

Some useful information:

$$\Delta \vec{p} = \vec{F}_{net} \Delta t$$

$$\Delta \vec{r} = \vec{v}_{avg} \Delta t$$

$$|\vec{F}_{grav}| = G \frac{Mm}{|\vec{r}|^2}; \text{ approx. } mg \text{ near surface of Earth}$$

$$|\vec{F}_{spring}| = k_s |s|, \text{ opposite the stretch}$$

$$G = 6.7 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$$

$$g = 9.8 \text{ N/kg}$$

$$c = 3 \times 10^8 \text{ m/s}$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

$$\vec{p} = m\vec{v}$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\vec{p} \approx m\vec{v}, \text{ if } |\vec{v}| \text{ is small compared to } c$$

$$U_{electric} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$$

$$U_{gravity} = \frac{-GMm}{r}$$

$$\Delta E_{system} = W_{surroundings} + Q$$

$$E = m\gamma c^2 \text{ for a single particle}$$

$$E = mc^2 + \frac{1}{2}mv^2 \text{ for a single particle if } v \ll c$$

$$F_{air} = \frac{1}{2} C \rho_{air} A v^2$$

$$|\vec{F}_{net \perp}| = \frac{mv^2}{R} = m\omega^2 R$$

$$F_{buoyancy} = \frac{\rho_{air}}{\rho_{object}} mg$$

$$f = \mu N$$

$$\Delta E_{thermal} = mC_v \Delta T$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

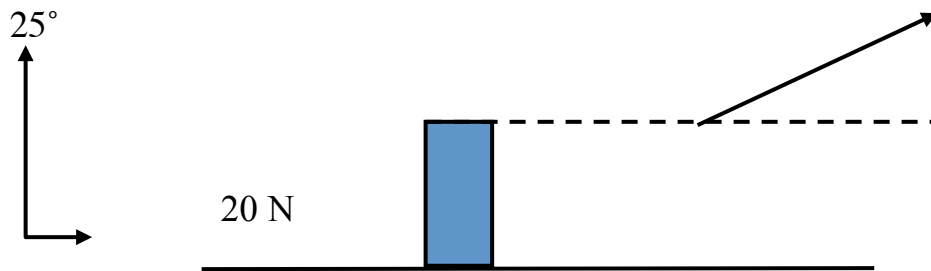
Problem 1. An unstable Pu-240 nucleus (mass 240.002 u) is at rest when it fissions into two Ag-120 nuclei (mass 119.893 u) which then fly off far from each other. Find the final kinetic energy of one Ag-120 nucleus when it is far from the other one. (1u = 1 atomic mass unit = 1.66×10^{-27} kg)

- A) 1.61×10^{-11} J
- B) 9.56×10^{-13} J
- C) 10.82×10^{12} J
- D) 5.67×10^{-12} J
- E) 3.22×10^{-11} J

Problem2. When a falling object reaches terminal speed, its kinetic energy reaches a constant value. However, the gravitational potential energy of the system consisting of the object, Earth and atmosphere continues to decrease. Which of the following best describes why this is not a violation of the conservation of energy for the system consisting of the object plus the Earth?

- A) The air increases in temperature due to internal work done on the air molecules, W.
- B) The small number of nuclear decays within the object decreases the rest mass of the falling object.
- C) The chemical energy of the object increases in order to compensate for the decrease in gravitational potential energy.
- D) The air increases in temperature due to heat exchange, Q.
- E) The Earth's kinetic energy increases in order to compensate for the decrease in potential energy.

Problem 3. A block of mass 10 kg is being pulled across the floor at constant velocity by a rope. The tension in the rope is 20N and the rope is at an angle of 25° above the horizontal. Find the force that the floor exerts on the block.



- A) $\langle -18.1, 89.5, 0 \rangle$ N
- B) $\langle 9.23, 21.6, 0 \rangle$ N
- C) $\langle -8.45, 79.9, 0 \rangle$ N
- D) $\langle -2.43, 94.2, 0 \rangle$ N
- E) $\langle 6.78, -98.0, 0 \rangle$ N

Problem 4. A proton and an electron are far apart at rest. An external agent brings the electron and proton closer together and then holds them at rest. Which statement is correct about the work done by the external agent?

- A) The work done is negative.
- B) The work done is positive.
- C) The work done in this case is zero because the proton and the electron will spontaneously come close to each other even without any external force.
- D) None of the above.

Problem 5. A car is about to make a turn at $v=3\text{m/s}$ such that the radius of the kissing circle at the turn is 10m. What should the minimum coefficient of friction be so that the car does not slip on the road?

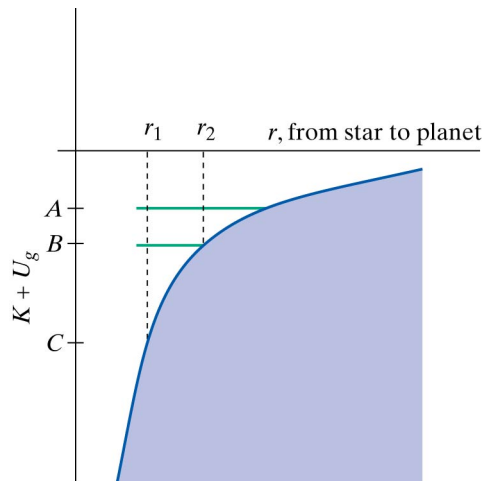
- A) 0.09
- B) 0.04
- C) 0.15
- D) 0.5
- E) One must know the mass of the car to answer the question.

Problem 6. 110 grams of boiling water are poured into an aluminum pan whose mass is 1000 grams. The initial temperature of the water is 100°C , with a heat capacity of $4.2 \frac{\text{J}}{\text{gram} \cdot \text{K}}$. The aluminum pan has an initial temperature of 24°C with a heat capacity of $0.9 \frac{\text{J}}{\text{gram} \cdot \text{K}}$. After a while, the water and pan come to a common temperature. What is that temperature?

- A) $T = 49.8^{\circ}\text{C}$
- B) $T = 105.2^{\circ}\text{C}$
- C) $T = -10.4^{\circ}\text{C}$
- D) $T = 75.9^{\circ}\text{C}$
- E) $T = 33.7^{\circ}\text{C}$

Problem 7. The figure below is a graph of the energy of a system of a planet interacting with a star. The gravitational potential energy U_g is shown as the thick curve, and plotted along the vertical axis are various values of $K+U_g$. Suppose that $K+U_g$ of the system is A . Find all of the true statements below.

1. The potential energy of the system decreases as the planet moves from r_1 to r_2 .
2. The potential energy of the system increases as the planet moves from r_1 to r_2 .
3. When the separation between the two bodies is r_2 , the kinetic energy of the system is $A-B$.
4. The system is a bound system; the planet can never escape.
5. The path traced by this orbiting system is a circle.
6. When the separation between the two bodies is r_1 , the kinetic energy of the system is $B-C$.



- A) 2, 3, 4
- B) 1, 3, 4
- C) 2, 4, 5
- D) 1, 4, 5
- E) 2, 4, 6

PHYS 172 – Hand-written Portion (30 points total)

Name (Print): _____

Signature: _____

PUID: _____

You will lose points if your explanations are incomplete, if we can't read your handwriting, or if your work is sloppy.

Hand-Written Problem: Tossing a Ball

You toss a ball (mass = 140 g) straight up into the air. The ball leaves your hand with a speed of 10 m/s, at a height of 1.5 meters above the ground, such that the initial position vector is $\langle 0, 1.5, 0 \rangle$ m. Our unit vectors are defined such that the y-direction points straight up into the air.

In this problem you'll use the energy principle to predict the speed of the ball when it has reached a certain height. You'll also compute how high the ball will rise before it starts falling back down.

Consider two possible choices for "system" and "surroundings".

Choice 1: The system includes everything in the universe.

Choice 2: The system consists of just the ball. All else resides in the surroundings.

In parts A-D, assume Choice 2 for the system and surroundings.

A. (5 points) The energy principle is $\Delta E_{system} = W_{external} + Q$. Express all of the terms in the energy principle for this selection of system and surroundings.

B. (5 points) List the external objects that interact significantly with the system. Make a carefully labeled free-body diagram showing the interaction between each object in the surroundings with each object in the system.

C. (8 pts) Use the energy principle to find the speed of the ball when it has risen to the position $\langle 0, 3, 0 \rangle$ m. Show all steps, clearly identify your initial and final states, indicate any approximations you're making, include units, and **circle the final answer**.

We suggest working with symbols, simplifying the algebra, and then plugging in numbers only at the end. (This will help you in part D).

D. (8 points) Use the energy principle to find the maximum height of the ball above the ground. Show all steps, clearly identify your initial and final states, indicate any approximations you're making, include units, and **circle the final answer**. You may quote any results that you derived in part C.

E. (4 points) If you had taken Choice 1 as system and surroundings, how would your expression for the terms in the energy principle $\Delta E_{system} = W_{external} + Q$ have changed?