NATIONAL UNIVERSITY OF SINGAPORE

PC1141 PHYSICS I

(Semester I: AY 2006-07, 25 November)

Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This examination paper contains **five** short-answer questions in Part I and **three** long-answer questions in Part II. It comprises **eight** printed pages.
2. Answer **ALL** questions in part I and any **TWO** questions in Part II. All answers are to be written on the answer books.
3. This is a **CLOSED BOOK** examination.
4. The total mark for Part I is 40 and that for Part II is 60.
5. 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
Mass of Earth, M_E	=	5.98×10^{24} kg
Radius of Earth, R_E	=	6.37×10^6 m
Density of air	=	1.20 kg/m^3
Density of helium	=	0.178 kg/m^3
I_{CM} (for a hoop)	=	MR^2
$\int x^\alpha dx$	=	$\frac{x^{\alpha+1}}{\alpha+1}$ (α is real)

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PART I

This part of the examination paper contains **five** short-answer questions from page 3 to 5. Answer **ALL** questions. The mark for each part is indicated in the square bracket.

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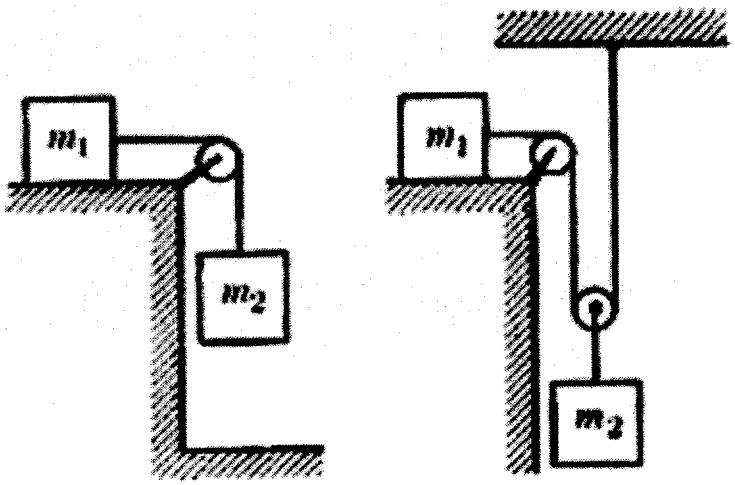
1. For each case below, calculate the acceleration of the bodies m_1 (= 4.00 kg) and m_2 (= 6.00 kg) and the tension in the ropes. All pulleys are weightless and frictionless and the bodies slide without friction. [3, 5]



(a) (b)

2. A party balloon (of mass 0.0025 kg when empty) is filled with helium to a volume of 0.0045 m^3. It is tied to a small stone of mass 0.015 kg by a light string of length 1.5 m to prevent it from flying away. A child holds the balloon at ground level and then releases it.

   (a) How long does it take for the balloon to rise 1.5 m, that is, for the string to become taut? [4]

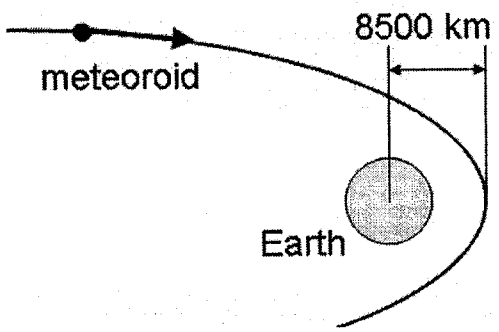
   (b) What is the velocity of the stone when it is lifted off the ground? You may assume that the time needed to bring the stone to this velocity is very short (impulse approximation) once the string is taut, and the string remains taut throughout. [4]

   (Neglect air resistance. Treat the stone as a particle.)

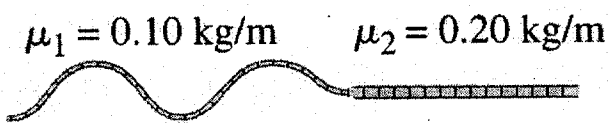
3. A meteoroid is 280,000 km from Earth and moving at 1.1 km/s. It is on a path that will come within 8500 km of Earth's centre.

   (a) What is the speed of the meteoroid at its closest approach to Earth? [5]

   (b) Will the meteoriod ever return to Earth's vicinity? Justify your answer. (You may assume that its path is not significantly perturbed by other heavenly objects except Earth's gravitational field) [1, 2]



4. A cord has two sections with linear densities of 0.10 kg/m and 0.20 kg/m as shown below. An incident wave given by $y = 0.050\sin(6.0x - 18.0t)$ where x and y are in metres, and t in seconds, travels along the lighter cord.

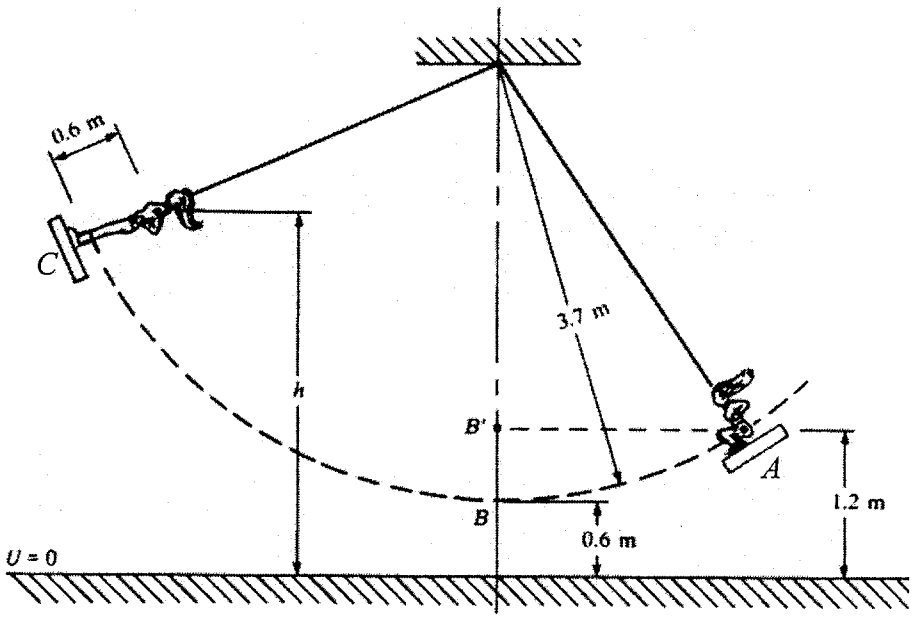


   (a) What is the wavelength on the lighter section of the cord? [2]

   (b) What is the tension in the cord? [4]

   (c) What is the wavelength when the wave travels on the heavier section? [2]

5. A girl of weight 400 N is crouching on a light swing when lifted to position A as indicated below. At this position, her cerntre of mass is 1.20 m above the ground and 3.7 m from the pivot of the swing. The swing is then released from rest. At the lowest point of the swing, the girl stands up instantaneously, thus raising her centre of mass by 0.60 m from B to B'. Note that B' is also 1.20 m above the ground as shown. What is the height of her centre of mass above the ground, h, when she reaches the top of the arc at position C? [8]



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PART II

This part of the examination paper contains **THREE** long-answer questions from page 6 to 8. Answer any **TWO** questions. The mark for each part is indicated in the square bracket.

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6. (a) A particle is subject to a force associated with the potential energy

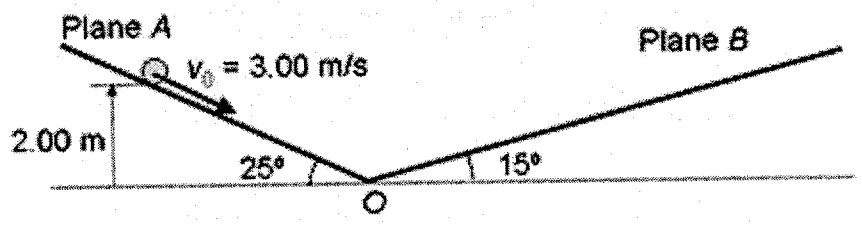
$$U(x) = 6x^2 - x^3.$$

i. Sketch $U(x)$, and mark the position of significant features. [4]

ii. Indicate the direction of the force in each appropriate range of the variable x on your sketch. [2]

iii. Discuss the possible motions of the particle for different values of its total energy E. Find its positions of equilibrium, indicating whether stable or unstable. [5]

(b) A particle moves on two inclined planes A and B as shown below. You may assume that the speed of particle remains the same when it transfers from plane A to plane B and vice versa at point O and it does not leave the surface at any point of its path. Initially, it is projected with a velocity of 3.00 m downwards along the plane at height of 2.00 m on inclined plane A.



i. If the planes are frictionless, describe its subsequent motion. What is the period of this motion? [9]

ii. If friction exists between the particle and the surfaces such that the coefficients of static and kinetic friction are $\mu_s = 0.20$ and $\mu_k = 0.15$ respectively, to what height will the particle reach on plane B during its first cycle? Describe its subsequent motion and state the point at which the particle will come to a permanent stop. [10]

7. (a) Two hoops are fastened togther as shown below. The smaller hoop has a mass of m and radius b. The mass and radius of the larger hoop are $3m$ and $3b$.

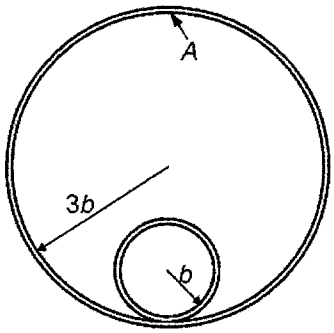


Figure 7(a)

i. Find the distance of the centre of mass of the system from the centre of the larger hoop. [4]

ii. What is the moment of inertia of the system about the axis perpendicular to the plane of the hoop and passing through the centre of mass of the system. [6]

(b) If the system is hung at point A and displaced slightly to the left, what is the period of oscillation? You may assume that the system does not slip from the point of support. [6]

(c) The system is now placed on the table and the system is released from rest in the position shown below. There is sufficient friction between the large hoop and the table so that it rolls without slipping. How fast relative to the table is the centre of the large hoop moving when the centres of the two hoops lie in a vertical line? [8]

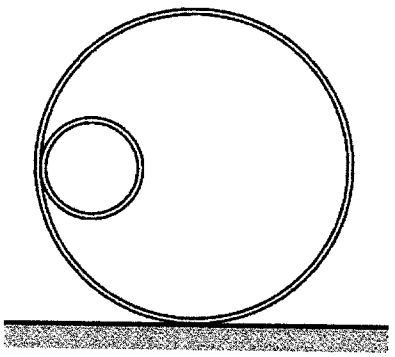


Figure 7(b)

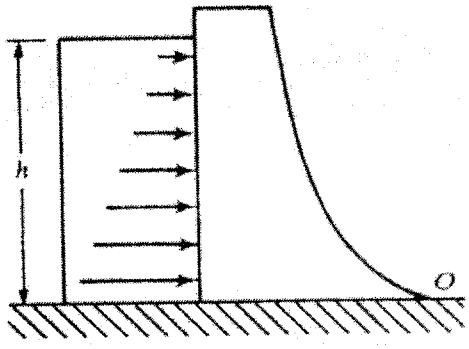
(d) The larger hoop is now fastened rigidly to the table and the small hoop is detached from the larger hoop. Suppose the smaller hoop is released from the position shown above in Figure 7(b). It rolls without slipping inside the larger hoop. What is the speed of the centre of the smaller hoop as it passes through its lowest point? [6]

8. (a) Water stands at a depth h behind the vertical face of a dam. It exerts a resultant horizontal force on the dam, tending to slide it along its foundation, and a torque, tending to overturn the dam about point O. Find in terms of density of water ρ, h, g and l the length of the dam (i.e., the width of the river),

i. the horizontal force, [5]

ii. the torque about O, and [5]

iii. the height at which the resultant force would have to act to produce the same torque. [2]

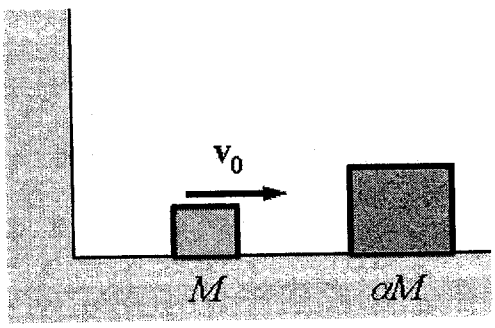


(b) A block of mass M is moving at speed v_0 on a frictionless surface. There is a rigid wall on the left of this block and a more massive block of mass αM on its right, initially at rest. The less massive block undergoes elastic collisions with the other block and with the wall, and the motion of both blocks is confined to one dimension.

i. Explain clearly why the two blocks will undergo only one collision if $\alpha \leq 3$. [9]

ii. If $\alpha = 4$, find their **<u>final</u>** speeds. [9]

(Hint: You may make use of the fact that the approach speed is equal to the separation speed for elastic collision to simplify your calculations.)



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