PRACTICE QUESTIONS

QUESTION 1

A deuteron is the nucleus of a hydrogen isotope and consists of one proton and one neutron. The plasma of deuterons in a nuclear fusion reactor must be heated to about 300 million K.
(1) What is the RMS speed of the deuterons? Is this a significant fraction of the speed of light c = 3×10^8 m/s?
(2) What would the temperature of the plasma be if the deuterons had an RMS speed equal to 0.10 c?

QUESTION 2

100 moles of an ideal monatomic gas in a cylinder expands from a volume of 0.1 m^3 to 0.32 m^3. Heat flows into the gas just rapidly enough to keep the pressure constant at 1.8×10^5 Pa during the expansion.
(1) Draw a *pV*-diagram for this process. Find the work done by the gas.
(2) Calculate the change in temperature of the gas.
(3) Find the change in internal energy in the gas.

QUESTION 3

A Carnot engine works between two heat reservoirs at temperatures of 300K and 200K.
(1) What is its efficiency?
(2) If it absorbs 100 J from the hot reservoir during each cycle, how much work does it do?
(3) What is the coefficient of performance of this engine when it works as a refrigerator between the same two reservoirs?

QUESTION 4

You pull a simple pendulum of length 0.24m to the side through an angle of 3.5^o and then release it from rest. The mass of the pendulum bob is 500g.
(1) How much time does it take the pendulum bob to reach its highest speed?
(2) What is the kinetic energy of the pendulum at that time?

IN ADDITION, ALSO REVIEW ALL THE PAST HOMEWORK PROBLEMS FOR CHAPTERS 18,19,20,13 AND THEIR SOLUTIONS AS DISCUSSED IN RECITATION.

The regulations for the second midterm are the same as for the first midterm. No textbook, no notes - a formula sheet will be provided.

Q 1

Deuteron mass : $m = m_p + m_n = 3.348 \times 10^{-27}$ kg

Temperature : $T = 300 \times 10^6$ K

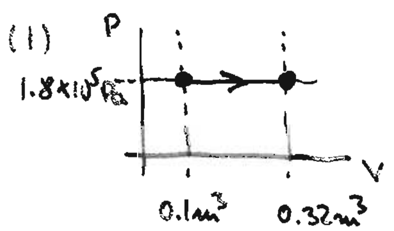
(1) $v_{rms} = \sqrt{\frac{3 k_B T}{m}} = 1.9 \times 10^6$ m/s

$v_{rms}/c = 0.64\%$ very small fraction

(2) $T = \frac{m v_{rms}^2}{3 k_B} = 7.3 \times 10^{10}$ K

Q 2

(1)



$W = p \Delta V = 1.8 \times 10^5 \text{ Pa} \cdot 0.21 \text{ m}^3$
$= 3.78 \times 10^4$ J

(2) $p \Delta V = n R \Delta T \Rightarrow \Delta T = \frac{p \Delta V}{n R} = \frac{3.78 \times 10^4 \text{ J}}{100 \text{ mol} \ \ 8.31 \text{ J/mol K}} = 45.5$ K

(3) $\Delta U = \frac{3}{2} R \Delta T \cdot n = \frac{3}{2} \cdot 8.31 \text{ J/mol K} \cdot 45.5 \text{ K} \cdot 100 \text{ mol} = 5.67 \times 10^4$ J

or :

$\Delta U = Q - W \Rightarrow \Delta U = (9.45 - 3.78) \times 10^4 \text{ J} = 5.67 \times 10^4$ J

$W = 3.78 \times 10^4$ J

$Q = n C_p \Delta T = 100 \text{ mol} \cdot \frac{5}{2} \cdot 8.31 \text{ J/mol K} \cdot 45.5 \text{ K} = 9.45 \times 10^4$ J

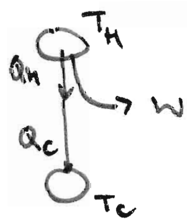
$C_p = C_v + R$
$= \frac{5}{2} R$

Q3

(1) $e_{CARNOT} = \frac{W}{Q_H} = 1 - \left|\frac{Q_C}{Q_H}\right| = 1 - \frac{T_C}{T_H} = 1 - \frac{200K}{300K} = 33.3\%$

$\left|\frac{Q_C}{Q_H}\right| = \frac{T_C}{T_H}$

(2)

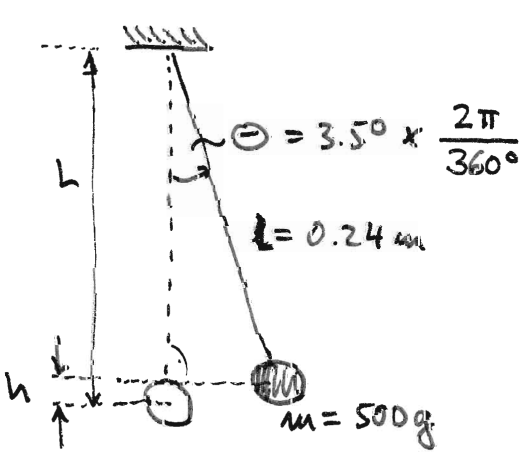


$W = |Q_H| - |Q_C| = |Q_H| \underbrace{\left(1 - \frac{|Q_C|}{|Q_H|}\right)}_{e_{CARNOT}} = 100J \cdot 33.3\% = 33.3J$

(3)

$K = \frac{|Q_C|}{|W|} = \frac{|Q_H| \cdot \frac{T_C}{T_H}}{|W|} = \frac{100J \cdot \frac{200K}{300K}}{33.3J} = 2$

Q4

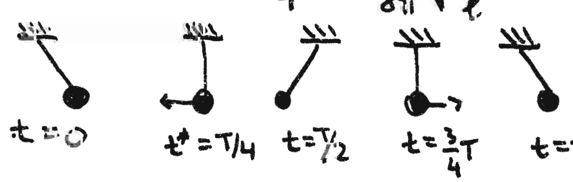


(1) $\omega = \sqrt{\frac{g}{\ell}} = \frac{2\pi}{T}$

$\Rightarrow T = \frac{1}{2\pi}\sqrt{g/\ell}$

- highest speed is reached after 1/4 period!

$\Rightarrow t^* = \frac{1}{4}T = \frac{1}{8\pi}\sqrt{\frac{g}{\ell}} = 0.25\ s$



(2) $E_{kin,max} \overset{!}{=} E_{pot,max} = mgh = mg(\ell - L\cos\Theta)$

CONSERVATION OF ENERGY

$= mg\,L(1 - \cos\Theta)$

$= 0.5\,kg \cdot 10\frac{m}{s^2} \cdot 0.24m \cdot \left(1 - \cos\left(3.5° \cdot \frac{2\pi}{360°}\right)\right)$

$= 2 \times 10^{-3}\ J$