Cover Type A

University of Technology, Sydney

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AUTUMN SEMESTER EXAMINATION, 2007
FACULTY OF SCIENCE

SUBJECT NAME: Foundations of Physics

SUBJECT NO.: 68101

DAY/DATE: Monday 25^{th} June, 2007

TIME ALLOWED: 3 hours + 10 minutes reading time

START/END TIME: 9:30 am – 12:40 pm

Instructions to Candidates:

This paper was designed to be completed in 3 hours. An extra 10 minutes have been added to the time allowed and it is recommended that you use these 10 minutes to read the paper before commencing to answer the questions.

THERE ARE 7 QUESTIONS IN THIS PAPER

ATTEMPT QUESTION 1 **AND** ANY OTHER FIVE (5) QUESTIONS

ANSWER EACH QUESTION IN A SEPARATE BOOKLET

CLEARLY MARK THE QUESTION NUMBER ON THE FRONT OF EACH BOOKLET

Calculators may be used. Any text or formulae stored in your calculator must have been removed before entering the examination room.

A *Physics Data Sheet* is provided on the next page.

Formula sheets and graph paper are provided at the end of the examination paper.

Physics Data Sheet

g	=	$9.81\ \text{m}\cdot\text{s}^{-2}$
σ	=	$5.670\times10^{-8}\ \text{W}\cdot\text{m}^{-2}\,\text{K}^{-4}$
R	=	$8.314\ \text{J}\cdot\text{mole}^{-1}\,\text{K}^{-1}$
N_A	=	6.022×10^{23} molecules$\cdot$mole^{-1}
k	=	$1.381\times10^{-23}\ \text{J}\cdot\text{K}^{-1}$ molecule^{-1}
c	=	$3.00\times10^{8}\ \text{m}\cdot\text{s}^{-1}$
h	=	$6.626\times10^{-34}\ \text{J}\cdot\text{s}$
I_0	=	$1.0\times10^{-12}\ \text{W}\cdot\text{m}^{-2}$
ε_0	=	$8.854\times10^{-12}\ \text{F}\cdot\text{m}^{-1}$
$\frac{1}{4\pi\varepsilon_0}$	=	$9\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$
μ_0	=	$4\pi\times10^{-7}\ \text{H}\cdot\text{m}^{-1}$
e	=	$1.602\times10^{-19}\ \text{C}$
m_e	=	$9.110\times10^{-31}\ \text{kg}$
	=	$0.00055\ \text{u}$
m_p	=	$1.673\times10^{-27}\ \text{kg}$
	=	$1.00728\ \text{u}$
m_n	=	$1.675\times10^{-27}\ \text{kg}$
	=	$1.00866\ \text{u}$
1u	=	$1.661\times10^{-27}\ \text{kg}$
G	=	$6.673\times10^{-11}\ \text{m}^2\,\text{N}\cdot\text{kg}^{-2}$
Rydberg's constant	=	$1.097\times10^{7}\ \text{m}^{-1}$
Temperature of Ice Point	=	273.15 K
1 atmosphere	=	$1.013\times10^{5}\ \text{Pa}$
Mass of Earth	=	$5.974\times10^{24}\ \text{kg}$
Radius of Earth	=	$6.37\times10^{6}\ \text{m}$
1 curie	=	3.70×10^{10} becquerel

SECTION A

THIS QUESTION IS COMPULSORY

(Answer this question in a separate booklet)

Question 1 (20 marks)

(a) i. If $a = (100 \pm 3)\,\text{m}^2$, $b = (50 \pm 1)\,\text{m}$ and $c = (4.0 \pm 0.2)\,\text{m}$, then the absolute uncertainty in $\frac{a}{b} - c$ is nearest to

A. 4.2 m

B. 1.7 m

C. 0.3 m

D. 0.1 m [1]

ii. Which one of the following principles best explains the ability of a hot air balloon to rise?

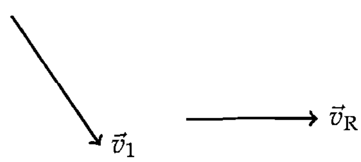
A. Pascal's principle

B. Bernoulli's principle

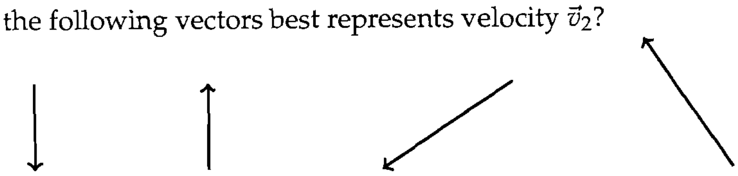
C. Archimedes' principle

D. Conservation of momentum principle [1]

iii. Velocities $\vec{v}_1$ and $\vec{v}_2$ add to produce the resultant velocity $\vec{v}_R$. The arrows below represent $\vec{v}_1$ and $\vec{v}_R$.



Which of the following vectors best represents velocity $\vec{v}_2$?



(1) (2) (3) (4)

A. 1

B. 2

C. 3

D. 4 [1]

iv. In the equation $pV = nRT$,

A. V is the velocity of the flowing gas.

B. R is the resistance of the system.

C. T is measured in degrees Celsius.

D. R has different values for different gases.

E. n is the number of moles of gas. [1]

Q1 continues on next page ...

v. Water flows in a horizontal pipe consisting of a narrow section and a wide section. Which one of the following statements is true?

A. Both the water speed and pressure are greater in the narrow section than in the wide section.

B. The water speed is greater and the pressure is less in the narrow section than in the wide section.

C. The water speed is less and the pressure is greater in the narrow section than in the wide section.

D. Both the water speed and the pressure are less in the narrow section than in the wide section.

E. The water speed is greater in the narrow section than in the wide section but the pressure is the same in both. [1]

vi. Consider the waves on a vibrating guitar string and the sound waves the guitar produces in the surrounding air. The string waves and the sound waves have the same

A. frequency.

B. wavelength.

C. velocity.

D. amplitude.

E. More than one of the above is true. [1]

vii. Which of the following is a FALSE statement?

A. Vibrational motion, as well as translational motion, can contribute to the heat capacities of gases.

B. Rotational motion, as well as translational motion, can contribute to the heat capacities of gases.

C. A dumbbell molecule like O_2 is considered to have eight degrees of freedom.

D. The average kinetic energy of a molecule moving in three dimensions is always $\frac{3kT}{2}$.

E. The average kinetic energy associated with each degree of freedom of a molecule is $\frac{1}{2}kT$. [1]

viii. Which of the following is a FALSE statement?

A. In a transverse wave the particle motion is perpendicular to the velocity vector of the wave.

B. Not all waves are mechanical in nature.

C. The speed of a wave and the speed of the vibrating particles that constitute the wave are different entities.

D. Waves transport energy and matter from one region to another.

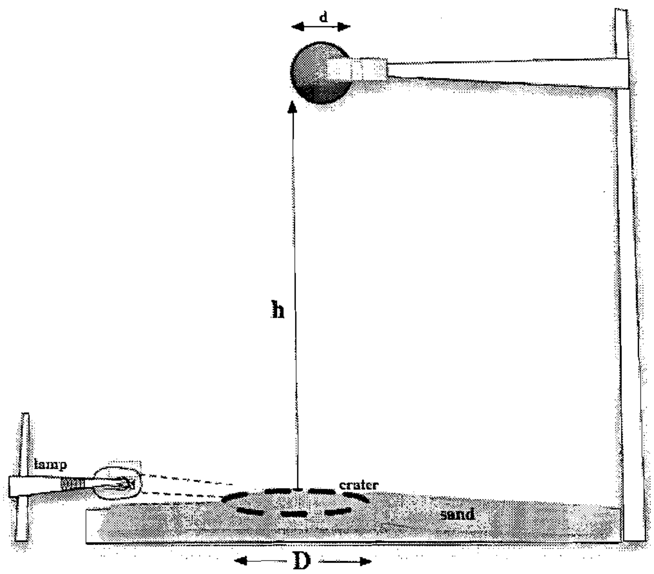
E. A wave in which particles move back and forth in the same direction as the wave is moving is called a longitudinal wave. [1]

Q1 continues on next page ...

(b) Researchers have proposed that the diameter of moon craters is related to the kinetic energy, E, of the impacting meteorites which caused them. Depending on the way it is assumed energy is dissipated in the crater after impact, theorists predict the relationship to be of the form

$$D = c\,E^n,$$

where c is a constant, and n is related to the nature of the impact.
To investigate this theory, some students take a series of measurements by dropping a ball bearing of mass 65 g and diameter $d = 15.0$ mm into a container of sand as in the diagram below. The lamp helps them to locate the crater edges.



They reason that in such a situation the kinetic energy at impact can be equated to the potential energy lost in falling through height h and that therefore they will be able to determine the energy, E, simply by measuring the height dropped and the mass of the ball bearing.
Knowing the difficulty of accurately measuring the craters formed and wanting to keep errors to a minimum, they drop the ball five times for each height and measure the corresponding diameters. Their results are tabulated below.

Reading	$h \pm 1$ mm	$D \pm 1$ mm				
1	100	59	60	57	60	58
2	220	69	70	68	71	67
3	314	72	74	75	73	75
4	450	81	81	79	80	80
5	680	86	85	88	86	87

Q1 continues on next page ...

i. Explain how the students can determine the kinetic energy, E, of the ball at impact, using the data in the table. [1]

On page 17 there is a blank table consisting of seven columns labelled (in order) "h", "E", "$D_{av.}$", "$\Delta D_{av.}$", "$\log E$", "$\log D_{av.}$", and "$\Delta(\log D_{av.})$". Tear off this page and use it to answer the next 3 parts.

ii. For each of the five heights, add the following to the appropriate columns of the table: [2]

α) the value of E

β) the average diameter, $D_{av.}$, of the craters

γ) the uncertainty, $\Delta D_{av.}$, in each average diameter.

iii. Calculate and add to your table the values of $\log E$ and $\log D_{av.}$ for each of the five heights. [1]

iv. Finally, add to your table the uncertainty $\Delta(\log D_{av.})$ for each of the five heights. [1]

v. Tear off the sheet of graph paper provided (page 15) and plot $\log D_{av.}$ versus $\log E$ on it. Include on your plot error bars for the $\log D_{av.}$ values, but not for the $\log E$ values. [4]

vi. By analysing the graph, determine the value of n. [2]

vii. Why is it reasonable to not plot error bars for the $\log E$ values? [1]

Write your name on both the table and graph sheets and place them inside your Q1 answer booklet.

Total Q1= 20

Question 2 (20 marks)

(a) It can be shown that the terminal velocity, v_t, of a sphere (s) falling through a fluid (f) is given by

$$v_t = \frac{2r^2 g(\rho_s - \rho_f)}{9\eta},$$

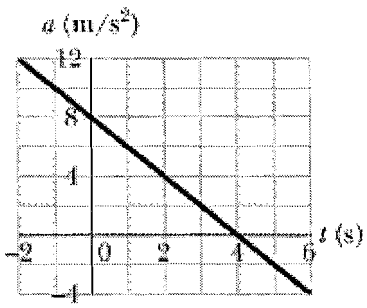
where r is the radius of the sphere, g is the acceleration due to gravity, ρ is the corresponding density, and η is the viscosity of the fluid.

i. Determine the *dimensions* of viscosity. [2]

ii. Hence determine the SI units of viscosity. [2]

(b) Light travels through space at 3.0×10^8 m/s. Express this speed in pm/μs (pico metres per micro second). [2]

(c) The plot below shows the acceleration a versus time t for a particle moving along the x-axis.



i. Write down an expression for a as a function of time. [2]

ii. Given that at $t = 2.0$ s the particle's velocity is 7.0 m/s, determine its velocity as a function of time. [2]

iii. Hence determine the particle's velocity when $t = 5.0$ s. [2]

(d) It is a rainy day. Against your better judgement, you round a bend on a country road at 115 km/h. Emerging from the bend at time $t = 0$ and position $x = 0$, you are horrified to see that a truck has entered onto the road from a side street 50.0 m ahead, moving at only 30.0 km/h.

i. To avoid a rear-end collision, what must be your speed, v_0, at the instant when you reach the truck? [1]

ii. In the poor driving conditions, your car brakes allow you to slow down at a constant rate of no more than 6.5 m/s^2. What distance will you have travelled by the time your speed has reduced to v_0? [2]

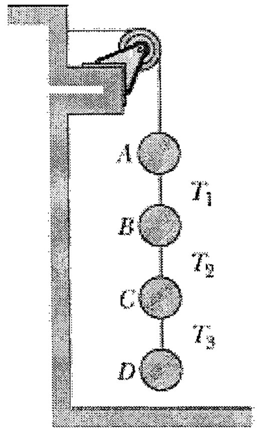
iii. How long does it take to reach this speed? [2]

iv. Do you collide with the truck? If "yes", how far from your starting position (i.e. from $x = 0$) is the collision? If "no", what is your distance of closest approach to the truck? [3]

Total Q2= 20

Question 3 (20 marks)

(a) The diagram below shows an arrangement in which four disks are suspended by light, inextensible strings. The top string loops over a frictionless pulley and pulls with a force of magnitude 98 N on the wall to which it is attached. The tensions in the shorter strings are $T_1 = 58.8\,\text{N}$, $T_2 = 49.0\,\text{N}$, and $T_3 = 9.8\,\text{N}$.



Determine the masses of each of the four disks. [6]

(b) The coefficient of static friction between a certain titanium/ceramic alloy and scrambled eggs is about 0.025. Through what minimum angle from the horizontal must such an alloy-coated frying pan be tilted to cause the eggs to slide across it? [4]

(c) i. Using the concept of *impulse*, briefly explain how the landing mat works in avoiding injury during high-jump competitions. [1]

ii. An average resistive force of 8.0 N acts for 0.50 s on a 6.0 kg object initially moving at 5.0 m/s.

α) What impulse does the object experience? [2]

β) What is its speed after 0.50 s? [1]

iii. A floating block of ice is pushed through a displacement $\vec{d} = (15\,\hat{\imath} - 12\,\hat{\jmath})\,\text{m}$ along a straight embankment by rushing water, which exerts a force $\vec{F} = (210\,\hat{\imath} - 150\,\hat{\jmath})\,\text{N}$ on the block.
How much work does the force do on the block during this displacement? [2]

(d) An 80 kg rider on a Ferris wheel goes around in a vertical circle of radius 10 m at a constant speed of 6.3 m/s.

i. What is the period of the motion? [1]

What is the magnitude of the normal force on the rider *from the seat* when both go through:

ii. the highest point of the circular path, and [2]

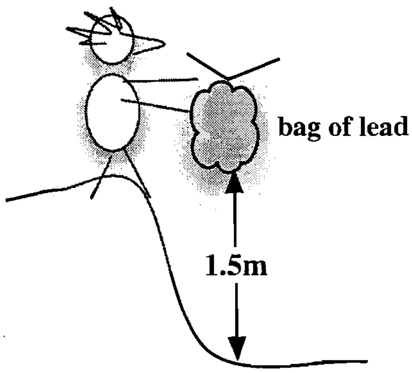
iii. the lowest point. [1]

Total Q3= 20

Question 4 (20 marks)

(a) A circular hole in an aluminum plate is 2.254 cm in diameter at 0.000°C.
Given that the linear expansion coefficient of aluminum is $23 \times 10^{-6}/°C$, what is the area of the hole when the temperature of the plate is raised to 133.1°C? Give your answer to four significant figures. [4]

(b) A primitive demonstration of the mechanical equivalent of heat consists of repeatedly dropping a bag of lead shot from a given height and measuring the temperature change in the bag after a number of drops.



Given that the heat capacity of lead is 128 J/(kg·K), how many times would the bag have to be dropped from a height of 1.5 m to change its temperature by 2.0°C. All heat flow *from* the lead can be ignored. [5]

(c) Ice has formed on a shallow pond, and a steady state has been reached, with the air above the ice at −8.1°C and the bottom of the pond at 3.8°C.
If the total depth of ice + water is 1.5 m, how thick is the ice? [6]

$$k_{\text{ice}} = 2.18\,\text{W}/(\text{m}\cdot\text{K})$$
$$k_{\text{water}} = 0.58\,\text{W}/(\text{m}\cdot\text{K})$$

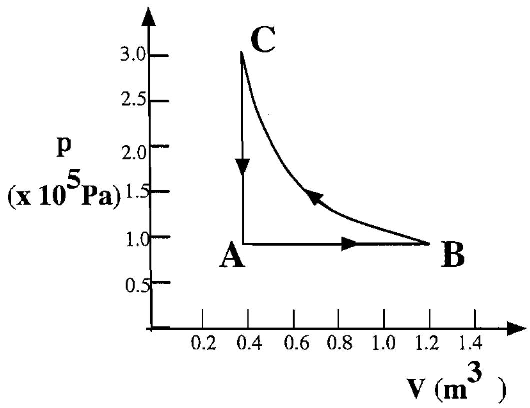
(d) The emissivity of tungsten is 0.35. A tungsten sphere with radius 1.50 cm is suspended within a large evacuated enclosure whose walls are at 290 K.
What power input is required to maintain the sphere at a temperature of 3000 K if heat conduction along the supports is neglected? [5]

Total Q4= 20

Question 5 (20 marks)

(a) List three assumptions of ideal gas behaviour. [3]

(b) The following p-V diagram shows a cyclic process $ABCD$ of a gas system consisting of pure oxygen ($\mathrm{M} = 32$). At A the temperature of the gas is 300 K.



i. Show that the process from B to C is isothermal. [1]

ii. At what temperature is the system when in the BC part of the cycle? [1]

iii. How many moles of gas are involved in the cyclic process as represented? [2]

iv. What is the likely average velocity of the molecules in the gas during part BC of the cycle? [2]

(c) A cork floating on a lake moves in simple harmonic motion, bobbing up and down over a range of 4 cm. The period of the motion is $T = 1.35$ s.

If a clock is started at $t = 0$ s when the cork is at its lowest position, determine at $t = 11.75$ s its:

i. height [1]

ii. velocity [2]

iii. acceleration. [2]

(d) A man standing at the narrow entrance to a harbour observes sinusoidal water waves moving into the harbour. In one minute he counts 50 wave crests passing him and, using the length of an anchored boat whose size he knows, he estimates the distance between the crests to be 3.0 m.

For these waves, determine the

i. wavelength [1]

ii. wavenumber [1]

iii. frequency

iv. angular frequency [1]

v. speed [1]

Using these values and estimating an amplitude of 300 mm,

vi. write an expression for the form of the wave height at the position where the person is standing. [1]

Total Q5= 20

Question 6 (20 marks)

(a) The howler monkey is the loudest land animal and can be heard up to a distance of 1.4 km.

Assuming the acoustic output of a howler to be uniform in all directions, determine the distance at which the intensity level of a howler's call is 49 dB. [5]

(b) An organ pipe which is closed at one end and open at the other end has a length of 4.0 m. Assume the speed of sound in air is 320 m/s.

i. Sketch the formation of a standing wave in such an organ pipe and indicate whether the diagram you have drawn is for the fundamental frequency of the pipe or a higher order harmonic. [2]

ii. Determine the fundamental frequency for the pipe. [1]

iii. Determine the frequency for the 1st overtone in the pipe. [1]

iv. Which harmonic is equivalent to the 2nd overtone? [1]

(c) i. State Snell's Law, including a labelled diagram to identify the terms used. [1]

ii. Using Snell's Law, explain the concept of *Total Internal Reflection*. [2]

iii. Why is total internal reflection important in the field of *fibre optics*? [1]

(d) A thin biconvex lens forms an image of a distant mountain at a position 250 mm from the lens.

i. What is the focal length of the lens? [1]

A pine cone is place 100 cm from the lens.

ii. Describe the resulting image i.e. its magnification, location and whether it is real or virtual, erect or inverted. [3]

The original lens is made of crown glass ($n = 1.5$). A second lens of identical dimensions is made of flint glass ($n = 1.6$).

iii. At what distance will this lens form an image of the distant mountain? [2]

Total Q6= 20

Question 7 (20 marks)

(a) A steel rod has a radius $R = 7.8\,\text{mm}$ and length $L = 83\,\text{cm}$. A force $\vec{F} = 65\,\text{kN}$ stretches the rod along its length. Given that Young's modulus for steel is $E = 2 \times 10^{11}\,\text{N/m}^2$ and its ultimate strength is $S = 4 \times 10^{11}\,\text{N/m}^2$, determine for the rod:

i. its stress [2]

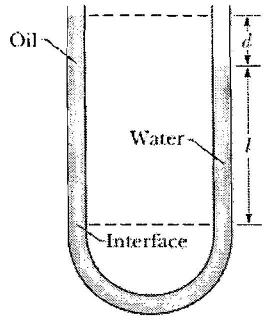
ii. the elongation produced [1]

iii. the strain [1]

iv. the maximum load it can support. [1]

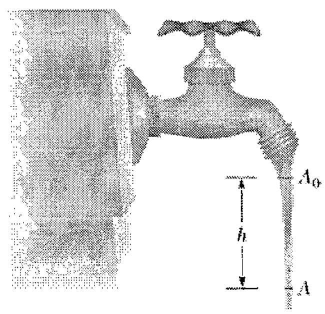
(b) The U-tube shown below contains two liquids in static equilibrium: water of density $\rho_{\text{water}} = 1000\,\text{kg/m}^3$ in the right arm, and oil of unknown density ρ in the left. It is found that $l = 135\,\text{mm}$ and $d = 12.3\,\text{mm}$.

Determine the density of the oil.



[5]

(c) The stream of water emerging from a tap becomes narrower as it falls.



The indicated cross-sectional areas are $A_0 = 1.2\,\text{cm}^2$ and $A = 0.35\,\text{cm}^2$. The two levels are separated by a vertical distance $h = 45\,\text{mm}$.

Calculate the volume flow rate from the tap. [5]

(d) Ethanol of density $\rho = 791\,\text{kg/m}^3$ flows smoothly through a horizontal pipe that tapers in cross-sectional area from $A_1 = 1.20 \times 10^{-3}\,\text{m}^2$ to $A_2 = \frac{1}{2}A_1$. The pressure difference between the wide and narrow sections of pipe is 4 200 Pa.

Calculate the volume flow rate of the ethanol. [5]

Total Q7= 20

Mechanics Equation Sheet

$$\sum F_x = 0$$
$$\sum F_y = 0$$
$$\sum M = 0$$
$$F = ma$$
$$F = \mu N$$
$$F = -ks$$
$$W = Fs$$
$$W = \int \mathbf{F} \cdot d\mathbf{s}$$
$$P = Fv$$
$$KE = \tfrac{1}{2}mv^2$$
$$p = mv$$
$$J = Ft$$
$$J = \int F dt$$

$$\mathbf{v}_{ac} = \mathbf{v}_{ab} + \mathbf{v}_{bc}$$
$$s = ut + \tfrac{1}{2}at^2$$
$$v = u + at$$
$$v^2 = u^2 + 2as$$
$$c^2 = a^2 + b^2 - 2ab\cos C$$
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$
$$W = -\tfrac{1}{2}ks^2$$
$$I = Mk^2$$
$$I_d = I_c + md^2$$
$$\overline{x} = \frac{\sum m_i x_i}{\sum m_i}$$
$$J_\theta = \int T dt$$

$$\theta = \omega_0 t + \tfrac{1}{2}\alpha t^2$$
$$\omega = \omega_0 + \alpha t$$
$$\omega^2 = \omega_0^2 + 2\alpha\theta$$
$$s = R\theta$$
$$v = R\omega$$
$$a_t = R\alpha$$
$$a_n = \frac{v^2}{R} = \omega^2 R$$
$$\vec{T} = \vec{r} \times \vec{F} \qquad \vec{v} = \vec{\omega} \times \vec{r}$$

Solid cylinder/Disk $I_C = \frac{1}{2}MR^2$

Hollow cylinder $I_C = \frac{1}{2}M(R^2 + r^2)$

Sphere $I_C = \frac{2}{5}MR^2$

Rod $I_C = \frac{1}{12}Ml^2$

$$L = I\omega \qquad L = mvr$$
$$T = I\alpha$$
$$W = T\theta$$
$$KE = \tfrac{1}{2}I\omega^2$$
$$P = T\omega$$

Thermal Equation Sheet

$$\Delta l = l_0 \alpha \Delta T \qquad \Delta V = V_0 \beta \Delta T$$

$$Q = mc\Delta T \qquad Q = nC\Delta T \qquad Q = mL$$

$$H = \frac{dQ}{dt} = -kA\frac{dT}{dx} \qquad H = \frac{dQ}{dt} = e\sigma A\left(T^4 - T_0^4\right) \qquad \frac{dQ}{dt} = \frac{\Delta T}{R}$$

$$R = \frac{L}{k} \qquad T(t) = T_e + (T_0 - T_e)\mathbf{e}^{-\frac{kA}{mc}t} \qquad N = nN_A$$

$$PV = nRT \qquad PV = NkT \qquad PV^\gamma = \text{const.} \qquad n = \frac{m}{M}$$

$$PV = \frac{Nm\overline{v^2}}{3} \qquad \tfrac{1}{2}m\overline{v^2} = \tfrac{3}{2}kT \qquad H = -qA(T - T_S)$$

$$C_p - C_v = R \qquad C_v = \begin{cases} \tfrac{3}{2}R & \text{(mono-)} \\ \tfrac{5}{2}R & \text{(di-)} \\ \tfrac{6}{2}R & \text{(poly-)} \end{cases} \qquad \gamma = \frac{C_p}{C_v}$$

$$Q = W + \Delta U \qquad \Delta U = nC_v\Delta T \qquad W = P\left(V_f - V_i\right)$$

$$W = \frac{P_iV_i - P_fV_f}{\gamma - 1} \qquad W = nRT\ln\left(\frac{V_f}{V_i}\right) \qquad W = nC_v\left(T_f - T_i\right)$$

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2} \qquad e = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1} \qquad \text{C.O.P.} = \frac{Q}{W} = \frac{T_2}{T_1 - T_2}$$

$$dS = \frac{dQ}{T} \qquad T_iV_i^{\gamma-1} = T_fV_f^{\gamma-1}$$

Waves / Optics Equation Sheet

$F = -kx$

$T = 2\pi\sqrt{\frac{l}{g}}$

$\omega^2 = \frac{k}{m}$

$U = \frac{1}{2}kx^2$

$x = A\sin(\omega t + \alpha)$

$y = A\sin(kx - \omega t + \phi)$

$y = 2A\sin kx \cos\omega t$

$c = f\lambda$

$c = \sqrt{\frac{F}{\mu}}$

$n_1 \sin i = n_2 \sin r$

$n_1 c_1 = n_2 c_2$

$d_a = \frac{d}{n}$

$\mathrm{P} = 2\pi^2 A^2 f^2 \mu c$

$I = 2\pi^2 A^2 f^2 \rho c$

$c = \sqrt{\frac{\gamma P}{\rho}}$

$\beta = 10\log_{10}\left(\frac{I}{I_0}\right)$

$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$

$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$m = -\frac{i}{o}$

$d\sin\theta = m\lambda$

$a\sin\theta = m\lambda$

$a\sin\theta = 1.22\lambda$

$m_l = \frac{250}{f} + 1$

$\alpha = \frac{\pi a \sin\theta}{\lambda}$

$\beta = \frac{\pi d \sin\theta}{\lambda}$

$I = \frac{I_{\mathrm{max}} \sin^2\alpha \cos^2\beta}{\alpha^2}$

$I = I_0 \cos^2\theta$

$m_\theta = \frac{f_{\mathrm{o}}}{f_{\mathrm{e}}}$

$\mathrm{R} = \frac{\lambda}{\Delta\lambda} = mN$

$\mathrm{D} = \frac{d\theta}{d\lambda}$

$$\sin A + \sin B = 2\sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)$$

Properties of Matter / Fluids Equation Sheet

$$Y = \frac{F/A}{\Delta l / l_0} \qquad B = \frac{-\Delta p}{\Delta V / V_0} \qquad S = \frac{F/A}{d/y} \qquad \sigma = \frac{-\Delta b / b_0}{\Delta l / l_0}$$

$$p = p_0 + \rho g h \qquad p + \tfrac{1}{2}\rho v^2 + \rho g y = \text{const.} \qquad v = \sqrt{2gh}$$

$$\gamma = \frac{F}{l} = \frac{W}{\Delta A} \qquad h = \frac{2\gamma \cos\theta}{\rho g R} \qquad \Delta p = \frac{2\gamma}{R} \text{ or } \frac{4\gamma}{R}$$

$$Q = Av = \text{ const.} \qquad Q = \frac{\pi R^4 \Delta p}{8\eta l} \qquad v_1^2 = \frac{2(p_1 - p_2)}{\rho\left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}$$

$$\eta = \frac{F/A}{\Delta v / \Delta y} \qquad F = 6\pi\eta R v$$

$$N_R = \frac{\rho v D}{\eta} \qquad v_t = \frac{2r^2 g(\rho_s - \rho_f)}{9\eta}$$

Family name: ____________________

Other names: ____________________

Student ID: ____________________

Tear off this sheet and use it for the graph required in Q1. Use the grid on the reverse of this page if you need a second sheet.

Tear off this page and use it to complete Q1(b).

Family name: ______________________

Other names: ______________________

Student ID: ______________________

h (m)	E (J)	$D_{av.}$ (m)	$\Delta D_{av.}$ (m)	$\log E$	$\log D_{av.}$	$\Delta(\log D_{av.})$
0.100						
0.220						
0.314						
0.450						
0.680						

<u>END OF EXAMINATION PAPER</u>