

# OCR

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## A Level Further Mathematics B (MEI) Y431 Mechanics Minor Sample Question Paper

### Date – Morning/Afternoon

Time allowed: 1 hour 15 minutes

#### OCR supplied materials:

- Printed Answer Booklet
- Formulae Further Mathematics B (MEI)

#### You must have:

- Printed Answer Booklet
- Formulae Further Mathematics B (MEI)
- Scientific or graphical calculator



#### INSTRUCTIONS

- Use black ink. HB pencil may be used for graphs and diagrams only.
- Complete the boxes provided on the Printed Answer Booklet with your name, centre number and candidate number.
- Answer **all** the questions.
- **Write your answer to each question in the space provided in the Printed Answer Booklet.**
- Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.
- 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

- The total number of marks for this paper is **60**.
- The marks for each question are shown in brackets [ ].
- 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 used. You should communicate your method with correct reasoning.
- The Printed Answer Booklet consists of **12** pages. The Question Paper consists of **8** pages.

## 2

Answer **all** the questions.

1 In this question, **i** and **j** are perpendicular unit vectors in a horizontal plane.

A particle P has mass 10 kg and a speed of  $20 \text{ m s}^{-1}$  in the direction of  $4\mathbf{i} + 3\mathbf{j}$ . A force of  $(-4\mathbf{i} + 15\mathbf{j}) \text{ N}$  acts on P for 8 seconds.

(i) Calculate the impulse of the force over the 8 seconds. [1]

(ii) Hence find the speed of P at the end of the 8 seconds. [3]

2 A car of mass 1200 kg is travelling in a straight line along a horizontal road. At a time when the power of the driving force is 25 kW, the car has a speed of  $12.5 \text{ m s}^{-1}$  and is accelerating at  $1.5 \text{ m s}^{-2}$ .

Calculate the magnitude of the resistance to the motion of the car. [5]

3 (i) Find the dimensions of

- density and
- pressure (force per unit area).

[2]

The frequency,  $f$ , of the note emitted by an air horn is modelled as  $f = ks^\alpha p^\beta d^\gamma$ , where

- $s$  is the length of the horn,
- $p$  is the air pressure,
- $d$  is the air density,
- $k$  is a dimensionless constant.

(ii) Determine the values of  $\alpha$ ,  $\beta$  and  $\gamma$ . [4]

A particular air horn emits a note at a frequency of 512 Hz and the air pressure and air density are recorded. At another time it is found that the air pressure has fallen by 2% and the air density has risen by 1%. The length of the horn is unchanged.

(iii) Calculate the new frequency predicted by the model. [2]

## 3

- 4 Fig. 4 shows a non-uniform rigid plank AB of weight 900 N and length 2.5 m. The centre of mass of the plank is at G which is 2 m from A. The end A rests on rough horizontal ground and does not slip. The plank is held in equilibrium at  $20^\circ$  above the horizontal by a force of  $T$  N applied at B at an angle of  $55^\circ$  above the horizontal as shown in Fig. 4.

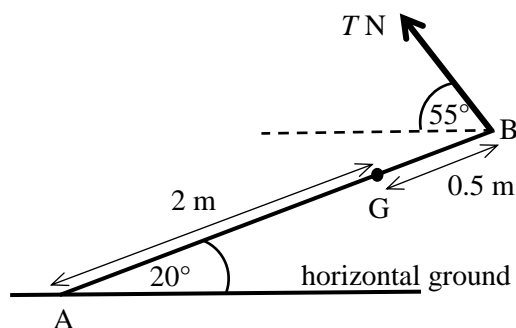


Fig. 4

- (i) Show that  $T = 700$  (correct to 3 significant figures). [4]
- (ii) Determine the possible values of the coefficient of friction between the plank and the ground. [5]

## 4

- 5 A young man of mass 60 kg swings on a trapeze. A simple model of this situation is as follows.

The trapeze is a light seat suspended from a fixed point by a light inextensible rope. The man's centre of mass, G, moves on an arc of a circle of radius 9 m with centre O, as shown in Fig. 5. The point C is 9 m vertically below O. B is a point on the arc where angle COB is  $45^\circ$ .

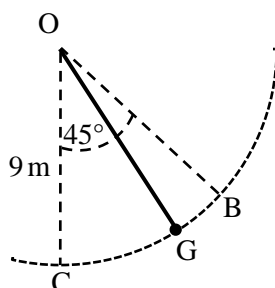


Fig. 5

- (i) Calculate the gravitational potential energy lost by the man if he swings from B to C. [3]

In this model it is also assumed that there is no resistance to the man's motion and he starts at rest from B.

- (ii) Using an energy method, find the man's speed at C. [2]

A new model is proposed which also takes into account resistance to the man's motion.

- (iii) State whether you would expect any such model to give a larger, smaller or the same value for the man's speed at C. Give a reason for your answer. [1]

A particular model takes account of the resistance by assuming that there is a force of constant magnitude 15 N always acting in the direction opposing the man's motion. This new model also takes account of the man 'pushing off' along the arc from B to C with a speed of  $1.5 \text{ m s}^{-1}$ .

- (iv) Using an energy method, find the man's speed at C. [5]

## 5

- 6 My cat Jeffrey has a mass of 4 kg and is sitting on rough ground near a sledge of mass 8 kg. The sledge is on a large area of smooth horizontal ice.

Initially, the sledge is at rest and Jeffrey jumps and lands on it with a horizontal velocity of  $2.25 \text{ m s}^{-1}$  parallel to the runners of the sledge. On landing, Jeffrey grips the sledge with his claws so that he does not move relative to the sledge in the subsequent motion.

- (i) Show that the sledge with Jeffrey on it moves off with a speed of  $0.75 \text{ m s}^{-1}$ . [2]

With the sledge and Jeffrey moving at  $0.75 \text{ m s}^{-1}$ , the sledge collides *directly* with a stationary stone of mass 3 kg. The stone may move freely over the ice. The coefficient of restitution in the collision is  $\frac{4}{15}$ .

- (ii) Calculate the velocity of the sledge and Jeffrey immediately after the collision. [6]

In a new situation, Jeffrey is initially sitting at rest on the sledge when it is stationary on the ice. He then walks from the back to the front of the sledge.

- (iii) Giving a brief reason for your answer, describe what happens to the sledge during his walk. [2]

Jeffrey is again sitting on the sledge when it is stationary on the ice. He jumps off and, after he has lost contact with the sledge, has a horizontal speed relative to the sledge of  $3 \text{ m s}^{-1}$ .

- (iv) Determine the speed of the sledge after Jeffrey loses contact with it. [4]

## 6

- 7 Fig. 7 shows a container for flowers which is a vertical cylindrical shell with a closed horizontal base. Its radius and its height are both  $\frac{1}{2}$  m. Both the curved surface and the base are made of the same thin uniform material. The mass of the container is  $M$  kg.

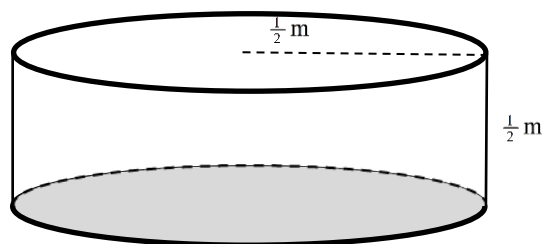


Fig. 7

- (i) Find, as a fraction, the height above the base of the centre of mass of the container. [3]

The container would hold  $\frac{3}{2}M$  kg of soil when full to the top.

Some soil is put into the empty container and levelled with its top surface  $y$  m above the base. The centre of mass of the container with this much soil is  $z$  m above the base.

- (ii) Show that  $z = \frac{1+9y^2}{6(1+3y)}$ . [4]

- (iii) It is given that  $\frac{dz}{dy} = 0$  when  $y = 0.14$  (to 2 significant figures) and that  $\frac{d^2z}{dy^2} > 0$  at this value of  $y$ .

When putting in the soil, how might you use this information if the container is to be placed on slopes without it tipping over? [2]

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