Activity ID: ____________ First Letter of Last Name: ☐

The University of British Columbia
Midterm 2 - November 14, 2012
Physics 153
Elements of Physics **TIME:** 60 minutes

CANDIDATE'S NAME: ________________________________
Last Name First Name or Initials

STUDENT NUMBER: ________________________________

SIGNATURE: ____________________

THIS EXAMINATION CONSISTS OF 5 PAGES. CHECK TO ENSURE THAT THIS PAPER IS COMPLETE.

INSTRUCTOR'S NAME/ SECTION NUMBER (circle one):

Don Witt Sec 001 MWF 9am	Sarah Burke Sec 002 MWF 1pm	Andrzej Kotlicki Sec 003 Tues/Thurs 2pm

Read and observe the following additional rules:

1. Each candidate must place on the desk their UBC card for identification.

2. No candidate shall be permitted to enter the examination room after the expiration of one-half hour, or leave during the first half-hour of the examination.

3. Candidates are not permitted to ask questions of the invigilators, except in cases of supposed errors or ambiguities in examination questions.

CAUTION: Candidates guilty of any of the following, or similar, dishonest practices shall be immediately dismissed from the examination and shall be liable to disciplinary action.

(a) Making use of any books, memoranda, calculators, **cell phones**, audio or visual players or other memory aid devices and electronics, other than authorized by the examiners.

(b) Speaking or communicating with other candidates.

Each Question is 10 points:

1 $\frac{\quad}{10}$ 2 $\frac{\quad}{10}$ 3 $\frac{\quad}{10}$

Total Mark out of 30. Total: $\frac{\quad}{30}$

Name: ______________________ Activity ID: ______________________

Problem 1. The picture below shows a fragment of the seismogram recorded in Old Harbor (Alaska) during the Earthquake near the Queen Charlotte Islands on October 28, 2012. Using this trace, determine the following quantities for this earthquake:

(a) Period of the oscillation.

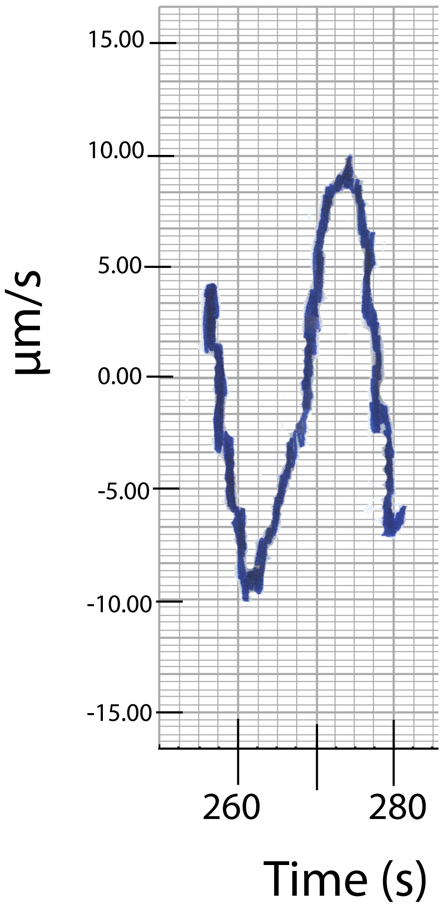
(b) Amplitude of the recorded movement of the seismograph sensor.

(c) Maximum velocity of the movement.

(d) Maximum acceleration of the movement.

(e) At what time was the maximum positive velocity observed?

(f) At what time was the maximum positive acceleration observed?



Name: ______________________ Activity ID: ______________________

Problem 2. You have been asked to design a combustion chamber based on adiabatic compression of a gas for graphitizing polymers to produce high tensile strength carbon fibre. For the particular process you are using you need to heat the polymer in air (mixture of mostly N_2 and O_2 gas) to a temperature of $1700°C$. The adiabatic compression chamber you are using to test the concept has an air inlet which opens to exchange the gas in the cylinder with the atmosphere ($20°C$ and 101kPa) when the piston is at the top of the cylinder where it has a volume of 0.500L (1L=0.001m^3).

(a) What compression ratio is needed to reach the necessary temperature for this process?

(b) Calculate the total work done *on the gas* in compressing it to reach the necessary temperature.

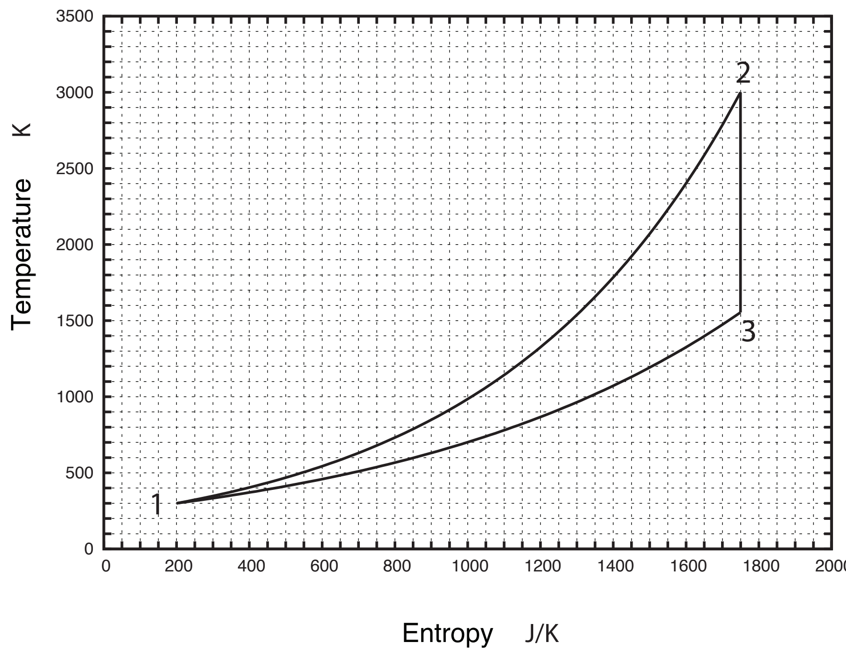
(c) Normally, the process is done by heating the polymer in air in a furnace. How much energy is required to reach the same temperature by heating at constant pressure assuming the same starting conditions and how does this compare with the adiabatic compression method described above?

(d) Since you want to scale up this process for industrial production, how does the energy required change with the volume of gas? Which process is better for large volumes or does it matter?

Name: ________________ Activity ID: ________________

Problem 3. A TS diagram for a Pulse Jet Engine using a diatomic ideal gas is shown below. This particular engine performs 100 cycles per second.

(a) Estimate to within 10% the heat added along each process, $Q_{1\to2}$, $Q_{2\to3}$, and $Q_{3\to1}$.



Using the estimates from (a) answer (b)-(d).

Note: In addition to providing numerical answers, express your answers and formulas in terms of $Q_{1\to2}$, $Q_{2\to3}$, $Q_{3\to1}$, and W_{cycle}.

(b) Find the work done in one cycle.

(c) Find the efficiency of this engine. Compare this efficiency to the Carnot cycle efficiency.

(d) Find the power produced by this engine.

Useful Constants

$R = 8.31451 J/\text{mol } K$, 1 atm $= 1.013 \times 10^5$Pa, 1 atm litre $= 101.3$ J

One can use 1 atm $\approx 1 \times 10^5$Pa and 1 atm litre ≈ 100 J. StefanBoltzmann constant $\sigma = 5.6704 \times 10^{-8} W\, m^{-2}\, K^{-4}$.

$\gamma_{air} = 1.4$, $C_{V\ air} = 20.8 J mol^{-1} K^{-1}$, The density of water is 1 gram/cm^3=1000 kg/m^3.

Mechanics

Linear Motion: $x = x_0 + \frac{1}{2}(v_{x_0} + v_x)t$, $x = x_0 + v_{x_0}t + \frac{1}{2}a_x t^2$, $v_x = v_{x_0} + a_x t$,
${v_x}^2 = {v_{x_0}}^2 + 2a_x(x - x_0)$

Circular Motion: $a_c = \frac{v^2}{r}$

Forces: $\vec{F} = m\vec{a}$, $\vec{F} = \frac{d}{dt}\vec{p}$, Friction: $F = \mu N$, Spring: $F = -kx$, Damping: $\vec{F} = -b\vec{v}$

Bouyant: $F_B = \rho V g$

$W = \int_{\vec{r}_i}^{\vec{r}_f} \vec{F} \cdot d\vec{r}$, $W = \vec{F} \cdot \Delta\vec{r}$, $K = \frac{1}{2}mv^2$, $\Delta U_{gravity} = mgy$, $\Delta U_{spring} = \frac{1}{2}kx^2$, $P = \frac{dW}{dt}$, $P = \vec{F} \cdot \vec{v}$.

Thermodynamics

Thermal Expansion: $\Delta L = \alpha L \Delta T$ Stress and Strain: $\frac{F}{A} = Y\frac{\Delta L}{L}$

Ideal Gas Law: $PV = nRT$, $K_{av} = \frac{3}{2}kT$, $\frac{1}{2}kT$ for each degree of freedom.

Thermal Conductivity: $I = \frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{\Delta x}$

Black Body Radiation: $P = e\sigma AT^4$, $\lambda_{max}T = 2.8977685 \times 10^{-3} m \cdot K$

Internal Energy: $U = nC_V T$

First Law: $dQ = dU + dW$ for an ideal gas $dW = PdV$.

Work for *isothermal process* $W = nRT\ln(V_f/V_i)$.

For *adiabatic expansion* $TV^{\gamma-1}$ = constant, if the number of moles is constant $PV^\gamma = C$ where C is a constant and $\gamma = C_p/C_v$.

Work for adiabatic process

$$W = \int_{V_1}^{V_2} PdV = C\int_{V_1}^{V_2} \frac{dV}{V^\gamma} = \frac{C}{1-\gamma}({V_2}^{1-\gamma} - {V_1}^{1-\gamma})$$

$Q = mc\Delta T$, $Q = mL$. $C_P = C_V + R$, $C_V = \frac{f}{2}R$ where f =degrees of freedom. $f = 3$ for monatomic and $f = 5$ for diatomic.

$dS = dQ/T$

$e = W/Q_H$ $\quad COP_{\text{Cooling}} = |Q_C|/|W|$ $\quad COP_{\text{Heating}} = |Q_H|/|W|$

$e_{\text{Carnot}} = 1 - T_C/T_H$

Integrals

$$\int x^n dx = \frac{x^{n+1}}{n+1} + \text{constant} \quad n \neq -1 \qquad \int x^{-1}dx = \ln x + \text{constant}$$

Trig

$$\sin\theta_1 + \sin\theta_2 = 2\cos(\frac{\theta_1 - \theta_2}{2})\sin(\frac{\theta_1 + \theta_2}{2})$$

Area and Volume Area of a sphere $A = 4\pi r^2$. Area of a cylinder $A = 2\pi rl$. Area of a circle $A = \pi r^2$. Volume of a cylinder $V = l\pi r^2$. Volume of a sphere $V = \frac{4}{3}\pi r^3$.

Oscillations

$\omega = 2\pi f$, $T = \frac{1}{f}$, $x = A\cos(\omega t + \phi)$, $\omega^2 = \frac{k}{m}$.

Damped Oscillations: $x = A_0 e^{-\frac{bt}{2m}}\cos(\omega t + \phi)$, where $\omega = \sqrt{{\omega_0}^2 - (\frac{b}{2m})^2}$, $Q = 2\pi\frac{E}{\Delta E}$.

Energy for damped $E = E_0 e^{-\frac{bt}{m}}$

Waves

$v = \sqrt{\frac{T}{\mu}}$, $k = \frac{2\pi}{\lambda}$, $v = \lambda f$, $P = \frac{1}{2}\mu\omega^2 A^2 v$, $\quad p_0 = \rho\omega v s_0$

$v = \sqrt{\frac{\gamma RT}{M}}$, $I = \frac{P_{av}}{4\pi r^2}$, $\beta = 10 dB \log_{10}(\frac{I}{I_0})$ Doppler Effect $f' = f_0 \frac{(1 \pm \frac{v_D}{v})}{(1 \mp \frac{v_S}{v})}$ Beats $\Delta f = f_2 - f_1$

$$y = A\cos(kx \mp \omega t + \phi)$$

Interference $k\Delta x + \Delta\phi = 2\pi n$ or $\pi(2n+1)$ $n = 0, \pm 1, \pm 2, \pm 3, \pm 4, \ldots$
Standing Waves $f_m = \frac{mv}{2L}$ $m = 1, 2, 3, \ldots$ $f_m = \frac{mv}{4L}$ $m = 1, 3, 5, \ldots$