

Study Guide Final Exam

~~The final exam will consist of a two sections.~~

~~Section 1: multiple choice concept questions. There may be a few concept questions on time and special relativity but no analytic questions.~~

~~Section 2: analytic problems with some concept questions requiring written responses. The analytic questions will be divided into part A covering the material since the third test. Part B will cover problems from the entire year. Examples of section 2 questions are given below. Test questions will not use numbers so you do not need a calculator.~~

Part A: Kinetic Theory, First Law of Thermodynamics, Heat Engines

Problem 1 *Energy Transformation, Specific Heat and Temperature*

Suppose a person of mass $m = 6.5 \times 10^1 \text{ kg}$ is running at a speed $v = 3.8 \text{ m/s}$ and is expending $9.45 \times 10^2 \text{ W}$ of power during a $1.0 \times 10^1 \text{ km}$ workout. Suppose the runner converts 20% of the internal energy change into mechanical work. The rest of the energy goes into heat. If the specific heat of the runner is $c = 4.19 \times 10^3 \text{ J/kg} \cdot \text{K}$, how much would the body temperature rise after running the 10 km ?

~~Problem 2 Kinetic Theory~~

~~An ideal gas has a density of 1.78 kg/m^3 is contained in a volume of $44.8 \times 10^{-3} \text{ m}^3$. The temperature of the gas is 273 K . The pressure of the gas is $1.01 \times 10^5 \text{ Pa}$. The gas constant $R = 8.31 \text{ J} \cdot \text{K}^{-1} \cdot \text{mole}^{-1}$.~~

- ~~a) What is the root mean square velocity of the air molecules?~~
- ~~b) How many moles of gas are present?~~
- ~~c) What is the gas?~~
- ~~d) What is the internal energy of the gas?~~

Study Guide Final Exam Solutions

Part A: Kinetic Theory, First Law of Thermodynamics, Heat Engines

Problem 1 *Energy Transformation, Specific Heat and Temperature*

Suppose a person of mass $m = 6.5 \times 10^2 \text{ kg}$ is running at a speed $v = 3.8 \text{ m/s}$ and has a catabolic power output (rate of internal energy consumption) $9.45 \times 10^2 \text{ W}$ during a $1.0 \times 10^1 \text{ km}$ workout. Suppose the runner converts 20% of the internal energy change into mechanical work. The rest of the energy goes into heat. If the specific heat of the runner is $c = 4.19 \times 10^3 \text{ J/kg} \cdot \text{K}$, how much would the body temperature rise after running the 10 km ?

The total energy generated by the runner is

$$\Delta U = P \Delta t$$

The runner runs for a time

$$\Delta t = \frac{d}{v} = \frac{1.0 \times 10^4 \text{ m}}{3.8 \text{ m/s}} = 2.6 \times 10^3 \text{ s}$$

The change of internal energy

$$\Delta U = P \Delta t = \frac{P d}{v} = (9.45 \times 10^2 \text{ W}) \frac{(1.0 \times 10^4 \text{ m})}{3.8 \text{ m/s}}$$

$$\Delta U = 2.49 \times 10^6 \text{ J}$$

Note if the runner is only 20% efficient then the mechanical power output

$$P_{\text{mech}} = \epsilon P_{\text{cat}} = (0.20)(9.45 \times 10^2 \text{ W}) \\ = 1.89 \times 10^2 \text{ W}$$

The change of internal energy

$$\Delta U = -W_{i \rightarrow f} + Q_{i \rightarrow f}$$

$$\frac{\Delta U}{\Delta t} = - \frac{W_{i,f}}{\Delta t} + \frac{Q_{i,f}}{\Delta t}$$

in
catabolic
rate
positive

=

mechanical
power
positive

+ power of
heat
generated

$$\frac{Q_{i,f}}{\Delta t} = \frac{\Delta U}{\Delta t} + \frac{W_{i,f}}{\Delta t} \\ = 9.45 \times 10^2 \text{ W} - 1.89 \times 10^2 \text{ W}$$

$$\frac{Q_{i,f}}{\Delta t} = m c \frac{\Delta T}{\Delta t}$$

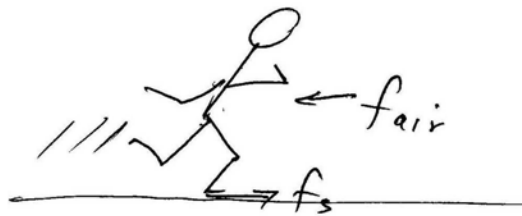
$$\Delta T = \frac{Q_{i,f}}{m c} = \frac{Q_{i,f} \Delta t}{m c} = \frac{Q_{i,f} d}{m c v}$$

$$= \frac{(7.56 \times 10^2 \text{ W})(1.0 \times 10^4 \text{ m})}{(6.5 \times 10^1 \text{ kg})(3.8 \text{ m/s})(4.19 \times 10^3 \text{ J/kg}\cdot\text{K})}$$

$$= 7.3^\circ \text{ K}$$

The average force of friction of the atmosphere

$$\vec{f}_{\text{air}} = -\vec{f}_s$$



Since $P_{\text{mech}} = f_s v$, the friction force is

$$f_s = \frac{P_{\text{mech}}}{v} = \frac{1.89 \times 10^2 \text{ W}}{3.8 \text{ m/s}} = 4.97 \times 10^1 \text{ N}$$