浙江大学 20_21_ –20_22_学年__春夏_学期

《 普通物理学 I（H） 》课程期中考试试卷

课程号：__R61R0060__，开课学院：__物理学院____

考试试卷：A 卷、B 卷（请在选定项上打 √）

考试形式：闭、开卷（请在选定项上打 √），允许带_计算器和字典_入场

考试日期：__2022_年__04__月__20__日，考试时间：__95__分钟

诚信考试，沉着应考，杜绝违纪。

考生姓名：______________学号：______________所属院系：______

题序	一	二	三	四	总 分
得分					
评卷人					

Instructions:

1. There are 4 problems. They are comprehensive questions. Please find out the easier ones to solve first.

2. Please include the necessary intermediate results, for which you can get partial credits. If you guess the final results, please state clearly and write down why you guess so; otherwise, you may not get any credit.

3. In the long questions, even if you cannot solve the earlier part, you may still be able to solve the later ones. So do not give up easily.

4. If you cannot complete your answer in the corresponding box, indicate clearly where the rest of your answer can be found.

5. There are two blank pages at the end which you may use if you need scrap paper.

1. **Dynamics of a block (25 points).**

A hemisphere of mass M and radius R is put on a frictionless horizontal table and can move freely. A block of mass m is located on the top of this hemisphere. Initially both the hemisphere and the block are at rest, and the initial position of the block infinitesimally deviates from $\theta = 0$ so that it starts to slide down the hemisphere from rest. The block detaches the hemisphere at angle θ_0, as shown in Fig. 1. Neglect the size of the block and the friction between the block and the hemisphere.

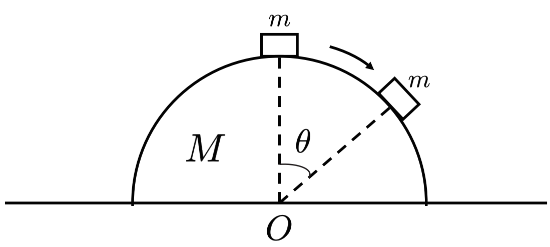

Figure 1: A block sliding down a hemisphere.

(a) Find the angle θ_0. (It is enough to give the equation in which θ_0 is the only unknown quantity. You do not need to solve this equation if it is too complicated for you.)

(b) What is the value of θ_0 when $m \ll M$ and $m \gg M$?

2. **A rolling body (25 points).**

   A round uniform body (sphere, cylinder, ring, etc.) of mass M and radius R is initially placed at the top of a ramp of height h at angle θ (Fig. 2). Then it rolls down the ramp from rest without slipping. The moment of inertia with respect to the rotation axis through its center of mass is I.

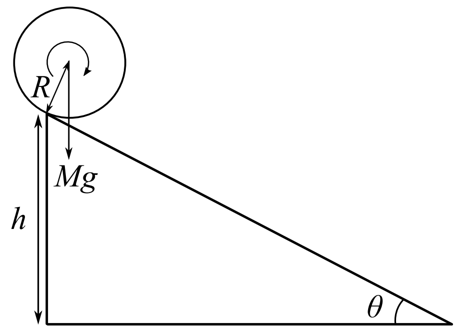

Figure 2: A round uniform body with mass M and radius R rolling down the ramp with angle θ.

(a) Determine the time required for the body to reach the bottom of the ramp.

(b) Is the time obtained in (a) shorter or longer for the body with larger I? Explain its physical reason.

(c) Assuming that the friction reaches the maximal static friction, find the static friction coefficient.

3. **Vibrational modes of CO_2 (25 points).**

Consider a linear triatomic molecule of CO_2 [Fig. 3(a)]. We model the CO_2 molecule by two kinds of balls (with mass m_1 for O atoms and m_2 for C atom) connected by two identical springs with the spring constant k [Fig. 3(b)], where the force F between the C and O atoms follows the simple relation

$$F = -k\Delta x\,, \tag{1}$$

where Δx is the deviation from their equilibrium distance a_0.

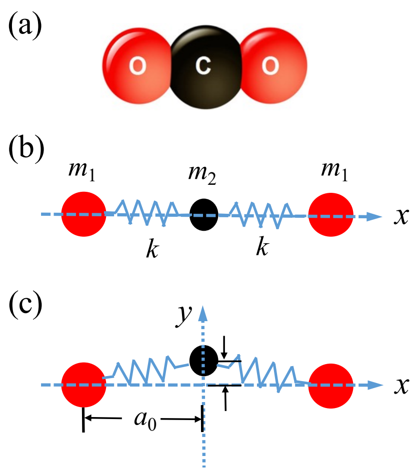

Figure 3: Schematic pictures of a CO_2 molecule.

(a) Calculate three eigenfrequencies for longitudinal vibrational modes along the C-O bond direction (x direction) and illustrate the motion of the atoms in each normal mode.

(b) For transverse vibrational modes, assume that the O atoms are stationary and fixed at $x = \pm a_0$, and the C atom oscillates in the y direction with a small amplitude compared to the equilibrium distance a_0 [Fig. 3(c)]. Calculate the restoring force acting on C atom as a function of the perpendicular displacement y. Is this vibrational mode a harmonic motion? Explain the reason of your answer.

4. **Galilean transformation of the wave equation (25 points).**

Consider an oscillatory wave traveling on a string (Fig. 4) whose linear density (mass per unit length) is σ. Introduce x and y coordinates as the horizontal and the vertical coordinates, respectively, and describe the wave by y coordinate of the string at x and time t as $y = y(x, t)$. Assume that the magnitude F of the tension is constant throughout the string, and the amplitude of the oscillation is small.

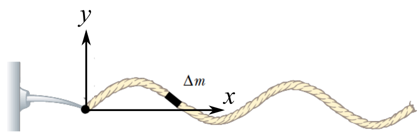

Figure 4: An oscillatory wave on a string.

(a) First, write down the equation of motion for the mass element Δm of the string between x and $x + \Delta x$. Then, derive the wave equation for $y(x, t)$ with F and σ.

(b) Consider a traveling wave moving at the speed c described by a wave function $y = y(x - ct)$. From the wave equation obtained in (a), derive an expression of c in terms of F and σ.

(c) Consider the following Galilean transformation from the original frame K with (x, t) to another inertial frame K' with (x', t') moving against K-frame at the relative velocity V in the x direction:

$$x' = x - Vt, \tag{2}$$
$$t' = t. \tag{3}$$

Express $\partial/\partial x$ and $\partial/\partial t$ in terms of the variables in K'-frame, i.e., $\partial/\partial x'$ and $\partial/\partial t'$.

(d) Using the result obtained in (c), derive the wave equation in K'-frame (i.e., write down the wave equation in terms of x' and t'). Here, express the final result using c instead of F and σ. Is the wave equation Galilean invariant?

(e) Discuss the physical meaning of c: in which reference frame(s) is the wave speed equal to c?