

OCR

Oxford Cambridge and RSA

Wednesday 17 May 2017 – Morning

A2 GCE MATHEMATICS (MEI)

4762/01 Mechanics 2

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:

- Printed Answer Book 4762/01
- MEI Examination Formulae and Tables (MF2)

Other materials required:

- Scientific or graphical calculator

Duration: 1 hour 30 minutes



INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found inside the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
- **Write your answer to each question in the space provided in the Printed Answer Book.** Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the barcodes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g \text{ m s}^{-2}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

This information is the same on the Printed Answer Book and the Question Paper.

- The number of marks is given in brackets [] at the end of each question or part question on the Question Paper.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **16** pages. The Question Paper consists of **8** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER/INVIGILATOR

- Do not send this Question Paper for marking; it should be retained in the centre or recycled. Please contact OCR Copyright should you wish to re-use this document.

- 1 Fig. 1.1 shows the masses and speeds of two small uniform circular discs, A and B, sliding towards one another on a smooth horizontal surface. Each of the discs is moving with its centre on the line shown in the figure; there is a barrier which is perpendicular to this line. The discs collide and separate.

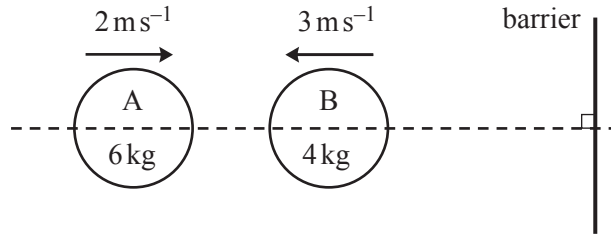


Fig. 1.1

- (i) By considering only linear momentum, explain how you know that the direction of motion of each disc must be reversed in the collision. [2]

You are now given that the coefficient of restitution is e .

- (ii) Show that after the collision A has speed $2e$. Find an expression in terms of e for the speed of B after the collision. [5]
- (iii) Find an expression in terms of e for the magnitude of the impulse in the collision. [1]

Three seconds after its collision with A, disc B has a perfectly elastic direct collision with the barrier shown in Fig. 1.1 and later collides again with A.

- (iv) What time will elapse between the two collisions of the discs? [3]

In a different situation, B has an oblique impact with a smooth barrier. This barrier is inclined at an angle α to the direction of motion of B. The coefficient of restitution in this collision is $\frac{1}{3}$ and the direction of motion of B is turned through 90° as a result of the collision, as shown in Fig. 1.2.

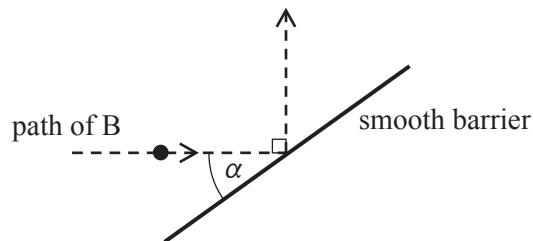


Fig. 1.2

- (v) Calculate α , giving your answer in degrees. [5]

2 In this question take $g = 10$.

Fig. 2 shows a small object Q, of mass 5 kg, which slides in a straight line up a rough ramp. The point D is at the top of the ramp, where the ramp is joined to a horizontal platform. The point C on the ramp is a vertical distance of 2 m below D. CD is inclined at an angle α to the horizontal.

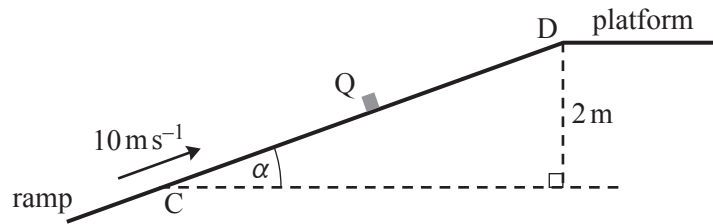


Fig. 2

Q is struck so that it moves up a line of greatest slope of the ramp. Q passes through C with a speed of 10 m s^{-1} and comes to rest at D.

The motion of Q is first modelled by assuming that the only resistance to its motion is friction with the plane.

- (i) Without assuming that the ramp is uniformly rough, calculate the work done by the frictional force as Q travels from C to D. [3]

Now assume that the coefficient of friction between the object and the plane has the constant value $\frac{5}{8}$.

- (ii) Show that the work done by the frictional force acting on Q as it travels from C to D may be expressed as $\frac{125}{2 \tan \alpha}$.

Calculate $\tan \alpha$. [7]

A new ramp is built that is inclined at an angle greater than α to the horizontal. This also ends at D. Q is now struck so that it moves up a line of greatest slope of the new ramp. As in the previous situation, it passes through a point at a vertical level 2 m below D at a speed of 10 m s^{-1} . The coefficient of friction between Q and the new ramp is the same as that between Q and the old ramp.

- (iii) Does Q now come to rest below D or still come to rest at D or is Q still moving at D? You should explain your answer but you need not produce detailed calculations. [2]

Subsequently Q is moving on the horizontal platform and is made to travel in a straight line by a force which has a constant power of 50 W. The resistance to the motion of Q is $F \text{ N}$, where F is constant. The velocity and acceleration of Q at time $t \text{ s}$ are $v \text{ m s}^{-1}$ and $a \text{ m s}^{-2}$ in the direction of its motion.

- (iv) Write down the equation of motion of Q in terms of F , v and a . [3]

- (v) Given that Q is travelling at a constant speed of 4 m s^{-1} , calculate F . [1]

- (vi) Show that a can only be constant if it is zero.

Q changes speed from $U \text{ m s}^{-1}$ to $V \text{ m s}^{-1}$ in $T \text{ s}$. Explain why it would not be appropriate to calculate the distance travelled in this time as $\frac{1}{2}T(U+V)$. [3]

- 3 (a) Fig. 3.1 shows a framework JKL in a vertical plane. The framework is made from three light rigid rods JK, KL and LJ which are freely pin-jointed to each other at J, K and L. The pin-joint at J is attached to a fixed vertical wall; the pin-joint at L is in contact with a fixed smooth horizontal beam. JK is 5 m, KL is 3 m and LJ is 4 m. Angle KLJ is 90° .

The framework is held in equilibrium with JK horizontal by means of a single applied force of 80 N acting at K parallel to JL. Fig. 3.1 shows this force and the angle α between JL and JK. Fig. 3.1 also shows the horizontal component, X N, of the force on the framework due to J being attached to the wall. Note that the diagram does not show the vertical component of the force acting at J nor the force on the framework at L due to contact with the beam.

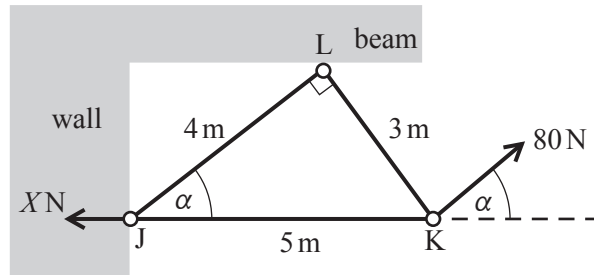


Fig. 3.1

Show that $X = 64$.

By first considering the equilibrium of the pin-joint at K, or otherwise, calculate the forces internal to the rods JK, KL and LJ, stating whether each rod is in tension or thrust (compression). [8]

- (b) Fig. 3.2 shows a uniform heavy ladder AB, of weight W N, standing on rough horizontal ground and resting on a smooth peg at C. The ladder has length 5 m. C is 3 m above the ground and is a horizontal distance of 1.25 m from A. The ladder is in equilibrium.

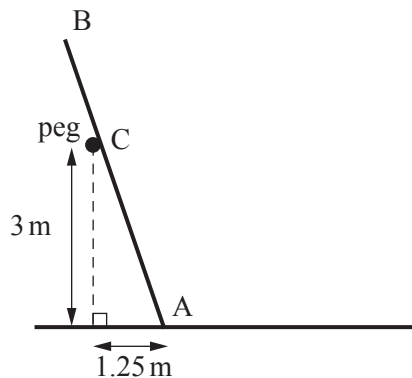


Fig. 3.2

Show that the force exerted on the ladder by the peg at C is $\frac{50W}{169}$.

Calculate the range of possible values of the coefficient of friction between the ladder and the ground. [12]

- 4 (a) In this part question, all coordinates refer to the axes shown in Fig. 4.1.

Fig. 4.1 shows a uniform rectangular lamina OABC with OA and OC on the x - and y -coordinate axes. The units of the axes are metres.

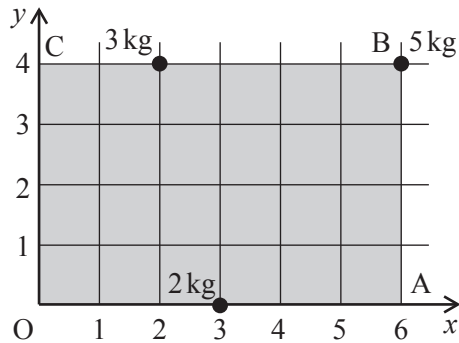


Fig. 4.1

The mass of the lamina is 2 kg and 3 heavy particles are fixed to it. The masses of these particles are 2 kg, 3 kg and 5 kg and they are at points with coordinates (3, 0), (2, 4) and (6, 4), respectively.

- (i) Calculate the coordinates of the combined centre of mass of the lamina and the 3 particles. [3]

A particle of mass m kg is now fixed to the lamina at a point $(X, 0)$, with $0 < X \leq 6$, so that the combined centre of mass of the original 3 particles, the lamina and the mass m kg lies on OB (part of the line with equation $y = \frac{2}{3}x$).

- (ii) Establish that $mX = 6$. [4]

- (b) Fig. 4.2 shows a thin heavy uniform wire ABC bent into the shape of a semi-circle with centre O and radius r . More of the same wire, DE, has its centre at O and lies on the straight line AOC. The distance DE is kr , where $k \geq 2$ is a constant. The two wires are joined at A and C to form object P.

You may use without proof the information that the centre of mass of the curved semi-circular section of the wire, ABC, lies on the line OB at a distance $\frac{2r}{\pi}$ from O.

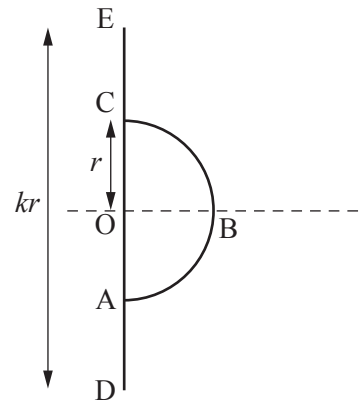


Fig. 4.2

- (i) Show that the centre of mass of P lies on OB at a distance $\frac{2r}{\pi + k}$ from O. [4]

Two light inelastic strings are attached to P , one at E and the other at B. Both strings are vertical and P is in equilibrium with DE vertical. The tension in the string attached at E is T_E and the tension in the string attached at B is T_B .

- (ii) Find the value of k for which $T_E = 2T_B$. [6]

END OF QUESTION PAPER

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