Student number ____________________

First Name _________________________

Last Name _________________________

University of Ottawa
Department of Physics

Midterm 1
February 5, 2017

PHY1122 B and C Fundamentals of Physics II
Examiner: Prof. Adina Luican-Mayer

VERSION A

This is a closed book exam.
Time to finish the exam: 75min.
You are allowed a one-sided 8.5 X 11 inch sheet of hand-written notes.
You are also allowed a calculator.
At the back of the exam there is an appendix you might find helpful.
Answer all questions, worth a total of 100 points.
Write your solutions on this exam
GOOD LUCK!

PART 1 : MULTIPLE CHOICE 40 points
Please circle the correct answer for the questions below. Each question is worth 5 points.

Question 1 A rock is suspended by a light string. When the rock is in air the tension in the string is $T_1 = 41.9N$. When the rock is totally immersed in water, the tension is 25N. When the rock is totally immersed in an unknown liquid, the tension is 15.8N. What is the density of the unknown liquid? The density of water is 1000 kg/m^3.

(a)1581 g/m^3
(b)1544 kg/m^3
(c)534 kg/m^3
(d)2362 kg/m^3
(e)875 kg/m^2

Question 2 A barrel contains 0.155 m layer of oil floating on water that is 0.280m deep. The density of oil is $550 kg/m^3$. What is the gauge pressure at the interface and what is the gauge pressure at the bottom of the barrel? The density of water is 1000 kg/m^3. Use gravitational acceleration g=9.8 m/s^2.

(a) 655 Pa and 5650 Pa
(b) 655Pa and 2744 Pa
(c) 1560Pa and 3580 Pa
(d) 835 Pa and 2744 Pa
(e) 835 Pa and 3580 Pa

Question 3 Water flows through a cylindrical pipe of varying cross-section. The velocity is 3.0 m/s at a point where the pipe diameter is 1.0 cm. At a point where the pipe diameter is 3.0 cm, the velocity is:

(a) 9 m/s
(b) 3 m/s
(c) 1 m/s
(d) 0.33 m/s
(e) 0.11 m/s

Question 4 Helium gas is confined within a chamber that has a moveable piston. The mass of the piston is 8.7 kg; and its radius is 0.013 m. If the system is in equilibrium, what is the pressure exerted on the piston by the gas? Use gravitational acceleration g=9.8 m/s^2.

(a) 1.63×10^4 Pa
(b) 8.49×10^4 Pa
(c) 1.01×10^5 Pa
(d) 1.60×10^5 Pa
(e) 2.61×10^5 Pa

Question 5 How many moles are in a 1 kg bottle of water? The molar mass of water 18.0 g/mol.

(a) N_A mol
(b) 1 mol
(c) 55 mol
(d) 35 mol
(e) 100 mol

Question 6 What is the limiting low temperature of a physical object?

(a) there is no limiting low temperature
(b) 0 K
(c) 0° C
(d) 0° F
(e) -100° C

Question 7 A rod of length L is heated so that its temperature increases by ΔT. As a result, the length of the rod increases by ΔL. The rod is then cut into two pieces, one of length L/3 and one of length 2L/3. What is the ratio of the change in length of the rod of length 2L/3 to ΔL of the original rod when its temperature is increased by ΔT?

(a) 1/3
(b) 2/3
(c) 1
(d) 3/2
(e) 3

Question 8 A system undergoes an adiabatic process in which its internal energy increases by 20 J. Which of the following statements is true?

(a) 20 J of work was done on the system
(b) 20 J of work was done by the system
(c) the system received 20 J of energy as heat
(d) the system lost 20 J of energy as heat
(e) none of the above are true

PART 2 : SHOW FULL SOLUTIONS 60 points

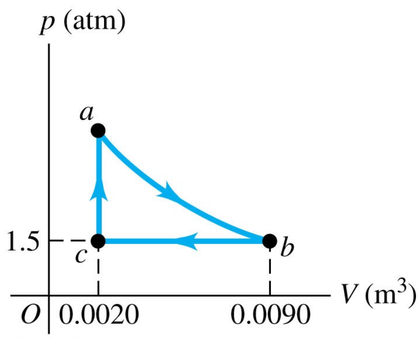
Please show your full solutions to the questions below.

Question 9 (20 points) An insulated Thermos contains 130 cm^3 of hot coffee at 80°C. You put in a 12g ice cube at its melting point in order to cool down the coffee. You wait until equilibrium is reached. By how many degrees has your coffee cooled down? Treat the coffee as if it were pure water. Neglect energy exchanges with the environment.

The specific heat of water is c_w=4190 J/kg·K. The heat of fusion for water is L_F= 334 J/g. The density of water is 1000 kg/m^3.

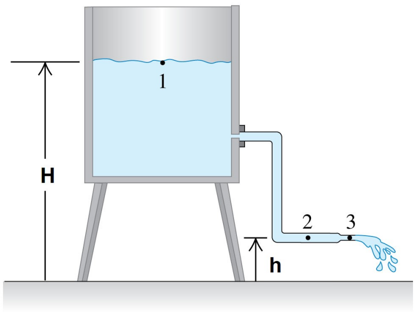
Question 10 (20 points) The p-V diagram in the figure below shows a cycle of a heat engine that uses 0.25mol of a diatomic ideal gas with γ=1.4. The process ab is adiabatic. For a diatomic ideal gas $C_V = \frac{5}{2}R$.

(a) (4 points) Find the pressure of the gas at point a.
(b) (4 points) How much hear *enters* this gas per cycle and where does it happen?
(c) (4 points) How much heat *leaves* this gas per cycle and where does it happen?
(d) (4 points) How much work does this engine do in a cycle?
(e) (4 points) What is the thermal efficiency of the cycle?



Question 11 (20 points) Water flows steadily from an open tank as shown in the figure below. The elevation at point i is H=10m and the elevation at points 2 and 3 is h=2m. The cross sectional area at point 2 is 0.0480 m^2. and at point 3 is 0.0160 m^2. The area of the tank is much larger than the cross sectional area of the pipe. Assume that Bernoulli's equation applies.

(a) (5 points) The discharge rate in cubic meters per second.
(b) (15 points) The *gauge pressure* at point 2.



Bonus Question (20 points) Evaporative cooling of beverages. A cold beverage can be kept cold even on a warm day if it is slipped into a porous ceramic container that has been soaked in water. Assume that energy lost to evaporation matches the net energy gained via the radiation exchange through the top and side surfaces. The container and beverage have temperature T = 15°C, the environment has temperature T_{env} = 32°C, and the container is a cylinder with radius r = 2.2 cm and height 10 cm. Approximate the emissivity as $\epsilon = 1$, and neglect other energy exchanges. At what rate dm/dt is the container losing water mass?

NUMERICAL CONSTANTS

Fundamental Physical Constants*

Name	Symbol	Value
Speed of light in vacuum	c	2.99792458×10^8 m/s
Magnitude of charge of electron	e	$1.602176565(35) \times 10^{-19}$ C
Gravitational constant	G	$6.67384(80) \times 10^{-11}$ N · m²/kg²
Planck's constant	h	$6.62606957(29) \times 10^{-34}$ J · s
Boltzmann constant	k	$1.3806488(13) \times 10^{-23}$ J/K
Avogadro's number	N_A	$6.02214129(27) \times 10^{23}$ molecules/mol
Gas constant	R	8.3144621(75) J/mol · K
Mass of electron	m_e	$9.10938291(40) \times 10^{-31}$ kg
Mass of proton	m_p	$1.672621777(74) \times 10^{-27}$ kg
Mass of neutron	m_n	$1.674927351(74) \times 10^{-27}$ kg
Magnetic constant	μ_0	$4\pi \times 10^{-7}$ Wb/A · m
Electric constant	$\epsilon_0 = 1/\mu_0 c^2$	$8.854187817\ldots \times 10^{-12}$ C²/N · m²
	$1/4\pi\epsilon_0$	$8.987551787\ldots \times 10^9$ N · m²/C²

Other Useful Constants*

Mechanical equivalent of heat		4.186 J/cal (15° calorie)
Standard atmospheric pressure	1 atm	1.01325×10^5 Pa
Absolute zero	0 K	−273.15°C
Electron volt	1 eV	$1.602176565(35) \times 10^{-19}$ J
Atomic mass unit	1 u	$1.660538921(73) \times 10^{-27}$ kg
Electron rest energy	$m_e c^2$	0.510998928(11) MeV
Volume of ideal gas (0°C and 1 atm)		22.413968(20) liter/mol
Acceleration due to gravity (standard)	g	9.80665 m/s²

*Source: National Institute of Standards and Technology (**http://physics.nist.gov/cuu**). Numbers in parentheses show the uncertainty in the final digits of the main number; for example, the number 1.6454(21) means 1.6454 ± 0.0021. Values shown without uncertainties are exact.

THE INTERNATIONAL SYSTEM OF UNITS

The Système International d'Unités, abbreviated SI, is the system developed by the General Conference on Weights and Measures and adopted by nearly all the industrial nations of the world. The following material is adapted from the National Institute of Standards and Technology (**http://physics.nist.gov/cuu**).

Quantity	Name of unit	Symbol	Equivalent units
	SI base units		
length	meter	m	
mass	kilogram	kg	
time	second	s	
electric current	ampere	A	
thermodynamic temperature	kelvin	K	
amount of substance	mole	mol	
luminous intensity	candela	cd	
	SI derived units		**Equivalent units**
area	square meter	m^2	
volume	cubic meter	m^3	
frequency	hertz	Hz	s^{-1}
mass density (density)	kilogram per cubic meter	kg/m^3	
speed, velocity	meter per second	m/s	
angular velocity	radian per second	rad/s	
acceleration	meter per second squared	m/s^2	
angular acceleration	radian per second squared	rad/s^2	
force	newton	N	$kg \cdot m/s^2$
pressure (mechanical stress)	pascal	Pa	N/m^2
kinematic viscosity	square meter per second	m^2/s	
dynamic viscosity	newton-second per square meter	$N \cdot s/m^2$	
work, energy, quantity of heat	joule	J	$N \cdot m$
power	watt	W	J/s
quantity of electricity	coulomb	C	$A \cdot s$
potential difference, electromotive force	volt	V	J/C, W/A
electric field strength	volt per meter	V/m	N/C
electrical resistance	ohm	Ω	V/A
capacitance	farad	F	$A \cdot s/V$
magnetic flux	weber	Wb	$V \cdot s$
inductance	henry	H	$V \cdot s/A$
magnetic flux density	tesla	T	Wb/m^2
magnetic field strength	ampere per meter	A/m	
magnetomotive force	ampere	A	
luminous flux	lumen	lm	$cd \cdot sr$
luminance	candela per square meter	cd/m^2	
illuminance	lux	lx	lm/m^2
wave number	1 per meter	m^{-1}	
entropy	joule per kelvin	J/K	
specific heat capacity	joule per kilogram-kelvin	$J/kg \cdot K$	
thermal conductivity	watt per meter-kelvin	$W/m \cdot K$	

Quantity	Name of unit	Symbol	Equivalent units
radiant intensity	watt per steradian	W/sr	
activity (of a radioactive source)	becquerel	Bq	s^{-1}
radiation dose	gray	Gy	J/kg
radiation dose equivalent	sievert	Sv	J/kg
	SI supplementary units		
plane angle	radian	rad	
solid angle	steradian	sr	

UNIT CONVERSION FACTORS

Length
1 m = 100 cm = 1000 mm = 10^6 μm = 10^9 nm
1 km = 1000 m = 0.6214 mi
1 m = 3.281 ft = 39.37 in.
1 cm = 0.3937 in.
1 in. = 2.540 cm
1 ft = 30.48 cm
1 yd = 91.44 cm
1 mi = 5280 ft = 1.609 km
1 Å = 10^{-10} m = 10^{-8} cm = 10^{-1} nm
1 nautical mile = 6080 ft
1 light-year = 9.461×10^{15} m

Area
1 cm^2 = 0.155 $in.^2$
1 m^2 = 10^4 cm^2 = 10.76 ft^2
1 $in.^2$ = 6.452 cm^2
1 ft^2 = 144 $in.^2$ = 0.0929 m^2

Volume
1 liter = 1000 cm^3 = 10^{-3} m^3 = 0.03531 ft^3 = 61.02 $in.^3$
1 ft^3 = 0.02832 m^3 = 28.32 liters = 7.477 gallons
1 gallon = 3.788 liters

Time
1 min = 60 s
1 h = 3600 s
1 d = 86,400 s
1 y = 365.24 d = 3.156×10^7 s

Angle
1 rad = 57.30° = 180°/π
1° = 0.01745 rad = π/180 rad
1 revolution = 360° = 2π rad
1 rev/min (rpm) = 0.1047 rad/s

Speed
1 m/s = 3.281 ft/s
1 ft/s = 0.3048 m/s
1 mi/min = 60 mi/h = 88 ft/s
1 km/h = 0.2778 m/s = 0.6214 mi/h
1 mi/h = 1.466 ft/s = 0.4470 m/s = 1.609 km/h
1 furlong/fortnight = 1.662×10^{-4} m/s

Acceleration
1 m/s^2 = 100 cm/s^2 = 3.281 ft/s^2
1 cm/s^2 = 0.01 m/s^2 = 0.03281 ft/s^2
1 ft/s^2 = 0.3048 m/s^2 = 30.48 cm/s^2
1 mi/h · s = 1.467 ft/s^2

Mass
1 kg = 10^3 g = 0.0685 slug
1 g = 6.85×10^{-5} slug
1 slug = 14.59 kg
1 u = 1.661×10^{-27} kg
1 kg has a weight of 2.205 lb when g = 9.80 m/s^2

Force
1 N = 10^5 dyn = 0.2248 lb
1 lb = 4.448 N = 4.448×10^5 dyn

Pressure
1 Pa = 1 N/m^2 = 1.450×10^{-4} $lb/in.^2$ = 0.0209 lb/ft^2
1 bar = 10^5 Pa
1 $lb/in.^2$ = 6895 Pa
1 lb/ft^2 = 47.88 Pa
1 atm = 1.013×10^5 Pa = 1.013 bar
= 14.7 $lb/in.^2$ = 2117 lb/ft^2
1 mm Hg = 1 torr = 133.3 Pa

Energy
1 J = 10^7 ergs = 0.239 cal
1 cal = 4.186 J (based on 15° calorie)
1 ft · lb = 1.356 J
1 Btu = 1055 J = 252 cal = 778 ft · lb
1 eV = 1.602×10^{-19} J
1 kWh = 3.600×10^6 J

Mass-Energy Equivalence
1 kg ↔ 8.988×10^{16} J
1 u ↔ 931.5 MeV
1 eV ↔ 1.074×10^{-9} u

Power
1 W = 1 J/s
1 hp = 746 W = 550 ft · lb/s
1 Btu/h = 0.293 W