

Using ChatGPT to write large numbers of isomorphic physics problems

Breakdown the task into multiple steps is the key. Prompt ChatGPT to use python to ensure numerical accuracy.

Title: Using ChatGPT to efficiently create large numbers of isomorphic assessment problems

We use a 5-step process to design a prompt chain which can easily generate 30+ isomorphic physics practice problems based on a template problem, including simple figures. The process can be implemented directly in ChatGPT.

Step 1: Break problem into components

1Problem context

2Numerical values

3Unknown variable

4Solution

Template Problem: A worker is pushing a wooden crate across a concrete floor at a uniform speed. The coefficient of kinetic friction between the crate and the floor is 0.36 . The worker applies a force at an angle of 12.74° downward with respect to the horizontal. The required force exerted is 465.64 N . The acceleration due to gravity is 9.81 m/s^2 . Find the mass of the crate in kilograms. Express your answer with two significant figures.

Step 2: Specify structural and contextual variations

Contextual Variation

- Can be pushing or pulling
- Everyday objects students are familiar with.
- Must be on rough surface
- Avoid difficult words or phrases

Structural Variation

- All forces must add up to zero
- Angle must be between $+60$ and -60
- Magnitude of force must be positive
- Unknown variable should be chosen from f , m or μ

Step 3 and 4: Design and Execute a Prompt Chain

Prompt Chain Design

1. Write 10 scenarios
(generate 10 problems at a time)

2. Create Random Variables and check availability

3. Select Unknown variable and write problem body

4. Write the solution

5. Combine them and output in a standard format

Prompts

I'm writing physics problems involving calculation of kinetic friction and balance of forces on a moving object. As a first step, please help me by doing the following:
Generate 10 different cases of an object being pulled or pushed by either a human, an animal, or a machine/vehicle across a surface. Indicate whether the pushing or pulling force must be angled upwards or downwards.
Here are some examples:
horse pulling a sledge on snow. upwards.
A person pushing a couch across carpeted floor. Downwards.
a person dragging a heavy luggage case. Upwards.
A towing truck dragging a damaged car on rough road. Upwards

Now for each of those 10 cases, first generate the following set of values
1. Coefficient of kinetic friction, μ_k . Between 0.1 and 0.9
2. Angle of the force θ . Positive 10 degrees to 60 degrees if the force is upwards, negative 10 degrees to 60 degrees if the force is downwards.
3. Mass of the object being pulled or pushed, M . Appropriate for the object being pushed or pulled, in units of kg.
4. In addition, generate a generous estimation of the force that can be exerted by the human, animal or machine doing the pushing or pulling (not the object).
Next, calculate the magnitude of the force according to:
$$F = \mu * m * g / (\cos(\theta) + \mu * \sin(\theta)).$$

Check if the magnitude of F (in Newtons) is within the estimated range, and if the magnitude is positive. If yes, list the values. If not, re-generate the random numbers.

For each of the 10 scenarios and the corresponding set of numbers, write a physics problem following those steps:
1. Choose either F , m , or μ_k as the unknown variable.
2. Describe the situation and explain the known variables.
3. Imply that the object is moving/sliding at constant or uniform speed.
4. When stating the angle, explicitly state if it is upward or downward with respect to the horizontal, but not write any negative signs.
5. If the object is pulled by a rope or a chain or similar objects, state the angle as the rope/chain forms an angle of with respect to the horizon
6. Ask students to calculate the unknown variable, and specify the unit. For example, find the force F in units of Newtons.
7. Specify significant figures required for the answer.

Write concise student facing solutions for the first 5 problems. Each solution should include the following elements:
1. Explain that due to the object moving at constant velocity along a flat surface, the acceleration is zero in both directions, so the total force on both horizontal and vertical directions must both add up to zero according to Newton's second law of motion.
2. set positive x in the direction of the object's motion and positive y pointing up in the vertical direction.
3. Write down the sum of forces along the y -axis equal to zero expression, starting with $\sum(\vec{F}_y) = \dots = 0$

Now please help me transform the first 5 problems into a YAML format, according to the example problem format below.

* The answer: value: field should contain the actual answer number from the data table above,
* The feedback: general field should contain the full solution generated above.
* Math equations and expressions should be written in LaTeX and enclosed in $\langle \text{latex} \rangle / \text{latex} \rangle$ tags:

Execution

Here are 10 varied cases of an object being pushed or pulled across a surface, with the force angle direction (upwards or downwards) specified:
1.Ox pulling a wooden cart on dirt road
→ **Force Angle:** Upwards
•The rope or harness is angled slightly upwards from the ox to the cart's attachment point.
2.Person pushing a wheelbarrow full of soil on grass
→ **Force Angle:** Downwards

ChatGPT called upon a python script to generate context specific random numbers and correct answer

```
import numpy as np
import pandas as pd
import random as tools

# Constants
g = 9.81 # Acceleration due to gravity (m/s^2)

# Cases with appropriate mass values and force estimation
cases = [
    ("Worker pushing a wooden crate", (50, 200), (200, 600)),
    ("Dog pulling a small sled", (10, 30), (50, 200)),
    ("Person dragging a backpack with wheels", (5, 20), (100, 300)),
    ("Child pushing a toy truck", (2, 10), (50, 150)),
    ("Farmer pulling a plow with an ox", (100, 300), (500, 1500)),
    ("Robot arm pushing a box", (20, 100), (200, 800)),
    ("Person dragging a kayak", (30, 80), (100, 400)),
    ("Car towing a trailer", (500, 2000), (1000, 10000)),
    ("Construction worker pushing a wheelbarrow", (40, 150), (200, 800)),
    ("Bulldozer pushing a pile of dirt", (1000, 5000), (5000, 20000)),
]
```

Example of Isomorphic problems generated:

A dog is pulling a small sled across an icy path at a steady speed. The coefficient of kinetic friction between the sled and the ice is 0.59 . The sled has a mass of 10.21 kg . The dog pulls the sled using a rope, which forms an angle of 31.21° with respect to the horizon. The acceleration due to gravity is 9.81 m/s^2 . Determine the force exerted by the dog in Newtons. Give your answer with two significant figures.

Step 5: Export problems in a specific format

- The format of choice is yaml which is readable and Latex friendly
- We have a tool to convert it into QTI for Canvas import
- A similar process can be used to create variations of simple diagrams using python and matplotlib (see github repo for example)

Scan here for Github repo containing sample problem banks and generation prompts.

```
- numerical:
  id: q3
  title: Person Dragging a Backpack with Wheels
  points: 3
  text: |
    A traveler is dragging a rolling backpack across an asphalt road at a constant speed.
    The coefficient of kinetic friction between the backpack and the ground is  $0.73$ .
    The person pulls the backpack at an angle of  $37.92^\circ$  upward with respect to the horizontal.
    The force applied by the traveler is  $59.81\text{ N}$ .
    The acceleration due to gravity is  $9.81\text{ m/s}^2$ .
    Calculate the mass of the backpack in kilograms. Express your answer with two significant figures.
  answer:
    value: 10.36
    tolerance: 0.05
  feedback:
    general: |
      Since the backpack is moving at a constant velocity, Newton's second law tells us that the forces must sum to zero in both directions.
```

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