EMMY NOETHER'S RULES OF CONSERVATION

1. Identify the system. You typically include all objects whose positions or motions change during the motion under consideration (unless using the work-energy theorem; then the system must be rigid).

2. Identify the conserved quantities, as seen from the great conservation laws of physics:

$$\Delta E = Q + W_{\text{ext}} \qquad \Delta \vec{p} = \vec{F}_{\text{ext}} \Delta t \qquad \Delta L = \tau_{\text{ext}} \Delta t$$

   Oftentimes we also consider the law of conservation of mechanical energy. This is not an independent physical law but rather a useful rewrite of the law of conservation of energy. It is most useful when

   (a) all conservative forces are internal OR the external member of the interaction pair changes state negligibly (e.g., the Earth) during the interaction, and
   (b) kinetic friction, if present, is an internal force.

   We then write that

$$\Delta \text{ME} = Q + W_{\text{nc,ext}} - \Delta E_{\text{internal}}$$

   Notice that the external work only includes non-conservative forces (because conservative work is now hiding inside of PE), and we have moved $\Delta E_{\text{internal}}$ from the the LHS to the RHS. In essence we have simply changed accounting (or "cooked the books"). The reason for condition (b) is that experience teaches us that when this is the case, friction transforms mechanical energy into thermal energy, so we may identify $\Delta E_{\text{internal}}$ with $-W_{\text{fr}}$ (assuming no other conversions of energy occur).

   Finally, we sometimes use a very special form the law conservation of energy, called the work-energy theorem. It is applicable only to the extent that system can be treated as completely rigid with no internal structure. (This necessarily excludes collisions, as deformations always occur which violate this approximation.) We then have

$$\Delta \text{KE} = W_{\text{net}}$$

3. Identify states. A state is a specification of the position and velocity of each object, and is typically associated with a single instant in time. States must be chosen so that the right hand side of at least one of the conservation laws is known (typically zero).

4. Write down symbolic equations for the conserved quantity (E, $\vec{p}$, L, or ME) of each object in every state. (Creating a table of knowns and unknowns is very helpful in this.)

5. If the right-hand side of the conservation law is zero, write down an equation of the form $Q_i = Q_f$; otherwise write $Q_f - Q_i = \Delta Q$.

6. Solve symbolically for the desired unknown variable.

7. Plug in numbers.

8. Evaluate the reasonableness of your answer. If it is not reasonale, you may have misidentified the conserved quantity (or quantities). Return to step 2.

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