Physics 301

Homework due 31 August 2022

1) Consider a system of two objects. Let Object 1 be a baseball and Object 2 be a moving truck. Show algebraically that if you throw the baseball at a truck that is approaching you, the baseball recoils with more energy than it had before it struck. Show that if you throw the ball at a receding truck, it recoils with reduced energy. Relate your results to the effect of compression or expansion upon the energy of a gas particle.

2) Stowe problem 6.4.

3) Stowe problem 6.5.

4) Consider a gas of linear triatomic molecules in a field-free environment. Predict the fraction of the total internal energy that is associated with their vibration.

5) Describe a situation in which the internal energy of a system is simultaneously changed thermally, diffusively, and by work. Choose a case in which the work is not associated with a macroscopic object like a piston. Pick reasonable numerical values for all the parameters that contribute to the internal energy, and use the First Law to calculate the change in internal energy. Be clear about signs.

Answers to homework due 31 August 2022

① (A) = ball

(B) = truck

Consider only $+\hat{x}$-direction motion.

v = velocity

p = momentum

m = mass

i, f = subscripts for initial, final

Momentum conservation:

$$m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf}$$

$$v_{Af} = \frac{m_A v_{Ai} + m_B(v_{Bi} - v_{Bf})}{m_A} = v_{Ai} + \frac{m_B}{m_A}(v_{Bi} - v_{Bf}) \quad \text{"Eq. 1"}$$

Energy conservation:

$$\frac{m_A v_{Ai}^2}{2} + \frac{m_B v_{Bi}^2}{2} = \frac{m_A v_{Af}^2}{2} + \frac{m_B v_{Bf}^2}{2}$$

Δ energy of ball is

$$\frac{m_A v_{Ai}^2}{2} - \frac{m_A v_{Af}^2}{2} = \frac{m_B}{2}(v_{Bf}^2 - v_{Bi}^2) \quad \text{"Eq 2"}$$

Pick a reference frame in which the truck is initially moving away from the ball, so

v_{Ai}, v_{Bi}, and v_{Bf} are positive; v_{Af} is negative.

According to Eq. 1,

This happens if $\frac{m_B}{m_A} > 1$ and $v_{Ai} + \frac{m_B}{m_A}(v_{Bi} - v_{Bf}) < 0$

$$\downarrow$$

$$v_{Bi} - v_{Bf} < -\frac{m_A}{m_B} v_{Ai}$$

$$v_{Bf} - v_{Bi} > \left(\frac{m_A}{m_B}\right) v_{Ai}$$

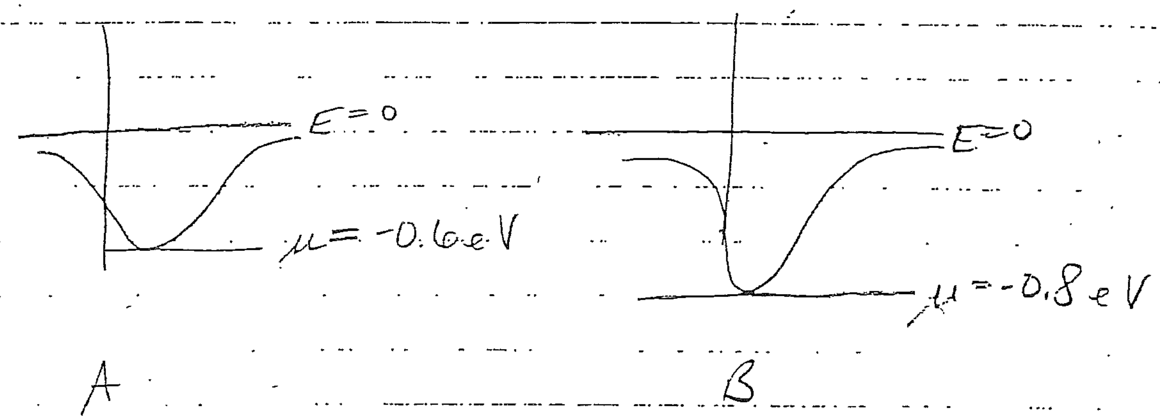
i.e., $v_{Bf} - v_{Bi}$ must be greater than some positive number, so $|v_{Bf}| > |v_{Bi}|$, so $\frac{m_B}{2}(v_{Bf}^2 - v_{Bi}^2)$

so according to Eq. 2, $\frac{m_A}{2}(v_{Ai}^2 - v_{Af}^2) > 0$, meaning that the ball has less energy on recoil than initially

Conversely if you begin with the initial condition that the truck is approaching, you find that the ball gains energy. This analysis is representative of the response of a classical non-interacting gas particle reacting to a moving wall (cha

[illegible])

(2)



Negative μ means that the molecules in the solution attract the ions. Since μ is more negative for solution B the ions in solutions B must feel a stronger attraction to the solvent than they do in solution A, So ions will migrate from A to B.

(3) The facts given in the problem suggest that boiling poin[t] is not correlated with mass (i.e., gravitation) Since boilin[g] is associated with release of the molecules from some confining potential, we propose that the next good candidate potential is the electrostatic one. So water molecules feel strong electrostatic mutual attraction. This implies that water has a large, negative chemical potenti[al]

4)  $N=3$

\# spatial coordinates $= 3N = 9$

A) # center-of-mass position coordinates = 3

B) # center-of-mass angular orientation coordinates = 2

C) ∴ # vibrational position coordinates $= 3N - 5 = 4$

\# momentum coordinates $= 3N =$

D) # center-of-mass linear momentum coordinates = 3

E) # center-of-mass angular momentum coordinates = 2

G) ∴ # vibrational momentum coordinates $= 3N - 5 = 4$

In a field-free region, only C, D, E, and G contribute to the internal energy. So the fraction of contributions due to vibration is

$$\frac{\#\text{ degrees of freedom in C and G}}{\#\text{ degrees of freedom in C, D, E, and G}} = \frac{4+4}{4+3+2+4} = \boxed{\frac{8}{13}}$$