1. A block is sliding down a frictionless incline of angle θ from an initial height h_2. When the block reaches h_1, it hits a spring of spring constant k and becomes attached to the spring.

   a. (5pts) What is the minimum height of the block when the block stops?
   b. (8pts) Because the block attaches to the spring, the block will undergo oscillatory motion. Define $x(t)$ as the distance from the initial location, and $t = 0$ when the block first hits the spring. What are the equation of motion and initial conditions for $x(t)$.
   c. (5pts) What is the oscillating frequency?
   d. (7pts) Plot the trajectory of the block in the plane of $x(t)$ and $v(t) = \frac{dx}{dt}$ from initial height h_2.

2. A uniform disc of radius R and mass m is rolling without slipping on a horizontal plane with a center-of-mass speed v.

   a. (5pts) Calculate the moment of inertia I_{CM} with respected to the center of the disc. You need to write down the derivations.
   b. (5pts) What is the angular momentum L_A with respected to the contact point A between the disc and the plane?
   c. (5pts) The disc hits the corner B of a step with a height h ($h < R$) and becomes attached to the corner. What is the angular momentum L_B with respected to B when the disc just after the disc hit the corner?
   d. (5pts) What is the kinetic energy of the disc just after hitting the corner?
   e. (5pts) What is the kinetic energy of the disc after the disc rotates around the corner and the whole disc is above the step?

3. An ideal gas of N molecules and $\gamma = C_P/C_V$ (ratio of specific heats of fixed pressure and fixed volume) has a volume of V_1 and temperature T_1.

   a. (5pts) The gas is compressed reversibly to a smaller volume V_2 with the temperature fixed at T_1, what is the pressure P_2?
   b. (5pts) What is the heat exchange ΔQ_a between the gas and outside environment during the above compression?
   c. (5pts) What is the entropy change ΔS during the above compression?
   d. (5pts) The gas then expands back to V_1 adiabatically (no heat exchange with outside), is the resulting pressure P_1^* larger or smaller than P_1? You need to state your derivations.
   e. (5pts) To bring the gas back to P_1 at the fixed volume V_1, how much heat ΔQ_b is needed? Being applied to or extracted from the gas?

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4. Two parallel-plate capacitors are connected in *series* to a voltage source of voltage V. The capacitors have plate area A and plate gap d. The capacitor connected to the high voltage end is filled with a dielectric material with a dielectric constant ϵ. The capacitor connected to the ground end is in vacuum between plates.

   a. (5pts) Plot the circuit.
   b. (5pts) What is the voltage at the location between the two capacitors, when the circuit is in steady state?

5. Two parallel-plate capacitors are connected in *parallel* to a voltage source of voltage V. The capacitors have plate area A and plate gap d. The first capacitor is filled with a dielectric material with a dielectric constant ϵ. The second capacitor is in vacuum between plates.

   a. (5pts) Plot the circuit.
   b. (5pts) What are the charges Q_1 and Q_2 on the two capacitors, when the circuit is in steady state?
   c. (5pts) If the circuit is connected to the voltage source when there are no charges on the capacitors, which capacitors will be charged to its full charges quicker? You need to state your reasoning.

參考用

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