



Oxford Cambridge and RSA

**Thursday 16 May 2019 – Afternoon**

**AS Level Further Mathematics B (MEI)**

**Y411/01 Mechanics a**

**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.
- Answer **all** the questions.
- **Write your answer to each question in the space provided in the Printed Answer Booklet.** If additional space is required, you should use the lined page(s) at the end of the Printed Answer Booklet. The question number(s) must be clearly shown.
- 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.

Answer **all** the questions.

- 1 A child is pulling a toy block in a straight line along a horizontal floor. The block is moving with a constant speed of  $2 \text{ m s}^{-1}$  by means of a constant force of magnitude  $20 \text{ N}$  acting at an angle of  $\theta^\circ$  above the horizontal.

The work done by the force in  $10 \text{ s}$  is  $350 \text{ J}$ .

Calculate the value of  $\theta$ . [3]

- 2 The surface tension of a liquid allows a metal needle to be at rest on the surface of the liquid. The greatest mass  $m$  of a needle of length  $l$  which can be supported in this way by a liquid of surface tension  $S$  is given by the formula

$$m = \frac{2Sl}{g}$$

where  $g$  is the acceleration due to gravity.

- (a) Determine the dimensions of surface tension. [3]

Surface tension also allows liquids to rise up capillary tubes. Molly is experimenting with liquids in capillary tubes and she arrives at the formula  $h = \frac{2S}{\rho gr}$ , where  $h$  is the height to which a liquid of surface tension  $S$  rises,  $\rho$  is the density of the liquid, and  $r$  is the radius of the capillary tube.

- (b) Show that the equation for  $h$  is dimensionally consistent. [3]

In SI units, the surface tension of mercury is  $0.475 \text{ kg s}^{-2}$  and its density is  $13\,500 \text{ kg m}^{-3}$ .

- (c) Find the diameter of a capillary tube in which mercury will rise to a height of  $10 \text{ cm}$ . [2]

In another experiment, Molly finds that when liquid of surface tension  $S$  is poured onto a horizontal surface, puddles of depth  $d$  are formed. For this experiment she finds that

$$d = kS^\alpha \rho^\beta g^\gamma$$

where  $k$  is a dimensionless constant.

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

- 3 A box weighing 130 N is on a rough plane inclined at  $12^\circ$  to the horizontal. The box is held at rest on the plane by the action of a force of magnitude 70 N acting up the plane in a direction parallel to a line of greatest slope of the plane. The box is on the point of slipping up the plane.

(a) Find the coefficient of friction between the box and the plane. [5]

The force of magnitude 70 N is removed.

(b) Determine whether or not the box remains in equilibrium. [2]

- 4 A shovel consists of a blade and handle, as shown in Fig. 4.1 and Fig. 4.2. The dimensions shown in the figures are in metres.

The blade is modelled as a uniform rectangular lamina ABCD lying in the  $Oxy$  plane, where O is the mid-point of AB. The handle is modelled as a thin uniform rod EF. The handle lies in the  $Oyz$  plane, and makes an angle  $\alpha$  with  $Oy$ , where  $\sin \alpha = \frac{7}{25}$ . The rod and lamina are rigidly attached at E, the mid-point of CD.

The blade of the shovel has mass 1.25 kg and the handle of the shovel has mass 0.5 kg.

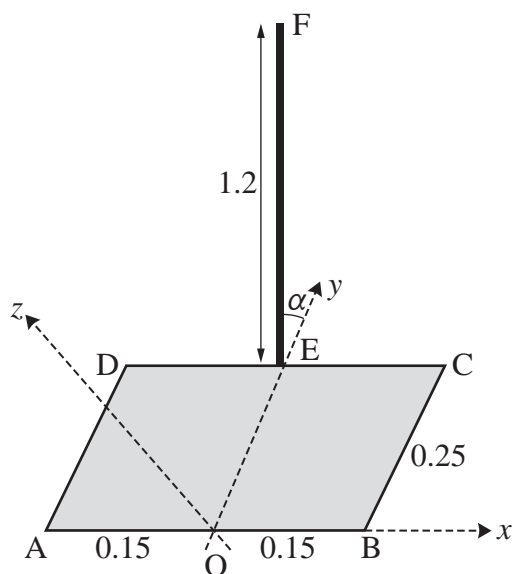


Fig. 4.1

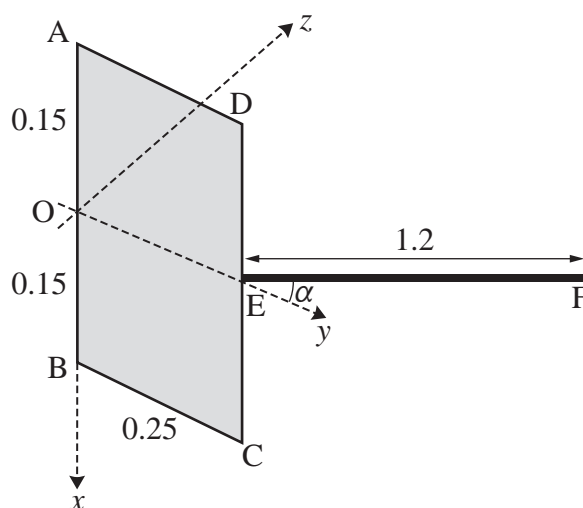


Fig. 4.2

(a) Find,

(i) the  $y$ -coordinate of the centre of mass of the shovel, [5]

(ii) the  $z$ -coordinate of the centre of mass of the shovel. [2]

The shovel is freely suspended from O and hangs in equilibrium.

(b) Calculate the angle that OE makes with the vertical. [2]

## 4

- 5 A car of mass 4000 kg travels up a line of greatest slope of a straight road inclined at an angle of  $\theta$  to the horizontal, where  $\sin \theta = 0.1$ .

The power developed by the car's engine is constant and the resistance to the motion of the car is constant and equal to 850 N. The car passes through a point A on the road with speed  $18 \text{ m s}^{-1}$  and acceleration  $0.75 \text{ m s}^{-2}$ .

- (a) Calculate the power developed by the car. [5]

The car later passes through a point B on the road with speed  $25 \text{ m s}^{-1}$ . The car takes 17.8 s to travel from A to B.

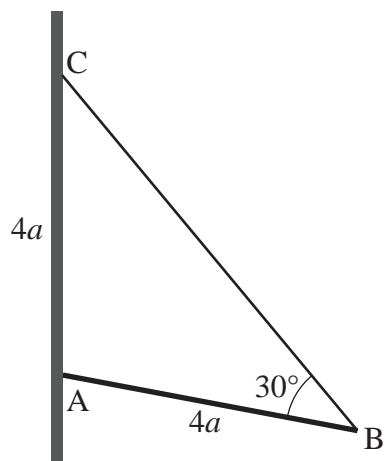
- (b) Find the distance AB. [5]

- 6 Three particles, A, B and C are in a straight line on a smooth horizontal surface. The particles have masses 5 kg, 3 kg and 1 kg respectively. Particles B and C are at rest. Particle A is projected towards B with a speed of  $u \text{ m s}^{-1}$  and collides with B. The coefficient of restitution between A and B is  $\frac{1}{3}$ .

Particle B subsequently collides with C. The coefficient of restitution between B and C is  $\frac{1}{3}$ .

- (a) Determine whether any further collisions occur. [7]

- (b) Given that the loss of kinetic energy during the initial collision between A and B is 4.8 J, find the value of  $u$ . [4]



**Fig. 7**

Fig. 7 shows a uniform rod AB of length  $4a$  and mass  $m$ .

The end A rests against a rough vertical wall. A light inextensible string is attached to the rod at B and to a point C on the wall vertically above A, where  $AC = 4a$ . The plane ABC is perpendicular to the wall and the angle ABC is  $30^\circ$ .

The system is in limiting equilibrium.

Find the coefficient of friction between the wall and the rod.

[8]

**END OF QUESTION PAPER**

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