

A Level Further Mathematics B (MEI)

Y431 Mechanics Minor

Sample Question Paper

Version 2

Date – Morning/Afternoon

Time allowed: 1 hour 15 minutes

You must have:

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

You may use:

- a 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 $g \text{ ms}^{-2}$. 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 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 m s^{-1} and is accelerating at 1.5 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 α , β and γ . [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]

- 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° above the horizontal by a force of T N applied at B at an angle of 55° above the horizontal as shown in Fig. 4.

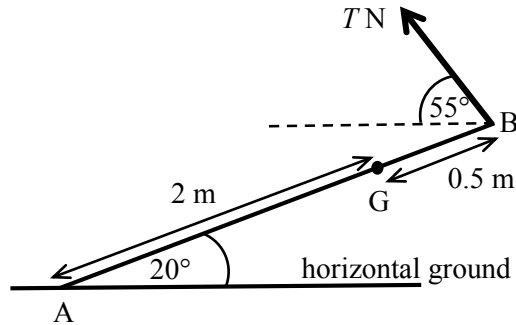


Fig. 4

- (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]

- 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° .

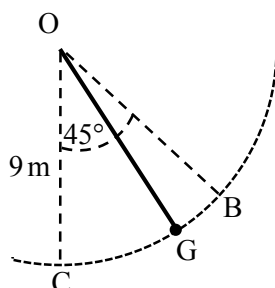


Fig. 5

- (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 m s^{-1} .

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

- 6 My cat Geoffrey 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 Geoffrey jumps and lands on it with a horizontal velocity of 2.25 m s^{-1} parallel to the runners of the sledge. On landing, Geoffrey 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 Geoffrey on it moves off with a speed of 0.75 m s^{-1} . [2]

With the sledge and Geoffrey moving at 0.75 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 Geoffrey immediately after the collision. [6]

In a new situation, Geoffrey 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]

Geoffrey 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 m s^{-1} .

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

- 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.

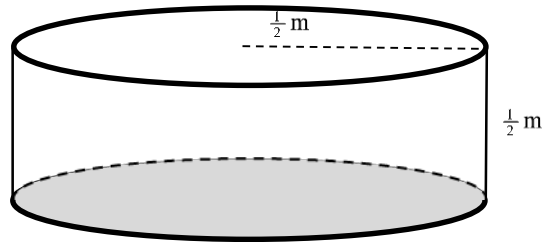


Fig. 7

- (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]

END OF QUESTION PAPER

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