Mechanics 2, exercises week 2, NWI-MOL160

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Question 1: Billiards, elastic collisions in 2D

A billiard ball moving at $v_{1,i} = 5.00$ m/s strikes a stationary ball of the same mass (m). After the collision, the first ball moves at an angle of $\alpha = 30.0°$ with respect to the original line of motion. Assume frictionless motion.

1a. Write down the initial velocities of the balls, $\boldsymbol{v}_{1,i}$ and $\boldsymbol{v}_{2,i}$ as two-dimensional vectors.

1b. Write the final velocity of the first ball as a vector, $\boldsymbol{v}_{1,f}$, and as function of its (as yet unknown) velocity $v_{1,f}$ and the angle $\alpha = 30°$.

1c. Compute the velocity of the center of mass, $\dot{\boldsymbol{X}}$.

1d. Compute the initial velocities, $\tilde{\boldsymbol{v}}_{1,i}$ and $\tilde{\boldsymbol{v}}_{2,i}$ in the c.o.m. frame. Also compute the initial relative velocity $\boldsymbol{v}_r$ of ball 1 with respect to ball 2.

1e. What are the magnitudes of the initial ($v_{r,i}$) and final ($v_{r,f}$) relative velocities?

1f. What is the relation between the final relative velocity $\boldsymbol{v}_{r,f}$ and the final c.o.m. frame velocity $\tilde{\boldsymbol{v}}_{1,f}$?

1g. What is the relation between the final velocity of particle 1 in the c.o.m. frame, $\tilde{\boldsymbol{v}}_1$ and in the lab-frame?

1h. Compute the final lab-frame velocities of $\boldsymbol{v}_{1,f}$ and $\boldsymbol{v}_{2,f}$ and their magnitudes, $v_{1,f}$ and $v_{2,f}$. Ignore the solution where particle 1 is not moving in the lab-frame after the collision. *Hint:* read section 2.4 in the lecture notes.

1i. What is the angle between final velocities $\boldsymbol{v}_{1,f}$ and $\boldsymbol{v}_{2,f}$?

1j. Check your answer using energy conservation computed in the lab-frame.

Question 2: Buffer gas cooling

An O_2 molecule with mass $m_1 = 2m_O = 32$ u and speed v_1 collides head-on and elastically with a helium atom with mass $m_2 = m_{He} = 4$ u, initially at rest.

2a. What are the final velocities of both particles?

2b. What fraction f of its initial kinetic energy does the O_2 molecule loose?

2c. In buffer gas cooling, a very cold gas of rare-gas atoms is used to cool molecules. Based on your results, which rare-gas atom is most suited to cool O_2 molecules, helium, neon (m =20 u), or xenon ($m = 131$ u)?

Question 3: A CD player

A CD (diameter 120 mm, mass 15 g) rotates at 500 rev/min.

3a. What is the angular velocity ω in rad/s?

3b. How far does a point on the rim of the CD travel in one second?

3c. What is the moment of inertia of the CD?

3d. What is the angular momentum L of the CD?

3e. What is the kinetic (rotational) energy of the CD?

3f. What is the force experienced by a dust particle of 0.1 g on the surface of the CD at 60 mm from the center?