Cover Type A

University of Technology, Sydney

THIS PAPER MAY BE REMOVED FROM THE EXAMINATION CENTRE

AUTUMN SEMESTER EXAMINATION, 2008
FACULTY OF SCIENCE

SUBJECT NAME: Foundations of Physics

SUBJECT NO.: 68101

DAY/DATE: Wednesday 11th June, 2008

TIME ALLOWED: 3 hours + 10 minutes reading time

START/END TIME: 6:00 pm – 9:10 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 this time 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.

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_B	=	$1.381\times10^{-23}\ \text{J}\cdot\text{K}^{-1}$ 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	=	1.013×10^{5} Pa
Mass of Earth	=	5.974×10^{24} kg
Radius of Earth	=	6.37×10^{6} m
1 curie	=	3.70×10^{10} becquerel

SECTION A

THIS QUESTION IS COMPULSORY

Answer this question in a separate booklet.

Do not write your answers on this question paper!

Question 1 (20 marks)

(a) i. The apparent colours seen in an oil slick are caused by

A. interference between light reflected from the top and bottom of the oil slick

B. a different refractive index for the top and bottom of the oil slick

C. a special property of the oil, which turns white light into colours

D. None of the above.

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

ii. The image produced by a convex lens

A. is always larger than the object

B. is imaginary and inverted if the object distance is less than the focal length of the lens.

C. is always real

D. is always inverted

E. is real and inverted if the object distance is greater than the focal length of the lens. [1]

iii. A helium-filled balloon is placed in a freezer. Which of the following is likely?

A. The volume of the balloon will increase.

B. The volume of the balloon will decrease.

C. The volume of the balloon will not be affected.

D. There is insufficient information to answer this question. [1]

iv. A circular metal plate of radius R has a hole of radius r at the centre. When the plate is heated

A. Both R and r will increase

B. R will increase and r will decrease

C. R will decrease and r will increase

D. Both R and r will decrease

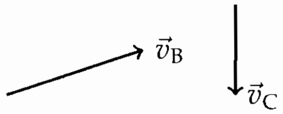
E. The increase/decrease of R and r are unrelated. [1]

v. If $a = (10.0 \pm 0.3)$, $b = (50 \pm 1)$ and $c = (4.0 \pm 0.2)$, then the absolute uncertainty in $\frac{b}{a}\sqrt{c}$ is

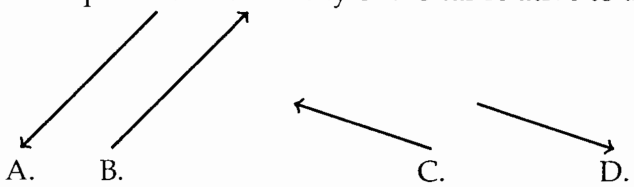
A. 7.5 B. 3.3 C. 1.5 D. 1.0 E. 0.75 [1]

Q1 continues on next page ...

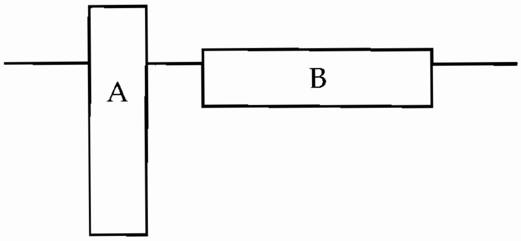
vi. Vectors $\vec{v}_B$ and $\vec{v}_C$ shown below represent the velocities of a bus and car (respectively), relative to the ground.



Which arrow below represents the velocity of the car relative to the bus, $\vec{v}_{CB}$? [1]



vii. Two identical blocks of ice float in water as shown below (not to scale).



Which one of the following statements is true?

A. Block A displaces a greater volume of water since the pressure acts on a smaller bottom area.

B. Block B displaces a greater volume of water since the pressure is less on its bottom.

C. The two blocks displace equal volumes of water since they have the same weight.

D. Block A displaces a greater volume of water since its submerged end is lower in the water

E. Block B displaces a greater volume of water since its submerged end has a greater area. [1]

viii. Two projectiles are in flight at the same time near the Earth's surface. The acceleration of one relative to the other

A. is always $9.8\ \text{m/s}^2$

B. can be as large as $19.6\ \text{m/s}^2$

C. can be horizontal

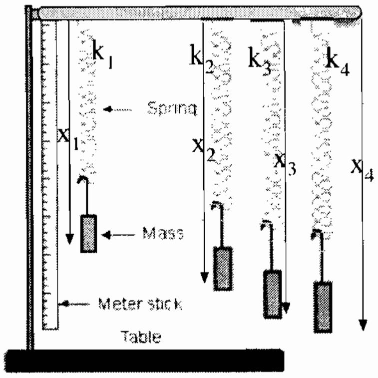
D. is zero

E. is none of these. [1]

(b) Students are given a large number of springs, some of which have their stiffness factor (i.e. spring constant, k) stamped on them.
Hooke's Law tells them that

$$F = kx,$$

so they decide to apply the same load, F, to all the springs and measure the corresponding extensions, x (see diagram on following page). From this they plan to use graphical methods to check that the springs obey Hooke's Law.



To do this, they rearrange the equation so that their expected plot will be LINEAR. They will then use the plot as a calibration curve to test any unknown spring.

Three measurements of extension are taken for each of 7 (known) springs. The results are tabulated below.

Reading	$k \pm 0.2$ N/m	$x \pm 0.1$ cm		
1	10.6	49.1	51.9	50.9
2	13.3	38.3	36.1	36.8
3	17.8	27.5	29.2	30.9
4	20.2	22.3	23.8	26.2
5	32.4	16.7	14.2	15.7
6	36.0	14.2	12.5	15.3
7	45.0	11.1	12.2	11.8

i. Rearrange the equation to show how the students could plot the data to produce a linear graph. [1]

ii. Determine for each spring

  α) the average value of x [1]

  β) the uncertainty in x [1]

iii. Calculate the appropriate functions of k and/or x as required in (i). [1]

iv. Calculate the error bars in 1 only of the data points (because of time considerations). [1]

v. Tear off the sheet of graph paper provided at the end of this examination paper (15), and on it plot the data as you have determined in (i). [4]

vi. EITHER

  α) By analysing the graph determine the value of F, including an estimate of its uncertainty.

  OR

  β) Use the graph as a calibration curve to determine the k value for an unlabelled spring which produces an extension of 22.4 ± 0.2 cm.

[2]

vii. Summarize the findings of the experiment. [1]

(Remember to write your name on the graph paper and to insert it into your answer booklet.)

Total Q1= 20

Question 2 (20 marks)

(a) The height h of a fluid that can be sustained in a capillary tube of radius R is given by the equation

$$h = \frac{2\gamma \cos\theta}{\rho g R},$$

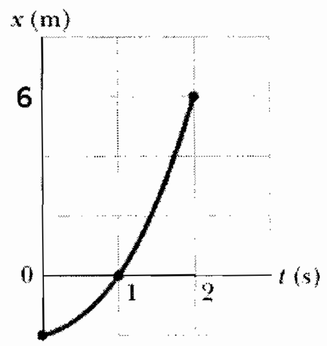
where ρ is the density of the fluid, γ is its surface tension, g is the acceleration due to gravity, and θ is the 'angle of contact' (measured in radians).

i. Determine the *dimensions* of surface tension from this equation. [3]

ii. Hence, or otherwise, express the units of surface tension in terms (only) of the SI units of force and length. [1]

(b) The *zoll* is a Swiss unit of length, with 1 zoll = 0.030 meter.
Use this information to convert the speed of sound (344 m/s) to microzolls per picosecond. [3]

(c) The plot below depicts the motion of a particle moving along the x-axis with a constant acceleration.



Determine the magnitude and direction of the particle's acceleration. [6]

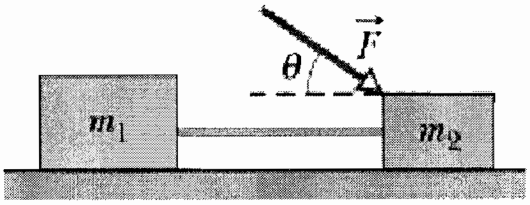
(d) Two pebbles are dropped 1.0 s apart from rest from the top of a 100 m cliff.
How long after the second pebble begins to fall will the two pebbles be 10.0 m apart? [7]

Total Q2= 20

Question 3 (20 marks)

(a) The tension at which a fishing line snaps is commonly called the line's *strength*. What minimum strength is needed for a line (pulling horizontally) that is to stop a salmon of weight 85 N in 11 cm if the fish is initially drifting horizontally at 2.8 m/s away from the fisherman? Assume a constant deceleration. [4]

(b) In the figure below, block 1 has mass $m_1 = 2.5\,\text{kg}$ and block 2 has mass $m_2 = 1.0\,\text{kg}$. The two blocks are connected by a string of negligible mass. Block 2 is pushed by a force $\vec{F} = 20\,\text{N}$ directed at $\theta = 30°$ to the horizontal as shown.



If the coefficient of kinetic friction between each block and the horizontal surface is 0.20, determine

i. the acceleration of the blocks [4]

ii. the tension in the string. [1]

(c) A force in the negative direction of the x-axis is applied for 30 ms to a 0.75 kg ball initially moving at 14 m/s in the positive direction of the axis. The force varies in magnitude, and the impulse has magnitude 32.4 N·s.

i. What is the ball's speed and direction of travel just after the impulse? [2]

ii. What is the average magnitude of the force on the ball during the impulse? [2]

(d) The *London Eye* is a giant Ferris wheel of diameter 122 m. It takes 30 minutes to complete one revolution in a vertical circle.

i. Passengers enter its 25-seat capacity cabins while the wheel is rotating. Calculate the linear speed of each cabin while passengers are getting in/out? [1]

ii. Calculate the *normal* (i.e. perpendicular) force on a 65 kg rider from the seat when both go through the highest point on the circular path. **Hint:**— draw a free-body diagram. [4]

iii. At what rotation period would London Eye passengers experience the sensation of weightlessness at the top of the ride? [2]

Total Q3= 20

Question 4 (20 marks)

(a) The concrete sections of a certain superhighway are designed to have a length of 25 m. The sections are poured and cured at 10°C. What minimum spacing should the engineer leave *between the sections* to eliminate buckling (warping) if the concrete is to reach a temperature of 50°C? The linear expansion coefficient of concrete is $12 \times 10^{-6}/°C$. [4]

(b) The walls of precast concrete passive solar homes are made from concrete panels and save energy by taking advantage of the sun and wind for heating and cooling. They moderate indoor temperatures in the winter by capturing solar energy during the daytime, storing it, and slowly releasing it; they moderate temperature in the summer by blocking sunlight and cooling down at night through ventilation.
A solar home contains 10^5 kg of concrete (specific heat = 1.02 kJ/(kg·K)).

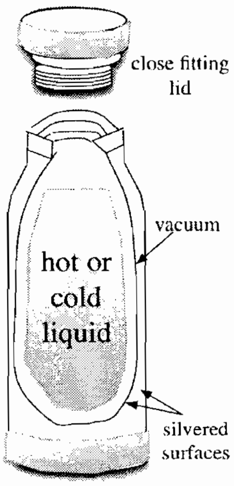
  i. How much heat is given off by the concrete when it cools from 25° C to 20° C? [3]

  ii. If there was a process which was 20% efficient in changing the thermal energy into electrical energy, how many 15 W light bulbs could be run from 6 pm to midnight using this energy? [4]

(c) A bar of gold is in thermal contact with a bar of silver of the same length and cross-sectional area. The gold end of the compound bar is maintained at 80°C while the opposite end is at 30°C. Find the temperature at the junction when the heat flow reaches a steady state . [5]

$$k_{\text{gold}} = 314\,\text{W}/(\text{m}\cdot\text{K})$$
$$k_{\text{silver}} = 427\,\text{W}/(\text{m}\cdot\text{K})$$

(d) A Dewar flask is a container designed to minimize heat losses. The diagram shows the main features of such a flask.



Describe the three ways in which heat is transferred and suggest why the features of the flask (e.g. silvered surface, vacuum,etc.) might minimise heat losses from fluids contained in the flask. [4]

Total Q4= 20

Question 5 (20 marks)

(a) Nitrogen molecules have an rms speed of 517 m/s at 300 K. What is their rms speed at 600 K? [2]

(b) i. State the *Ideal Gas Equation*, defining any symbols used. [1]

ii. Use the ideal gas law to calculate the volume occupied by 1 mole of ideal gas at 1 atm pressure and 0 °C. [2]

iii. Given that the average molecular weight of air is 28.9 g/mole, calculate the mass density of air, in kg/m^3 at the above conditions. [2]

iv. Under what state conditions is a real gas most like to behave like an ideal gas? [2]

(c) A particle undergoing simple harmonic motion travels a total distance of 6.98 cm during one cycle of 1.71 s.

i. What is the average velocity of the particle? [1]

ii. What is the maximum speed of the particle? [1]

iii. What is the maximum acceleration of the particle? [1]

iv. On a displacement-time graph of the motion indicate at which points in the motion the particle reaches its

α) maximum speed [1]

β) maximum acceleration. [1]

(d) A certain wave is described by the equation

$$y = 0.40(\text{m}) \sin \left[3.0(\text{m}^{-1})x + 2.0(\text{s}^{-1})t\right].$$

Determine for this wave the:

i. wavelength [1]

ii. frequency [1]

iii. maximum amplitude [1]

iv. period [1]

v. angular frequency [1]

vi. speed [1]

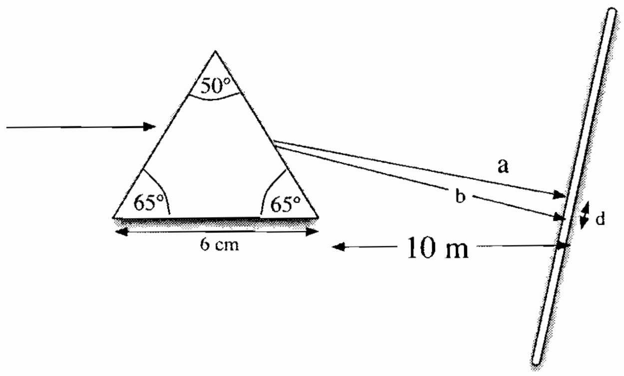
Total Q5= 20

Question 6 (20 marks)

(a) A telephone receiver is at your left ear, with the sound of the conversation at a level of 58 dB. At the same time, your little sister's screams, at a level of 93 dB, enter your right ear. What is the ratio of the sound intensities entering your two ears? [4]

(b) Two tuning forks produce a beat frequency of 2 beats per second. One of the tuning forks is a standard with frequency 330 Hz. When the other fork, of unknown frequency, has a small piece of chewing gum stuck to the vibrating end the two forks produce a beat frequency of 3 beats per second.
Determine the unknown frequency. [4]

(c) White light is refracted by a triangular prism shown below (not to scale).



A beam of light enters the prism along a path parallel to the prism base. The light is observed on a screen that is located 10 m from the prism and is perpendicular to the emerging rays.

i. How far apart on the screen are the spots of blue light (for which n = 1.528) and red light (n = 1.514)? [5]

ii. Which of rays *a* and *b* corresponds to blue and which to red? [1]

(d) A double concave lens has radii of curvature of 260 mm and 200 mm. If the index of refraction of the lens material is 1.53, what is the focal length of the lens

i. in air (n = 1) [3]

ii. in water (n = 1.33)? [3]

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 $\vec{F} = 58\,\text{kN}$ stretches the rod along its length. Given that Young's modulus for steel is $E = 2.0 \times 10^{11}\,\text{N/m}^2$ and its ultimate strength is $S = 4 \times 10^{11}\,\text{N/m}^2$, determine for the rod:

  i. the stress [2]

  ii. the elongation produced [1]

  iii. the strain [1]

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

(b) The maximum depth d_{max} that a diver can snorkel is set by the density of the water and the fact that human lungs can function against a maximum pressure difference (between inside and outside the chest cavity) of 0.050 atm.

What is the difference in d_{max} for fresh water and for the water of the Dead Sea (the saltiest natural water in the world, with a density of $1.5 \times 10^3\,\text{kg/m}^3$)? [5]

(c) An iron anchor of density $7\,870\,\text{kg/m}^3$ appears 200 N lighter in water than in air.

  i. What is the volume of the anchor? (**Hint:**— draw a free-body diagram!) [3]

  ii. How much does it weigh in air? [2]

(d) Water is moving with a speed of 5.0 m/s through a pipe with a cross-sectional area of $4.0\,\text{cm}^2$. The water gradually descends 10 m as the pipe cross-sectional area increases to $8.0\,\text{cm}^2$.

  i. What is the speed at the lower level?

  ii. If the pressure at the upper level is $1.5 \times 10^5\,\text{Pa}$, what is the pressure at the lower level? [2]

Total Q7= 20

Mechanics Equation Sheet

$$\sum F_x = 0 \qquad \mathbf{v}_{ac} = \mathbf{v}_{ab} + \mathbf{v}_{bc} \qquad \theta = \omega_0 t + \tfrac{1}{2}\alpha t^2$$

$$\sum F_y = 0 \qquad s = ut + \tfrac{1}{2}at^2 \qquad \omega = \omega_0 + \alpha t$$

$$\sum M = 0 \qquad v = u + at \qquad \omega^2 = \omega_0^2 + 2\alpha\theta$$

$$F = ma \qquad v^2 = u^2 + 2as \qquad s = R\theta$$

$$F = \mu N \qquad c^2 = a^2 + b^2 - 2ab\cos C \qquad v = R\omega$$

$$F = -ks \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad a_\mathrm{t} = R\alpha$$

$$W = Fs \qquad \frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c} \qquad a_\mathrm{n} = \frac{v^2}{R} = \omega^2 R$$

$$W = \int \mathbf{F} \cdot d\mathbf{s} \qquad W = -\tfrac{1}{2}ks^2 \qquad \vec{T} = \vec{r} \times \vec{F} \qquad \vec{v} = \vec{\omega} \times \vec{r}$$

$$P = Fv \qquad I = Mk^2 \qquad \text{Solid cylinder/Disk} \quad I_C = \frac{1}{2}MR^2$$

$$KE = \tfrac{1}{2}mv^2 \qquad I_\mathrm{d} = I_\mathrm{c} + md^2 \qquad \text{Hollow cylinder} \quad I_C = \tfrac{1}{2}M(R^2 + r^2)$$

$$p = mv \qquad \bar{x} = \frac{\sum m_i x_i}{\sum m_i} \qquad \text{Sphere} \quad I_C = \frac{2}{5}MR^2$$

$$J = Ft \qquad J = \int F dt \qquad \text{Rod} \quad I_C = \frac{1}{12}Ml^2$$

$$J_\theta = \int T dt \qquad L = I\omega \qquad L = mvr$$

$$T = I\alpha$$

$$W = T\theta$$

$$KE = \tfrac{1}{2}I\omega^2$$

$$P = T\omega$$

Thermal Equation Sheet

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

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

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

$R = \frac{L}{k}$ $\quad$ $\frac{dT}{dt} = -k(T_0 - T_S)$ $\quad$ $N = nN_A$

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

$PV = \frac{Nm\overline{v^2}}{3}$ $\quad$ $\frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$ $\quad$ $v_{\text{rms}} = \sqrt{\frac{3kT}{m}}$ $\quad$ $v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$

$H = -qA(T - T_S)$ $\quad$ $C_p - C_v = R$ $\quad$ $C_v = \begin{cases} \frac{3}{2}R & \text{(mono-)} \\ \frac{5}{2}R & \text{(di-)} \\ \frac{6}{2}R & \text{(poly-)} \end{cases}$ $\quad$ $\gamma = \frac{C_p}{C_v}$

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

Waves / Optics Equation Sheet

$F = -kx$	$a = -\omega^2 x$	$k = m\omega^2$
$\omega = 2\pi f$	$x = A\begin{pmatrix}\cos\\ \sin\end{pmatrix}(\omega t + \alpha)$	$U_x = \frac{1}{2}kx^2$
$T = \frac{2\pi}{\omega}$	$T = 2\pi\sqrt{\frac{\ell}{g}}$	$T = 2\pi\sqrt{\frac{M}{k}}$
$y = A\begin{pmatrix}\sin\\ \cos\end{pmatrix}(kx - \omega t + \phi)$	$v = f\lambda$	$v = \sqrt{\frac{F}{\mu}}$
$y = 2A\sin(kx)\cos(\omega t)$	$v = \sqrt{\frac{\gamma P}{\rho}}$	$v = \frac{\omega}{k}$
$v_{\text{max}} = \omega A$	$P = 2\pi^2 A^2 f^2 \mu v$	$I = 2\pi^2 A^2 f^2 \rho v$
$n_1 \sin\theta_1 = n_2 \sin\theta_2$	$n = \frac{c}{v}$	$n_1 c_1 = n_2 c_2$
$d_{\text{app}} = \frac{d}{n}$	$\beta = 10\log_{10}\frac{I}{I_0}$	$I = \frac{P}{A}$
$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$	$m = -\frac{i}{o}$	$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$
$d\sin\theta = m\lambda$	$a\sin\theta = m\lambda$	$a\sin\theta = 1.22\lambda$
$m_\theta = \frac{f_o}{f_e}$	$d = f_o + f_e$	$m_\ell = \frac{250}{f} + 1$

Properties of Matter / Fluids Equation Sheet

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

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

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

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

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

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

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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.

END OF EXAMINATION PAPER