NATIONAL UNIVERSITY OF SINGAPORE

PC1141 PHYSICS I

(Semester I: AY 2009-10)

26 November 2009

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 **FIVE** printed pages.
2. Answer **ALL** the questions.
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 is given on Page 2 of this examination paper.

Useful Information

1. Physical constants

$$G = 6.67\times10^{-11}\,\mathrm{N\cdot m^2/kg^2}$$
$$g = 9.80\,\mathrm{m/s^2}$$
$$M_{\mathrm{Sun}} = 1.99\times10^{30}\,\mathrm{kg}$$
$$R_{\mathrm{Earth}} = 6.37\times10^{6}\,\mathrm{m}$$
$$M_{\mathrm{Earth}} = 5.97\times10^{24}\,\mathrm{kg}$$
$$d_{\mathrm{Sun\text{-}Earth}} = 1.50\times10^{11}\,\mathrm{m}$$
$$R_{\mathrm{Mars}} = 3.40\times10^{6}\,\mathrm{m}$$
$$M_{\mathrm{Mars}} = 6.42\times10^{23}\,\mathrm{kg}$$
$$d_{\mathrm{Sun\text{-}Mars}} = 2.28\times10^{11}\,\mathrm{m}$$
$$\rho_{\mathrm{water}} = 1.00\times10^{3}\,\mathrm{kg/m^3}$$

2. Table of integrals

$$\int \frac{dx}{\sqrt{a+bx}} = \frac{2}{b}\sqrt{a+bx}$$
$$\int \frac{xdx}{\sqrt{a+bx^2}} = \frac{1}{b}\sqrt{a+bx^2}$$

PART I

This part of the examination paper contains five short-answer questions on page 3. Answer ALL questions. The mark for each question is 8.

1. A light ball and a heavy ball are dropped from a height of h from the ground (dimensions of balls negligible) with the light ball directly above the heavy ball. To approximately what height will the light ball bounce up after it hits the heavy ball, assuming that all collisions are elastic?

2. A rod has mass M and length L. Calculate the moment of inertia of the rod about an axis which is passing through its centre of mass and forming an angle θ to the rod.

3. A solid sphere with radius r is placed on top of a thin disk with radius R. The contact point is the centre of the disk. Both objects are uniform and have same mass M. Calculate the gravitational potential energy of the system. Take the potential energy to be zero when the sphere and the disk are infinitely far apart.

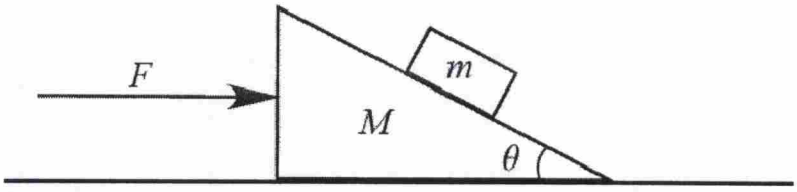
4. A physics student measures the period of a physical pendulum about one pivot point to be T. Then he finds another pivot point on the opposite side of the centre of mass that gives the same period. The two points are separated by a distance L. Can he find the acceleration due to gravity, g, without measuring the moment of inertia of the pendulum? Why?

5. Horseshoe bats emit sounds from their nostrils and then listen to the frequency of the sound reflected from their prey to determine the prey's speed. If a horseshoe bat flying at speed v_{bat} emits sound of frequency f_{bat}, the sound it hears reflected from an insect flying toward the bat has a higher frequency f_{refl}. What is the speed of the insect?

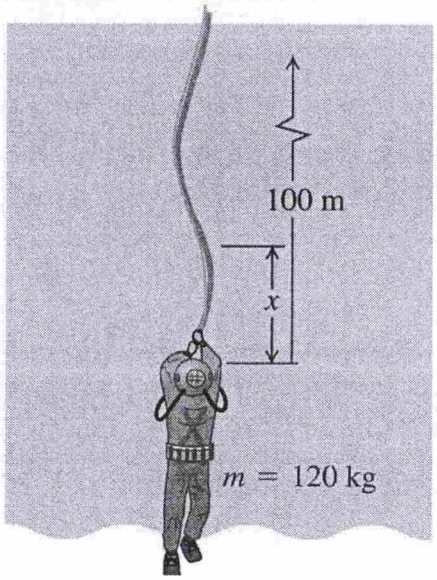
PART II

This part of the examination paper contains three long-answer questions from page 4 to 5. Answer ALL questions. The mark for each question is 20.

6. A right triangular wedge of mass M and angle θ, supporting a block of mass m on its side, rests on a horizontal table. When a horizontal force F applied to the system as shown in the figure below, what is the acceleration of the block m? Assume that all contacts are frictionless.



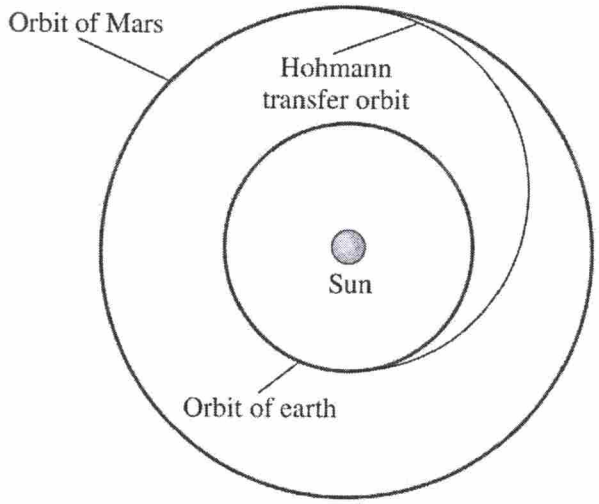
7. A deep-water diver is suspended beneath the water surface by a 100-m-long cable. The diver and his suit have a total mass of 120 kg and a volume of 0.0800 m^3. The cable has a diameter 2.00 cm and a linear mass density of $\mu = 1.10$ kg/m .



(a) Calculate the tension in the cable a distance x above the diver.

(b) The diver thinks he sees something approaching and jerks the end of the cable back and forth to send transverse waves up the cable as a signal to his companions. Calculate the time required for the first signal to reach the surface. Ignore the damping of the water.

8. The most efficient way to send a spacecraft from the earth to another planet is by using a *Hohmann transfer orbit* (see the figure below). If the orbits of the departure and destination planets are circular, the Hohmann transfer orbit is an elliptical orbit whose perihelion and aphelion are tangent to the orbits of the two planets. The rockets are fired briefly at the earth to put the spacecraft into the transfer orbit. Ignore the spin of each planet.



(a) In what direction must the spacecraft be launched at the earth: in the direction of motion or opposite the direction of motion?
(b) How long does a one-way trip from the earth to Mars take?
(c) What is the speed of the spacecraft (relative to the sun) when it just leaves the earth?
(d) What speed must the spacecraft to be launched near the surface of the earth?

(WQh)

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