

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව  
 இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம்  
 Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka  
 ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව  
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**සමස්ත පොදු කணிක පත්‍ර (උසස් පෙළ) විභාගය, 2016 අගෝස්තු**  
**கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2016 ஆகஸ்ட்**  
**General Certificate of Education (Adv. Level) Examination, August 2016**

සංයුක්ත ගණිතය II  
 இணைந்த கணிதம் II  
**Combined Mathematics II**

**10 E II**

පැය තුනයි  
 மூன்று மணித்தியாலம்  
**Three hours**

Index Number

**Instructions:**

- \* This question paper consists of two parts;  
**Part A** (Questions 1 – 10) and **Part B** (Questions 11 – 17)
- \* **Part A:**  
 Answer **all** questions. Write your answers to each question in the space provided. You may use additional sheets if more space is needed.
- \* **Part B:**  
 Answer **five** questions only. Write your answers on the sheets provided.
- \* At the end of the time allotted, tie the answer scripts of the two parts together so that **Part A** is on top of **Part B** and hand them over to the supervisor.
- \* You are permitted to remove **only Part B** of the question paper from the Examination Hall.
- \* In this question paper,  $g$  denotes the acceleration due to gravity.

**For Examiners' Use only**

| (10) Combined Mathematics II |                   |       |
|------------------------------|-------------------|-------|
| Part                         | Question No.      | Marks |
| A                            | 1                 |       |
|                              | 2                 |       |
|                              | 3                 |       |
|                              | 4                 |       |
|                              | 5                 |       |
|                              | 6                 |       |
|                              | 7                 |       |
|                              | 8                 |       |
|                              | 9                 |       |
|                              | 10                |       |
| B                            | 11                |       |
|                              | 12                |       |
|                              | 13                |       |
|                              | 14                |       |
|                              | 15                |       |
|                              | 16                |       |
|                              | 17                |       |
|                              | <b>Total</b>      |       |
|                              | <b>Percentage</b> |       |

|             |  |
|-------------|--|
| Paper I     |  |
| Paper II    |  |
| Total       |  |
| Final Marks |  |

**Final Marks**

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|------------|--|
| In Numbers |  |
| In Words   |  |

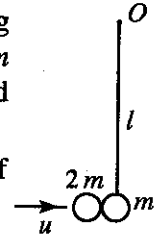
**Code Numbers**

|                  |   |
|------------------|---|
| Marking Examiner |   |
| Checked by:      | 1 |
|                  | 2 |
| Supervised by:   |   |

## Part A

1. A particle of mass  $m$  hangs in equilibrium at one end of a light inextensible string of length  $l$  whose other end is tied to a fixed point  $O$ . Another particle of mass  $2m$  collides horizontally with velocity  $u$  with the first particle and coalesces with it. Find the velocity with which the composite particle begins to move.

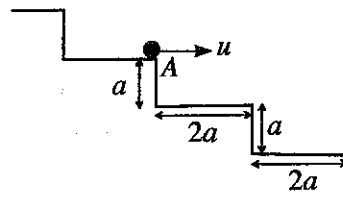
Show that if  $u = \sqrt{gl}$ , then the composite particle reaches a maximum height of  $\frac{2l}{9}$  above its initial level.



2. A particle  $P$  of mass  $m$  and a particle  $Q$  of mass  $3m$  move on a smooth horizontal table along the same straight line towards each other with speeds  $5u$  and  $u$  respectively, as shown in the figure. After their impact,  $P$  and  $Q$  move **away from each other** with speeds  $u$  and  $v$  respectively. Find  $v$  in terms of  $u$ , and show that the coefficient of restitution between  $P$  and  $Q$  is  $\frac{1}{3}$ .



3. A particle  $P$ , projected horizontally with velocity  $u$  given by  $u = \frac{3}{2}\sqrt{ga}$  from a point  $A$  at the edge of a step of a fixed stairway perpendicular to that edge, moves under gravity. Each step is of height  $a$  and length  $2a$  (see the figure). Show that the particle  $P$  will **not hit** the first step below  $A$ , and it will hit the second step below  $A$  at a horizontal distance  $3a$  from  $A$ .



4. A car of mass  $M$  kg moves along a straight level road against a resistance of constant magnitude  $R$  N. At an instant when the car is moving at speed  $v$  m s<sup>-1</sup>, its acceleration is  $a$  m s<sup>-2</sup>. Show that the power of its engine at this instant is  $(R + Ma)v$  W.

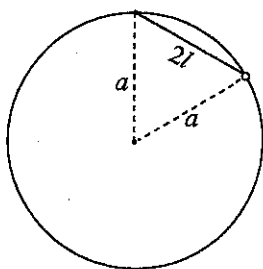
The car then moves with a constant speed  $v_1$  m s<sup>-1</sup> against a resistance of the same constant magnitude  $R$  N up a straight road inclined at an angle  $\alpha$  to the horizontal, working at the same power. Show

that  $v_1 = \frac{(R + Ma)v}{R + Mg \sin \alpha}$ .

(ii)  $\mathbf{a} \cdot \mathbf{c}$  and  $\mathbf{b} \cdot \mathbf{c}$  in terms of  $\alpha$ .

If the angle between **a** and **c** is equal to the angle between **b** and **c**, show that  $\alpha = \frac{1}{2}$ .

6. One end of a light inextensible string of length  $2l$  is attached to the highest point of a thin smooth rigid circular wire of radius  $a$  ( $> \sqrt{2}l$ ) which is fixed in a vertical plane. A small smooth bead of weight  $w$ , which is free to move along the wire, is attached to the other end of the string. The bead is in equilibrium with the string taut, as in the figure. Mark the forces acting on the bead and show that the tension of the string is  $\frac{2wl}{a}$ .



7. Let  $A$  and  $B$  be two events of a sample space  $\Omega$ . In the usual notation,  $P(A) = p$ ,  $P(B) = \frac{p}{2}$  and  $P(A \cup B) - P(A \cap B) = \frac{2p}{3}$ , where  $p > 0$ . Find  $P(A \cap B)$  in terms of  $p$ .

Deduce that if  $A$  and  $B$  are independent events, then  $p = \frac{5}{6}$ .

8. A bag contains 6 white balls and  $n$  black balls which are equal in all respects, except for colour. Two balls are taken out at random from the bag, one after the other, without replacement. The probability that the first ball is white and the second ball is black is  $\frac{4}{15}$ . Find the value of  $n$ .

- [illegible]

- |           |   |     |     |   |   |
|-----------|---|-----|-----|---|---|
| Number    | 1 | 2   | 3   | 4 | 5 |
| Frequency | 1 | $p$ | $q$ | 5 | 2 |

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the paper.

සියලු ම හිමිකම් ඇවිරිණි/முழுப் பதிப்புரிமையுடையது/All Rights Reserved

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව  
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Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka

අධ්‍යයන පොදු කණික පත්‍ර (පාඨ පෙළ) විභාග, 2016 අගස්තු  
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2016 ஆகஸ்ட்  
General Certificate of Education (Adv. Level) Examination, August 2016

සංයුක්ත ගණිතය II  
இணைந்த கணிதம் II  
Combined Mathematics II

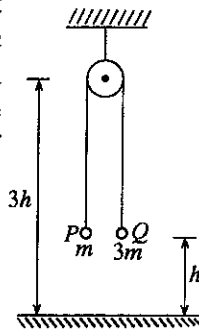
10 E II

### PART B

\* Answer five questions only.

(In this question paper,  $g$  denotes the acceleration due to gravity.)

11. (a) A particle  $P$  of mass  $m$  is connected to a particle  $Q$  of mass  $3m$  by a light inextensible string passing over a small smooth pulley fixed at a height  $3h$  above an inelastic horizontal floor. Initially the two particles are held at a height  $h$  above the floor with the string taut, and released from rest. (See the adjoining figure.) Applying Newton's second law separately to the motions of  $P$  and  $Q$ , show that the magnitude of acceleration of each particle is  $\frac{g}{2}$ .

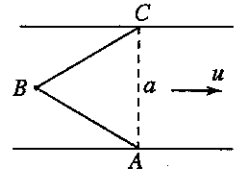


After a time  $t_0$  the particle  $Q$  strikes the floor, comes to rest instantly, remains at rest for a further time  $t_1$  and begins to move up. Sketch the velocity-time graphs separately for the motions of the two particles  $P$  and  $Q$  until the particle  $Q$  begins to move up.

Using these graphs, show that  $t_0 = 2\sqrt{\frac{h}{g}}$  and find  $t_1$  in terms of  $g$  and  $h$ .

Show further that the particle  $P$  reaches a maximum height  $\frac{5h}{2}$  above the floor.

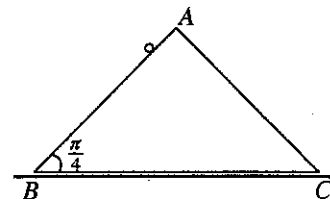
- (b) A straight river of breadth  $a$  flows with uniform speed  $u$ . The points  $A$  and  $C$  are situated on opposite banks of the river such that the line  $AC$  is perpendicular to the direction of flow of the river. Also, a stationary buoy  $B$  is fixed in the middle of the river, on the upstream side of  $AC$  such that  $ABC$  is an equilateral triangle. (See the adjoining figure.) A boat moving with speed  $v$  ( $> u$ ) relative to water starts off from  $A$  and moves until it reaches  $B$ . Then it moves from  $B$  to  $C$ . Sketch the velocity triangles for the motions of the boat from  $A$  to  $B$  and from  $B$  to  $C$ .



Show that the speed of the boat in its motion from  $A$  to  $B$  is  $\frac{1}{2}(\sqrt{4v^2 - u^2} - \sqrt{3}u)$  and find its speed in the motion from  $B$  to  $C$ .

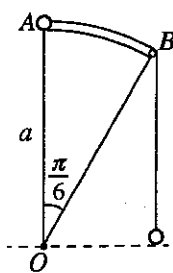
Hence, show that the total time taken by the boat for the paths  $AB$  and  $BC$  is  $\frac{a\sqrt{4v^2 - u^2}}{v^2 - u^2}$ .

12. (a) The triangle  $ABC$  in the figure is a vertical cross-section through the centre of gravity of a uniform wedge of mass  $2m$ . The line  $AB$  is a line of greatest slope of the face containing it and  $\hat{ABC} = \frac{\pi}{4}$ . The wedge is placed with the face containing  $BC$  on a rough horizontal floor. The face containing  $AB$  is smooth. A particle of mass  $m$  is held on  $AB$  as in the figure and the system is released from rest. It is given that the wedge moves in the direction of  $\vec{BC}$  and that



the magnitude of the frictional force exerted on the wedge by the floor is  $\frac{R}{6}$ , where  $R$  is the magnitude of the normal reaction exerted on the wedge by the floor. Obtain equations which are sufficient to determine  $R$ , in terms of  $m$  and  $g$ .

- (b)  $OAB$  in the figure is a circular sector of radius  $a$  subtending an angle  $\frac{\pi}{6}$  at the centre  $O$  with  $OA$  vertical. It is a cross-section perpendicular to the axis of a smooth cylindrical sector fixed with its axis horizontal. One end of a light inextensible string passing over a small smooth pulley fixed at  $B$  is attached to a particle  $P$  of mass  $3m$  and the other end is attached to a particle  $Q$  of mass  $m$ . Initially, the particle  $P$  is held at  $A$  and the particle  $Q$  hangs freely at the horizontal level of  $O$ . The system is released from rest in this position, with the string taut. When  $OP$  makes an angle  $\theta$  ( $0 < \theta < \frac{\pi}{6}$ ) with the upward vertical, show that  $2a\dot{\theta}^2 = 3g(1 - \cos \theta) + g\theta$  and that the tension in the string is  $\frac{3}{4}mg(1 - \sin \theta)$ , and find the normal reaction on the particle  $P$ .



13. One end of a light elastic string of natural length  $a$  and modulus of elasticity  $4mg$  is tied to a fixed point  $O$  and the other end to a particle  $P$  of mass  $m$ . The particle  $P$  is released from rest at  $O$ . Find the velocity of the particle  $P$  when it passes through the point  $A$ , where  $OA = a$ .

Show that the length of the string  $x$  ( $x \geq a$ ) satisfies the equation  $\ddot{x} + \frac{4g}{a} \left( x - \frac{5a}{4} \right) = 0$ .

Taking  $X = x - \frac{5a}{4}$ , express the above equation in the form  $\ddot{X} + \omega^2 X = 0$ , where  $\omega$  ( $> 0$ ) is a constant to be determined.

Assuming that  $\dot{X}^2 = \omega^2 (c^2 - X^2)$ , find the amplitude  $c$  of this simple harmonic motion.

Let  $L$  be the lowest point reached by the particle  $P$ . Show that the time taken by  $P$  to move from  $A$  to  $L$  is  $\frac{1}{2} \sqrt{\frac{a}{g}} \left\{ \pi - \cos^{-1} \left( \frac{1}{3} \right) \right\}$ .

At the instant when the particle  $P$  is at  $L$ , another particle of mass  $\lambda m$  ( $1 \leq \lambda < 3$ ) is gently attached to  $P$ . Show that the equation of motion of the composite particle of mass  $(1 + \lambda)m$  is

$$\ddot{x} + \frac{4g}{(1 + \lambda)a} \left\{ x - (5 + \lambda) \frac{a}{4} \right\} = 0.$$

Show further that the composite particle performs complete simple harmonic motion with amplitude  $(3 - \lambda) \frac{a}{4}$ .

14. (a) The position vectors of two points  $A$  and  $B$  with respect to an origin  $O$  are  $\mathbf{a}$  and  $\mathbf{b}$  respectively, where  $O$ ,  $A$  and  $B$  are **not collinear**. Let  $C$  be the point such that  $\overrightarrow{OC} = \frac{1}{3} \overrightarrow{OB}$  and let  $D$  be the point such that  $\overrightarrow{OD} = \frac{1}{2} \overrightarrow{AB}$ . By expressing  $\overrightarrow{AC}$  and  $\overrightarrow{AD}$  in terms of  $\mathbf{a}$  and  $\mathbf{b}$ , show that  $\overrightarrow{AD} = \frac{3}{2} \overrightarrow{AC}$ .

Let  $P$  and  $Q$  be the points on  $AB$  and  $OD$  respectively, such that  $\overrightarrow{AP} = \lambda \overrightarrow{AB}$  and  $\overrightarrow{OQ} = (1 - \lambda) \overrightarrow{OD}$ , where  $0 < \lambda < 1$ . Show that  $\overrightarrow{PC} = 2 \overrightarrow{CQ}$ .

- (b) In a parallelogram  $ABCD$ , let  $AB = 2$  m and  $AD = 1$  m, and let  $\hat{BAD} = \frac{\pi}{3}$ . Also, let  $E$  be the mid-point of  $CD$ . Forces of magnitudes 5, 5, 2, 4 and 3 newtons act along  $AB$ ,  $BC$ ,  $DC$ ,  $DA$  and  $BE$  respectively, in the directions indicated by order of the letters. Show that their resultant force is parallel to  $\overrightarrow{AE}$ , and find its magnitude.

Also, show that the line of action of the resultant force meets  $AB$  produced at a distance  $\frac{3}{2}$  m from  $B$ .

An additional force acting through  $C$  is now added to the above system of forces so that the resultant force of the new system is along  $\overrightarrow{AE}$ . Find the magnitude and direction of the additional force.

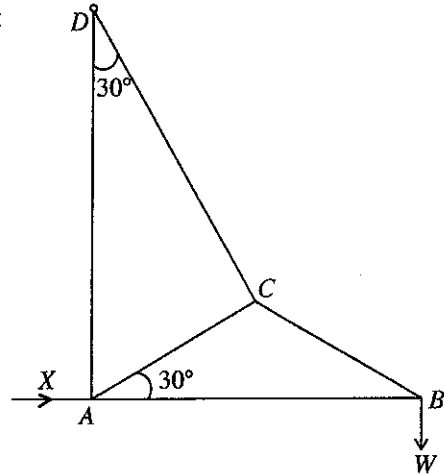
[see page nine]

15. (a) Four equal uniform rods, each of weight  $w_1$ , are smoothly jointed at their ends to form a rhombus  $ABCD$ . The mid-points of  $BC$  and  $CD$  are connected by a light rod such that  $\hat{B}AD = 2\theta$ . Each of the joints  $B$  and  $D$  carries equal loads of weight  $w_2$ . The system, hanging symmetrically from the joint  $A$ , is in equilibrium in a vertical plane with the light rod horizontal. Show that the thrust in the light rod is  $2(2w_1 + w_2) \tan \theta$ .

- (b) The adjoining figure represents a framework of five light rods  $AB$ ,  $BC$ ,  $CD$ ,  $AC$  and  $AD$ , smoothly jointed at the ends. It is given that  $AC = CB$  and  $\hat{B}AC = 30^\circ = \hat{A}DC$ . The framework is smoothly hinged at  $D$ . A weight  $W$  is suspended at the joint  $B$  and the framework is kept in equilibrium in a vertical plane with  $AB$  horizontal and  $AD$  vertical, by a horizontal force of magnitude  $X$  acting at  $A$ .

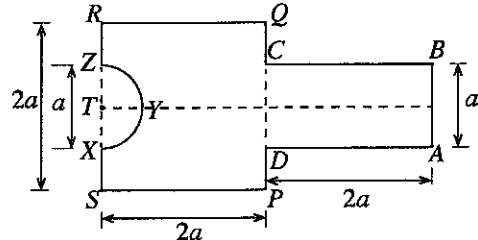
Using Bow's notation, draw stress diagrams for the joints  $B$ ,  $C$  and  $A$  in the same figure.

Hence, find the value of  $X$  and the stresses in all rods, distinguishing between tensions and thrusts.

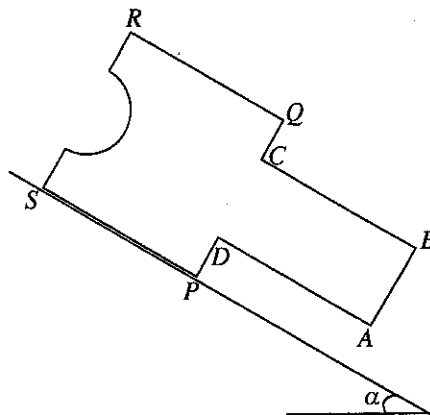


16. Show that the centre of mass of a uniform semi-circular lamina of radius  $r$  and centre  $O$  is at a distance  $\frac{4r}{3\pi}$  from  $O$ .

As shown in the adjoining figure, a uniform plane lamina  $L$  is made by rigidly attaching a rectangle  $ABCD$  to a square  $PQRS$  such that  $DC$  and  $PQ$  lie on the same line with their mid-points coinciding, and removing a semi-circular region  $XYZ$  of radius  $\frac{a}{2}$  centred at the mid-point  $T$  of  $RS$ . It is given that  $AB = a$  and  $AD = PQ = 2a$ . Show that the centre of mass of the lamina  $L$  lies on the axis of symmetry at a distance  $ka$  from  $RS$ , where  $k = \frac{238}{3(48 - \pi)}$ .



As shown in the adjoining figure, the lamina  $L$  is in equilibrium on a rough plane inclined at an angle  $\alpha$  to the horizontal with its plane vertical and the edge  $PS$  on a line of greatest slope such that the point  $P$  lies below  $S$ . Show that  $\tan \alpha < (2 - k)$  and  $\mu \geq \tan \alpha$ , where  $\mu$  is the coefficient of friction between the lamina and the inclined plane.



- 17.(a) An unbiased cubical die  $A$  shows 1, 2, 3, 3, 4, 5 on its six separate faces. The die  $A$  is tossed twice. Find the probability that the sum of the two numbers obtained is 6.

Another die  $B$ , identical to  $A$  in all respects except for the numbers on the faces, shows 2, 2, 3, 4, 4, 5 on its six separate faces. The die  $B$  is tossed twice. Find the probability that the sum of the two numbers obtained is 6.

Now, the two dice  $A$  and  $B$  are put in a box. One die is taken out of the box at random and tossed twice. Given that the sum of the two numbers obtained is 6, find the probability that the die taken out of the box is the die  $A$ .

- (b) The mean and the standard deviation of  $n$  numbers  $x_1, x_2, \dots, x_n$  are  $\mu_1$  and  $\sigma_1$  respectively, and the mean and the standard deviation of  $m$  numbers  $y_1, y_2, \dots, y_m$  are  $\mu_2$  and  $\sigma_2$  respectively. Let the mean and the standard deviation of all of these  $n + m$  numbers be  $\mu_3$  and  $\sigma_3$  respectively.

Show that  $\mu_3 = \frac{n\mu_1 + m\mu_2}{n + m}$ .

Let  $d_1 = \mu_3 - \mu_1$ . Show that  $\sum_{i=1}^n (x_i - \mu_3)^2 = n(\sigma_1^2 + d_1^2)$ .

By taking  $d_2 = \mu_3 - \mu_2$ , write down a similar expression for  $\sum_{j=1}^m (y_j - \mu_3)^2$ .

Deduce that  $\sigma_3^2 = \frac{(n\sigma_1^2 + m\sigma_2^2) + (nd_1^2 + md_2^2)}{n + m}$ .

The number of copies sold per day, during the first 100 days after publishing a new book, had mean 2.3 and variance 0.8. During the next 100 days, the number of copies sold per day had mean 1.7 and variance 0.5. Find the mean and the variance of the number of copies sold per day during the first 200 days.

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