NATIONAL UNIVERSITY OF SINGAPORE

PC1141 PHYSICS I

(Semester I: AY 2005–06 November)

Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This examination paper contains **five (5) short** questions in Part I and **three (3) long** questions in Part II. It comprises 7 printed pages.
2. Answer **ALL** the questions in Part I and **TWO** questions in Part II.
3. Answers to the questions are to be written in 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:

$$G = 6.673 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$$

$$g = 9.80\ \mathrm{m/s^2}$$

$$I_{CM} = \frac{1}{12}ML^2 \quad \text{for a uniform rod}$$

$$\int x^\alpha dx = \frac{x^{\alpha+1}}{\alpha+1} \quad (\alpha \text{ is real})$$

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PART I

This part of the examination paper contains five (5) short questions from page 3 to 4. Answer **ALL** questions.

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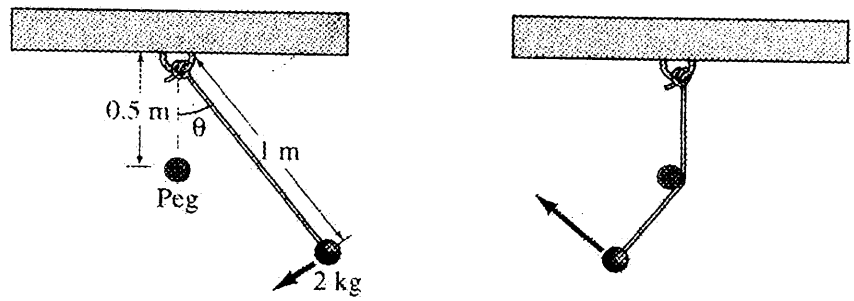
1. A student wants to determine the coefficients of static friction and kinetic friction between a box and a plank. He places the box on the plank and gradually raises the plank. When the angle of inclination with the horizontal reaches 30°, the box starts to slip and slides 4.0 m down the plank in 4.0 s. What are the coefficients of static friction and kinetic friction?

2. A small lead ball of mass 2.0 kg is suspended at the end of a light string 1.00 m in length. A small peg, 0.50 m below the suspension point, catches the string in its swing. The ball is set swinging through small angles.



   (a) What is the period of this pendulum?

   (b) The ball starts swinging on the side that does not catch the peg, at an initial height 0.050 m above the lowest point of swing. How high does it rise on the side where the peg restricts the pendulum length to 0.50 m?

3. The position of a 0.280-kg object is given (in metres) by $x = 5.0t^3 - 8.0t^2 - 30t$, where t is in seconds.

   (a) Determine the rate of work done on this object at $t = 2.0$ s and at $t = 4.0$ s.

   (b) What is the average net power input during the interval from $t = 2.0$ s to $t = 4.0$ s?

4. During a hurricane, winds can whip horizontally at speeds of 150 km/h. Given that the density of air is 1.20 kg/m^3 and the wind after striking the person is brought to rest, calculate the force of the wind on the person. You may assume the person's area to be 1.50 m high by 0.50 m wide. Will this person be knocked off his feet if he is not holding on to any support? State any further assumptions you have made regarding the person and the ground.

5. The equation of a transverse travelling wave on a string is given by

$$y = 2.0\cos(0.50\pi x - 200\pi t)$$

where x and y are in cm and t is in seconds.

(a) Find the amplitude, wavelength, frequency, period, velocity (magnitude and direction) of propagation.

(b) If the mass per unit length of the string is 5.00 g/cm, find the tension in the string.

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PART II

This part of the examination paper contains THREE (3) long questions from page 5 to 7. Answer any **TWO** questions.

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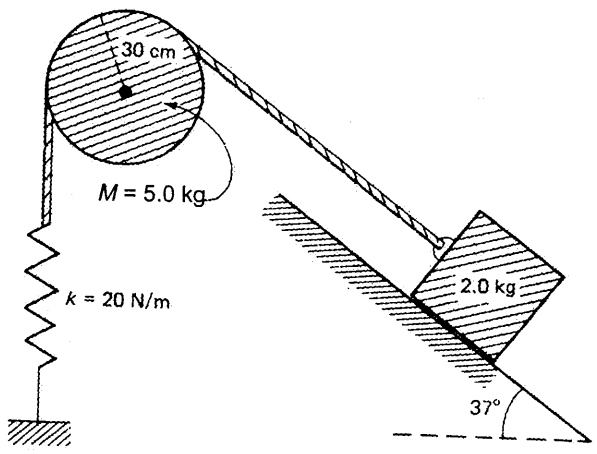
6. (a) Use direct integration to show that the moment of inertia of a uniform cylinder I of mass M, radius R and height h about the symmetry axis through its centre of mass is given by

$$I = \frac{1}{2}MR^2 \ .$$

(b) The system shown consists of a spring, a solid cylindrical pulley of radius 0.30 m and mass of 5.0 kg, a 2.0-kg block and a light rope connecting the spring and the block. The spring obeys Hooke's Law with a spring constant of 20 N/m. You may assume that the pulley rotates about a frictionless axle through its centre of mass and that there is no slipping between the rope and the pulley. You may further assume that friction is negligible between the incline plane and the block. The system is released from rest with the spring in the unstretched position.



i. What is the speed of the mass when it has slid 1.0 m down the incline?

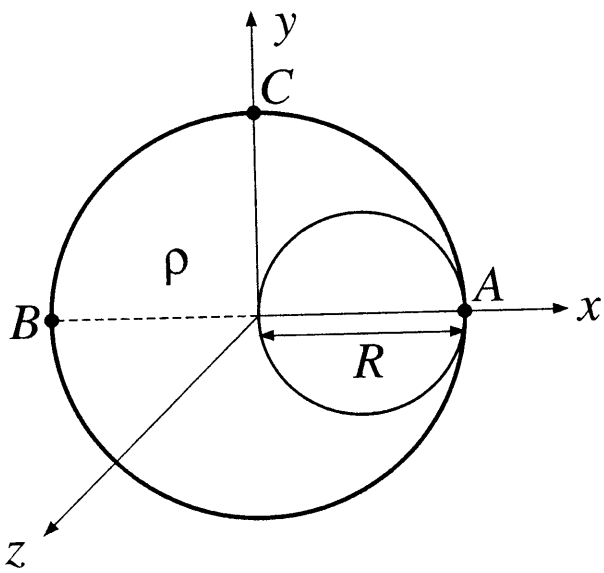
ii. To what maximum distance will the block slide down the incline?

iii. At what distance from its initial position will the mass have slid when its speed is maximum? What will its speed be then?

iv. Show that the mass execute simple harmonic motion. What is the period of this motion?

7. (a) A planet has a radius of $R = 5400$ km and a uniform density of $\rho = 4400\ \text{kg/m}^3$. Find the gravitational field $\vec{g}$ on its surface and the speed an object on the surface needs to escape completely from the planet's gravitational pull, i.e., its escape velocity.

(b) A hypothetical planet has the same dimension and composition as in part (a) except for an empty cavity of radius $\frac{1}{2}R$, i.e., 2700 km on one side of the planet as shown in the figure below.



i. Find the coordinates of the centre of mass of this planet.

ii. What will the escape velocity of an object be if it were originally at position A. Perform the same calculation if it were at position B.

iii. Explain whether the escape velocity at C is higher than or lower than the values at A and B. You need not work out its numerical value.

iv. Calculate the gravitation field at points A and B.

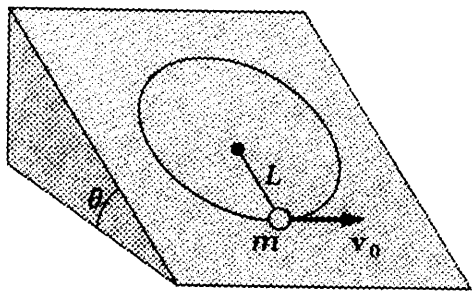
v. Sketch and label the graph of the gravitational field along the x-axis, extending a distance of about R beyond A and B outside the planet.

8. (a) In the figure below, one end of a light string is attached to a 1.2-kg puck which can slide with negligible friction on a 40° ramp. The other end of the string is fixed to a point on the ramp, and the puck moves in a circular path of radius = 0.75 m as shown below. At the lowest position, the tension in the string is 110 N. Determine

   i. the speed of the puck at this lowest point,

   ii. the speed of the puck at the highest point,

   iii. the tension in the string for this highest point.



(b) Suppose that the puck has speed v_0 at the lowest position. Determine the minimum value of v_0 such that the puck can complete the circular path. Find the tension in the string at the lowest position.

(c) Describe the motion qualitatively if the puck has this minimum value of v_0 at the lowest position as in part (b), but frictional effects, while small, are not negligible.

(d) Suppose the string is replaced by a rod of negligible mass, calculate the new minimum speed needed to complete the circular path.

(e) Repeat the calculation if the mass of the rod in part (d) is not negligible, but has the same value as the puck.

— End of Paper —

(CKY)