OCR
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 $g\,\mathrm{m\,s^{-2}}$. 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 $2\,\text{m}\,\text{s}^{-1}$ by means of a constant force of magnitude 20 N acting at an angle of $\theta°$ above the horizontal.

The work done by the force in 10 s is 350 J.

Calculate the value of θ. **[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 $h = \frac{2S}{\rho g r}$, where h is the height to which a liquid of surface tension S rises, ρ 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 $0.475\,\text{kg}\,\text{s}^{-2}$ and its density is $13\,500\,\text{kg}\,\text{m}^{-3}$.

(c) Find the diameter of a capillary tube in which mercury will rise to a height of 10 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 α, β and γ. **[4]**

3 A box weighing 130 N is on a rough plane inclined at 12° 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 O*xy* plane, where O is the mid-point of AB. The handle is modelled as a thin uniform rod EF. The handle lies in the O*yz* plane, and makes an angle α with O*y*, 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.

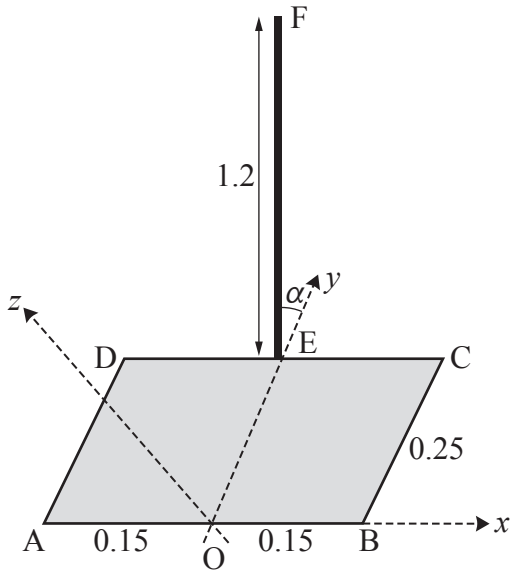

Fig. 4.1

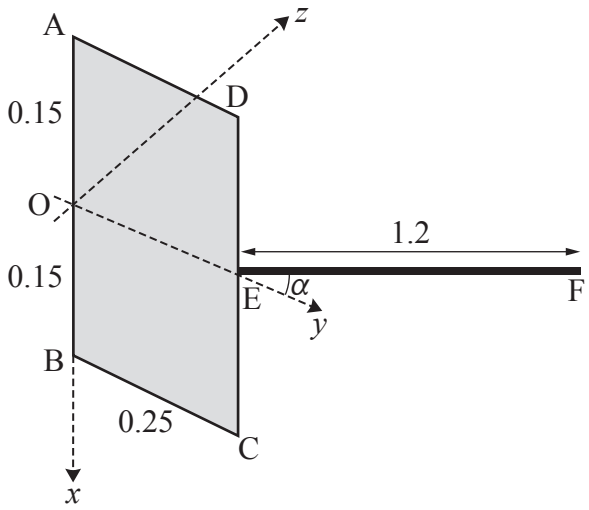

Fig. 4.2

(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]**

5 A car of mass 4000 kg travels up a line of greatest slope of a straight road inclined at an angle of θ 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]**

7

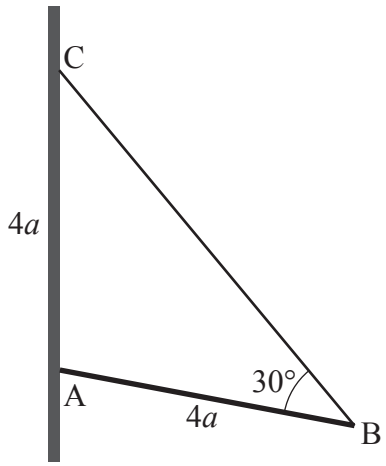

Fig. 7

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°.

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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