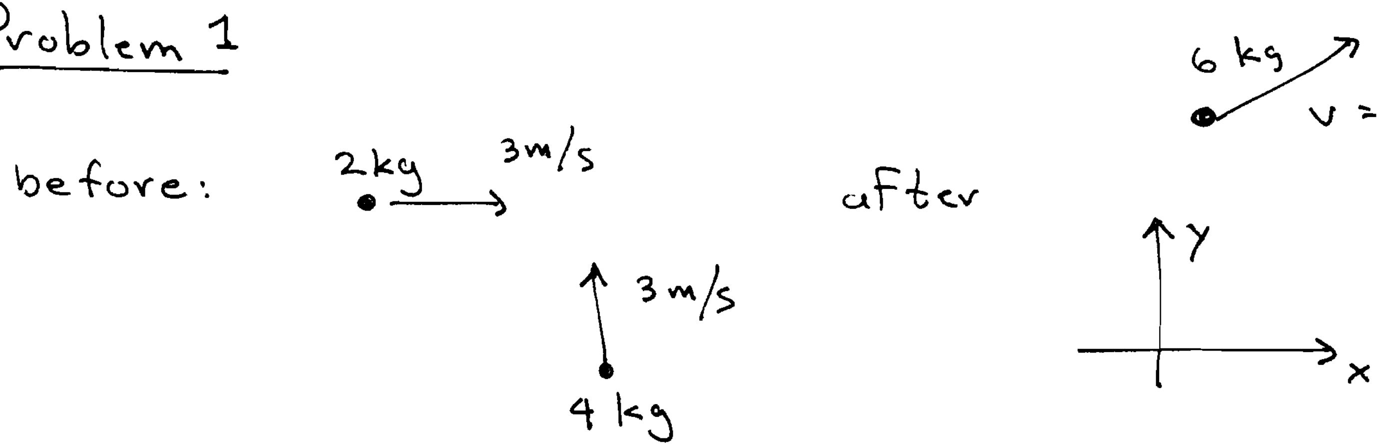
Sample Midterm 2

Problem 1



P_x before = P_x after

$$(2\text{ kg})(3\text{ m/s}) = (6\text{ kg})\, v_x \quad \Rightarrow \quad v_x = 1\text{ m/s}$$

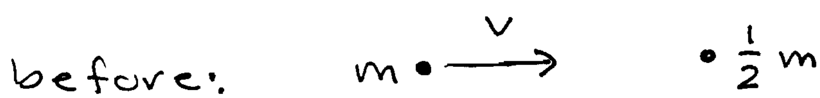
P_y before = P_y after

$$(4\text{ kg})(3\text{ m/s}) = (6\text{ kg})\, v_y \quad \Rightarrow \quad v_y = 2\text{ m/s}$$

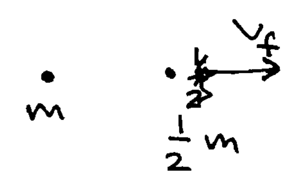
$$v^2 = v_x^2 + v_y^2 = (1 + 4)\text{ m}^2/\text{s}^2$$

$$\boxed{v = \sqrt{5}\text{ m/s}}$$

Problem 2



If it transfers all its energy, then after:



$$K_i = K_f$$

$$\tfrac{1}{2} m v^2 = \tfrac{1}{2}\left(\tfrac{1}{2} m\right) v_f^2 \qquad v_f = \sqrt{2}\, v_i$$

But then momentum is not conserved:

$$p_i = m v_i \qquad p_f = \left(\tfrac{1}{2} m\right) v_f = \tfrac{1}{2} m \cdot \sqrt{2}\, v_i = \tfrac{1}{\sqrt{2}}\, p_i$$

$\Rightarrow$ impossible

If it transfers all its momentum:

$$p_i = p_f$$

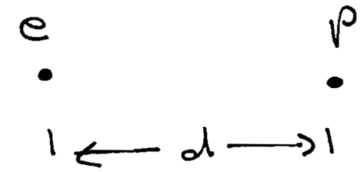
$$m v_i = \left(\tfrac{1}{2} m\right) v_f \quad \Rightarrow v_f = 2 v_i$$

$$K_i = \tfrac{1}{2} m v_i^2 \qquad K_f = \tfrac{1}{2}\left(\tfrac{1}{2} m\right)(2 v_i)^2 = 2 K_i$$

Kinetic energy <u>increases</u> $\Rightarrow$ impossible

<u>Problem 3</u>

sys = e



$$F = k \frac{e^2}{d^2} = m_e a_e$$

$$\boxed{a_e = \frac{k e^2}{m_e d^2}} \quad \text{toward } p$$

same for p: $\boxed{a_p = \frac{k e^2}{m_p d^2}}$ toward e

$$m_p > m_e \Rightarrow a_p < a_e$$

<u>Problem 4</u>

(1) Stability of the atom. According to classical physics, an electron orbiting a nucleus would lose energy due to radiation and fall in. Quantum mechanics allows only certain orbits and makes the atom stable.

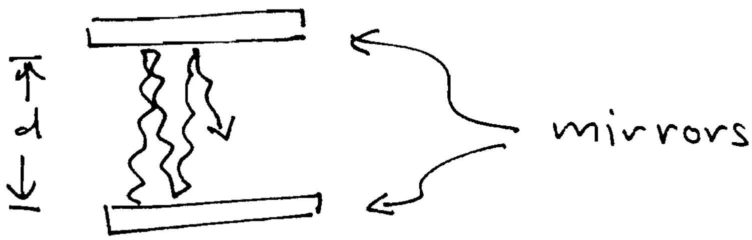
(2) The photoelectric effect. It requires a minimum energy to produce light with a given frequency. In classical mechanics, light of a given frequency can have arbitrarily low intensity, so we expect to produce light with arbitrarily low energy input. According to quantum mechanics, the minimum energy needed to create a photon of frequency f is $E = hf$ (h = Planck's const).

(3) Blackbody radiation. According to classical mechanics, there should be much more high energy radiation from a black body, assuming all frequencies are allowed with arbitrary energy. Quantum mechanics says that there is a relation between energy and frequency $E = hf$ ⇒ cuts off high energy photons.

... Any one of these answers is OK

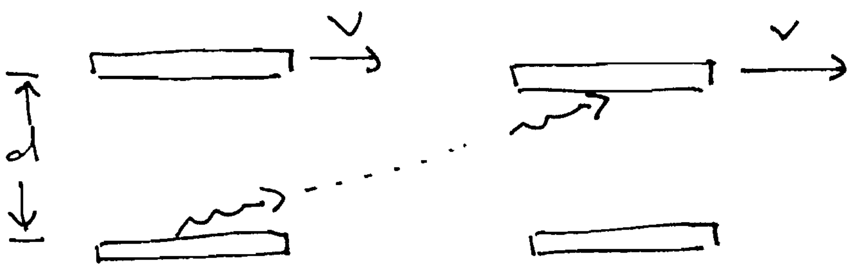
Problem 5

Consider the light clock:



Light bounces back and forth between mirrors. One "tick" of clock = time for light to go from one mirror to the other. $\Delta t = \frac{d}{c}$ c = speed of light

Moving light clock:



Light must travel farther to reach top mirror. Light still goes at speed c (!)
⇒ takes longer to "tick"