

(a) Find the work done by this force as P moves from O to A . [2]

The motion of P is resisted by a constant force of magnitude $R\text{ N}$. The velocity of P increases from 12 ms^{-1} at O to 18 ms^{-1} at A .

(b) Find the value of R . [3]

(c) Find the average power used in overcoming the resistance force on P as it moves from O to A . [3]

When P reaches A it collides directly with a particle Q of mass 1.6 kg which was at rest at A before the collision. The impulse exerted on Q by P as a result of the collision is 17.28 N s .

(d) (i) Find the speed of Q after the collision. [2]

(ii) Hence show that the collision is inelastic. [2]

- 5 A particle of mass m moves in a straight line with constant acceleration a . Its initial and final velocities are u and v respectively and its final displacement from its starting position is s . In order to model the motion of the particle it is suggested that the velocity is given by the equation

$$v^2 = pu^\alpha + qa^\beta s^\gamma$$

where p and q are dimensionless constants.

(a) Explain why α must equal 2 for the equation to be dimensionally consistent. [2]

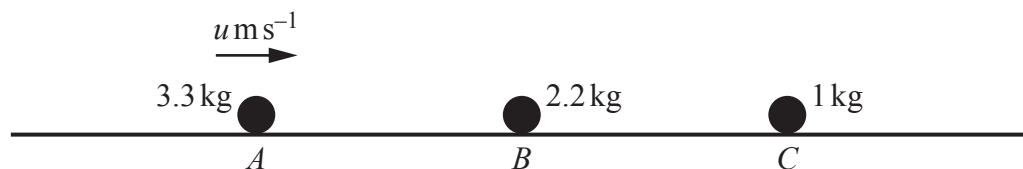
(b) By using dimensional analysis, determine the values of β and γ . [4]

(c) By considering the case where $s = 0$, determine the value of p . [1]

(d) By multiplying both sides of the equation by $\frac{1}{2}m$, and using the numerical values of α , β and γ , determine the value of q . [2]

- 6 Three particles A , B and C are free to move in the same straight line on a large smooth horizontal surface. Their masses are 3.3 kg, 2.2 kg and 1 kg respectively. The coefficient of restitution in collisions between any two of them is e .

Initially, B and C are at rest and A is moving towards B with speed $u \text{ ms}^{-1}$ (see diagram). A collides directly with B and B then goes on to collide directly with C .

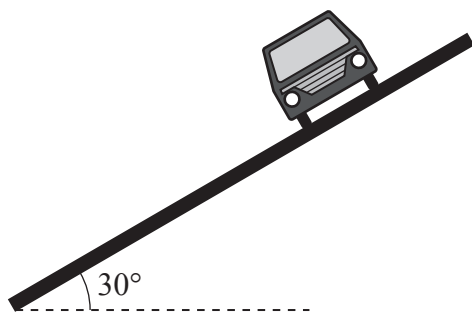


- (a) The velocities of A and B immediately after the first collision are denoted by $v_A \text{ ms}^{-1}$ and $v_B \text{ ms}^{-1}$ respectively.
- Show that $v_A = \frac{u(3-2e)}{5}$.
 - Find an expression for v_B in terms of u and e . [4]
- (b) Find an expression in terms of u and e for the velocity of B immediately after its collision with C . [4]

After the collision between B and C there is a further collision between A and B .

- (c) Determine the range of possible values of e . [4]

- 7 It is required to model the motion of a car of mass m kg travelling at a constant speed v ms⁻¹ around a circular portion of banked track. The track is banked at 30° (see diagram).



In a model, the following modelling assumptions are made.

- The track is smooth.
- The car is a particle.
- The car follows a horizontal circular path with radius r m.

(a) Show that, according to the model, $\sqrt{3} v^2 = gr$. [4]

For a particular portion of banked track, $r = 24$.

(b) Find the value of v as predicted by the model. [2]

A car is being driven on this portion of the track at the constant speed calculated in part (b). The driver finds that in fact he can drive a little slower or a little faster than this while still moving in the same horizontal circle.

(c) Explain

- how this contrasts with what the model predicts,
- how to improve the model to account for this.

[3]

END OF QUESTION PAPER

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