NATIONAL UNIVERSITY OF SINGAPORE

PC1141 PHYSICS I

(Semester I: AY 2007-08, 27, November)

Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This examination paper contains **five short** questions in Part I and **three long** questions in Part II. It comprises **seven** printed pages.
2. Answer **ALL** questions.
3. All answers are to be written on the answer books.
4. This is a **CLOSED BOOK** examination.
5. The total mark for Part I is 40 and that for Part II is 60.
6. Some useful information are given on Page 2 of this question paper.

Useful Information:

Gravitational constant, G	=	6.673×10^{-11} N $\cdot$ m^2/kg^2
Acceleration due to gravity, g	=	9.80 m/s^2
Density of water	=	1.00×10^3 kg/m^3
Density of aluminium	=	2.70×10^3 kg/m^3
I_{CM} (for a hoop)	=	MR^2
I_{CM} (for a disk)	=	$\frac{1}{2}MR^2$
$\int x^\alpha dx$	=	$\frac{x^{\alpha+1}}{\alpha+1}$ (α is real and $\alpha \neq -1$)

PC1141 – PHYSICS I

PART I

This part of the examination paper contains **five** short-answer questions from page 3 to 4. Answer **ALL** questions. The mark for each part is indicated in the square bracket.

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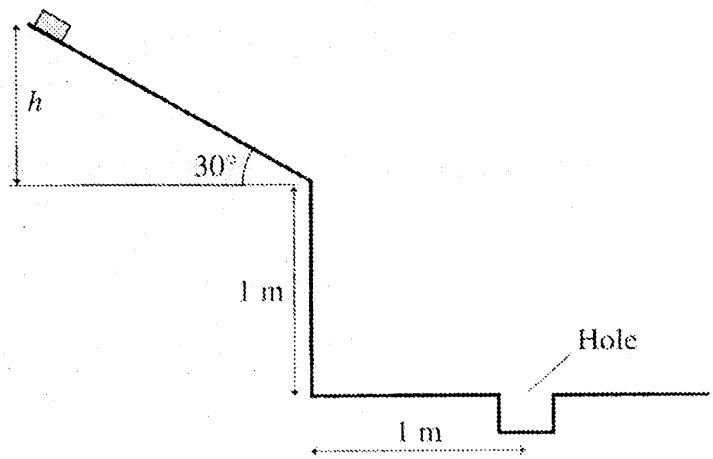
1. A small block is placed at height h on a frictionless 30° ramp. When released, the block slides down the ramp and then falls 1.0 m to the floor. A small hole is located 1.0 m from the end of the ramp. From what height h should the block be released in order to land directly in the hole? [8]



2. A man of mass M exerts a horizontal force F on a moving sled of mass m. The coefficient of kinetic friction between the sled and the snow is μ_k, and the coefficient of static friction between the man's feet and the snow is μ_s. The man and the sled move with a common acceleration a.

   (a) Draw free body diagrams to show all the forces acting (i) on the sled and (ii) on the man. [2]

   (b) Write down expressions for all the other horizontal forces acting on the sled or the man in terms of F, m, M and a. [3]

   (c) What is the maximum value of the acceleration a? [3]

3. A movie crew is driving through a desert when their car overheats. After they stop to let it cool down, an argument breaks out. They agree that they must go easy on the engine, but they disagree about when the engine works the hardest, and therefore about how they should drive for the rest of the trip.

   Carolyn says, "The work done by the car in accelerating from 0 to 20 km/h is less than that required to accelerate from 20 to 30 km/h, meaning that we should drive more slowly."

   Ted disagrees, "No, the work done between 0 to 20 km/h is more than the work done between 20 and 30 km/h."

   Ernie says, "It all depends on the mass of the car."

   Dawn says, "It all depends on how long you take to change from one speed to another."

   Examine each argument carefully and explain who is/are right. [8]

4. A uniform horizontal disk of mass M and radius R is rotating about its vertical axis with an angular velocity ω. When it is placed on a horizontal surface, the coefficient of kinetic friction between the disk and the surface is μ_k. Find

   (a) the torque $d\tau$ exerted by the force of friction on a circular element of radius r with width dr; [3]

   (b) the total torque exerted by friction on the disk; and [2]

   (c) the total time required to bring the disk to a halt. [3]

5. An aluminium block of mass m is hung from a steel wire of length L. The fundamental frequency for transverse standing waves on the wire is 300 Hz. The block is then immersed in water so that half of its volume is submerged. What is the new fundamental frequency? (You may assume that the mass of the wire is small compared to the mass of the block and the change in length of the wire under different loads is negligible.) [8]

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PART II

This part of the examination paper contains **THREE** long-answer questions from page 5 to 7. Answer **ALL** questions. The mark for each part is indicated in the square bracket.

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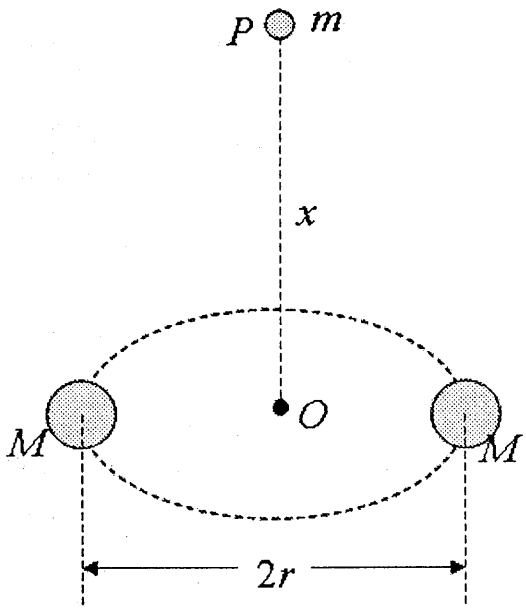
6. Consider a system of binary stars, each of mass M and separated by a distance $2r$. These stars move in the same circular orbit about their common centre of mass O. A mass m is located at a point P, equidistant from the stars and x from point O as shown in the figure below.



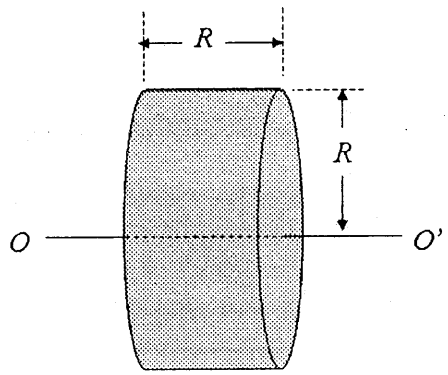
(a) Write down an expression for the period of the orbit T in terms of M, r and G (the Newtonian gravitational constant). Neglect the effect of m for this part of the question. [5]

(b) Calculate the gravitational potential energy U and gravitational force $\vec{F}$ on m due to the two stars. [5]

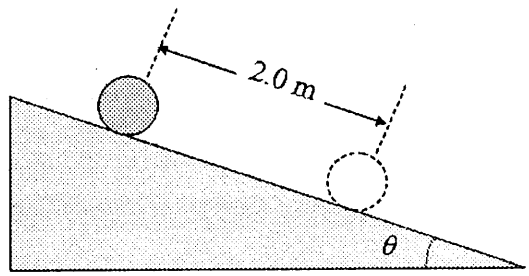
(c) What are the values of U and $|\vec{F}|$ if (i) $x \gg r$, and (ii) $x = 0$? [4]

(d) Suppose the mass m is at point O and then is slightly displaced along OP such that $x \ll r$. Show that it executes simple harmonic motion, and write down its period. [6]

7. Consider an empty cylindrical can of radius R, length R and mass M as shown below. It has a uniform thickness t both at the flat endcaps and the curved portion of the body.



(a)



(b)

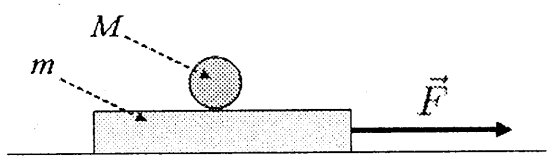
(a) If $t \ll R$, show that the moment of inertia about its symmetric axis OO' is given by

$$I_{CM} = \frac{3}{4}MR^2.$$

You need not start from first principles, but may use the formulae for the moment of inertia of the different shapes given in page 2. [5]

(b) The can is placed on an inclined plane where $\theta = 20°$. It rolls without slipping down the slope. What is the time taken for it to travel 2.0 m down the plane? [6]

(c) The can is now placed on a block of mass m which in turn is initially at rest on a horizontal frictionless table. If a horizontal force $\vec{F}$ is applied to the block, it accelerates and the cylinder rolls without slipping. Find the linear accelerations of the block and the can with respect to the table, and the angular acceleration of the can about its centre of mass. [9]

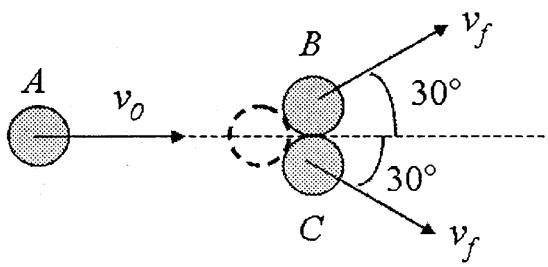


(c)

8. (a) Ball A, sliding with an initial speed $v_0 = 10.0$ m/s on a frictionless surface, collides elastically with balls B and C as shown in the figure below. All the balls are identical. If balls B and C move off with the same speed v_f at 30° as indicated below, what are

i. the numerical value of v_f, and [4]

ii. the magnitude and direction of ball A's final velocity. [5]



(b) Consider three masses m_1, m_2 and m_3 whose positions are on a straight line. m_2 and m_3 are slightly separated and initially at rest. m_1 is moving towards m_2 with a speed v_0. The surface is frictionless and all collisions are elastic.

i. Show that the velocity of m_3 after being hit by m_2 is given by

$$v_3 = \frac{4m_1m_2}{(m_1+m_2)(m_2+m_3)}v_0.$$

[6]

ii. Hence deduce that if $m_2 = \sqrt{m_1m_3}$, maximum energy is transferred from m_1 to m_3. [5]

– End of Paper –

CKY