



Oxford Cambridge and RSA

Wednesday 15 June 2022 – Afternoon

A Level Further Mathematics B (MEI)

Y431/01 Mechanics Minor

Time allowed: 1 hour 15 minutes



You must have:

- the Printed Answer Booklet
- the Formulae Booklet for Further Mathematics B (MEI)
- 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 your final answers to a degree of accuracy that is appropriate to the context.
- 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 Newton's gravitational constant, G , is approximately $6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$.

(a) Find the dimensions of G .

[2]

The escape velocity, v , of a body from a planet's surface, is given by the formula

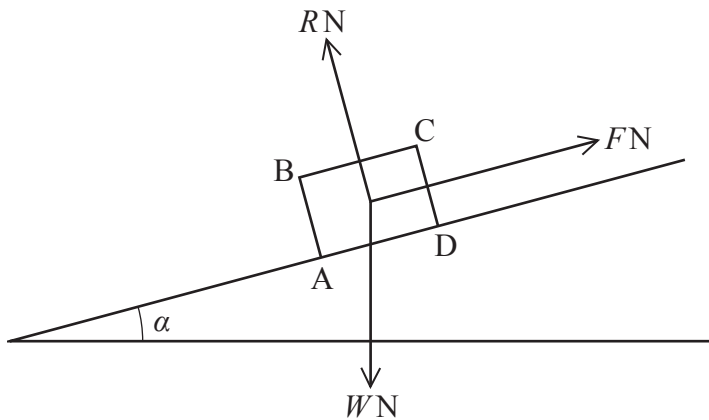
$$v = kG^\alpha M^\beta r^\gamma,$$

where M is the planet's mass, r is the planet's radius and k is a dimensionless constant.

(b) Use dimensional analysis to find α , β and γ .

[4]

- 2 The diagram below shows the cross-section through the centre of mass of a uniform block of weight WN , resting on a slope inclined at an angle α to the horizontal. The cross-section is a rectangle $ABCD$. The slope exerts a frictional force of magnitude FN and a normal contact force of magnitude RN .



- (a) Explain why a triangle of forces may be used to model the scenario. [2]
- (b) In the space provided in the Printed Answer Booklet, draw such a triangle, fully annotated, including the angle α in the correct position. [2]

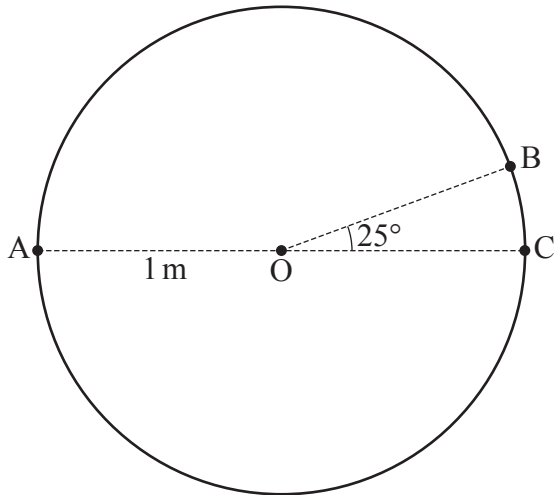
The coefficient of friction between the block and the slope is μ .

- (c) Given that the block is in limiting equilibrium, use your diagram in part (b) to show that $\mu = \tan \alpha$. [2]

It is given that $AB = 8.9$ cm and $AD = 11.6$ cm. The coefficient of friction between the slope and the block is 1.35. The slope is slowly tilted so that α increases.

- (d) Determine whether the block topples first without sliding or slides first without toppling. [2]

- 3 A rough circular hoop, with centre O and radius 1 m , is fixed in a vertical plane. A , B and C are points on the hoop such that A and C are at the same horizontal level as O , and OB makes an angle of 25° above the horizontal, as shown in the diagram.



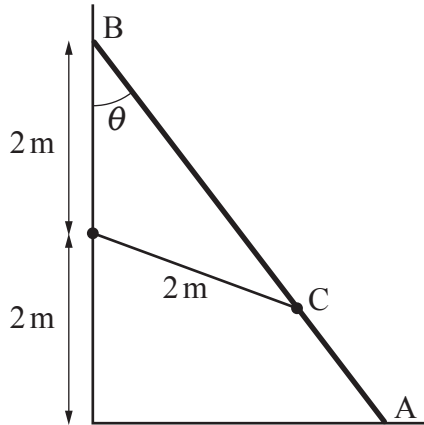
A bead P of mass 0.3 kg is threaded onto the hoop. P is projected vertically downwards from A on two separate occasions.

- The first time, when P is projected with a speed of 4 m s^{-1} , it first comes to rest at B .
- The second time, when P is projected with a speed of $v\text{ m s}^{-1}$, it first comes to rest at C .

The situation is modelled by assuming that during the motion of P the magnitude of the frictional force exerted by the hoop on P is constant.

- (a) Determine the value of v . [5]
- (b) Comment on the validity of the modelling assumption used in this question. [1]

- 4 A uniform beam AB of mass 6 kg and length 5 m rests with its end A on smooth horizontal ground and its end B against a smooth vertical wall. The vertical distance between the ground and B is 4 m, and the angle between the beam and the downward vertical is θ . To prevent the beam from sliding, one end of a light taut rope of length 2 m is attached to the beam at C and the other end of the rope is attached to a point on the wall 2 m above the ground, as shown in the diagram.



- (a) By considering the value of $\cos \theta$, determine the distance BC. [2]

An object of mass 75 kg is placed on the beam at a point which is x m from A.

It is given that the tension in the rope is T N and the magnitude of the normal contact force between the ground and the beam is R N.

- (b) By taking moments about B for the beam, show that $25R + 3675x - 16T = 19110$. [4]
- (c) Given that the rope can withstand a maximum tension of 720 N, determine the largest possible value of x . [4]

- 5 Point A lies 20 m vertically below a point B. A particle P of mass $4m$ kg is projected upwards from A, at a speed of 17.5 m s^{-1} . At the same time, a particle Q of mass m kg is released from rest at point B. The particles collide directly, and it is given that the coefficient of restitution in the collision between P and Q is 0.6.

- (a) Show that, immediately after the collision, P continues to travel upwards at 0.7 m s^{-1} and determine, at this time, the corresponding velocity of Q. [8]

In another situation, a particle of mass $3m$ kg is released from rest and falls vertically. After it has fallen 10 m, it explodes into two fragments. Immediately after the explosion, the lower fragment, of mass $2m$ kg, moves vertically downwards with speed $v_1 \text{ m s}^{-1}$, and the upper fragment, of mass m kg, moves vertically upwards with speed $v_2 \text{ m s}^{-1}$.

- (b) Given that, in the explosion, the kinetic energy of the system increases by 72%, show that $2v_1^2 + v_2^2 = 1011.36$. [3]
- (c) By finding another equation connecting v_1 and v_2 , determine the speeds of the fragments immediately after the explosion. [6]

- 6 **Fig. 6.1** shows a light rod ABC, of length 60 cm, where B is the midpoint of AC. Particles of masses 3.5 kg, 1.4 kg and 2.1 kg are attached to A, B and C respectively.

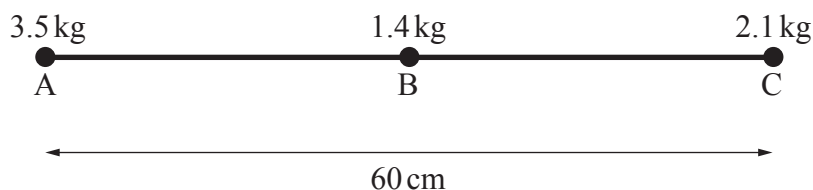


Fig. 6.1

The centre of mass is located at a point G along the rod.

- (a) Determine the distance AG. [2]

Two light inextensible strings, each of length 40 cm, are attached to the rod, one at A, the other at C. The other ends of these strings are attached to a fixed point D. The rod is allowed to hang in equilibrium.

- (b) Determine the angle AD makes with the vertical. [3]

The two strings are now replaced by a single light inextensible string of length 80 cm. One end of the string is attached to A and the other end of the string is attached to C. The string passes over a smooth peg fixed at D. The rod hangs in equilibrium, but is not vertical, as shown in **Fig. 6.2**.

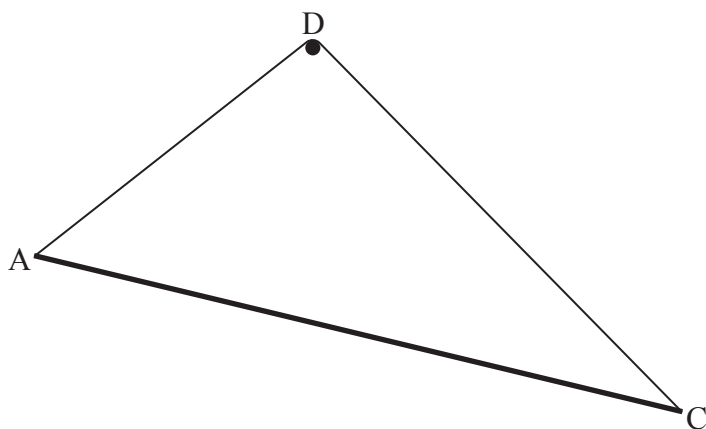


Fig. 6.2

- (c) Explain why angle ADG and angle CDG must be equal. [2]
- (d) Determine the tension in the string. [6]

END OF QUESTION PAPER

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