Cover Type A

University of Technology, Sydney

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AUTUMN SEMESTER EXAMINATION, 2009
FACULTY OF SCIENCE

SUBJECT NAME: Foundations of Physics

SUBJECT NO.: 68101

DAY/DATE: Wednesday 10th June, 2009

TIME ALLOWED: 3 hours + 10 minutes optional 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·mole^{-1}
k_B	=	$1.381 \times 10^{-23}\ \text{J}\cdot\text{K}^{-1}$ molecule^{-1}
c	=	$3.00 \times 10^{8}\ \text{m}\cdot\text{s}^{-1}$
h	=	$6.626 \times 10^{-34}\ \text{J}\cdot\text{s}$
I_0	=	$1.0 \times 10^{-12}\ \text{W}\cdot\text{m}^{-2}$
ε_0	=	$8.854 \times 10^{-12}\ \text{F}\cdot\text{m}^{-1}$
$\frac{1}{4\pi\varepsilon_0}$	=	$9 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$
μ_0	=	$4\pi \times 10^{-7}\ \text{H}\cdot\text{m}^{-1}$
e	=	1.602×10^{-19} C
m_e	=	9.110×10^{-31} kg
	=	0.00055 u
m_p	=	1.673×10^{-27} kg
	=	1.00728 u
m_n	=	1.675×10^{-27} kg
	=	1.00866 u
1u	=	1.661×10^{-27} kg
G	=	$6.673 \times 10^{-11}\ \text{m}^2\,\text{N}\cdot\text{kg}^{-2}$
Rydberg's constant	=	$1.097 \times 10^{7}\ \text{m}^{-1}$
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

THIS QUESTION IS COMPULSORY

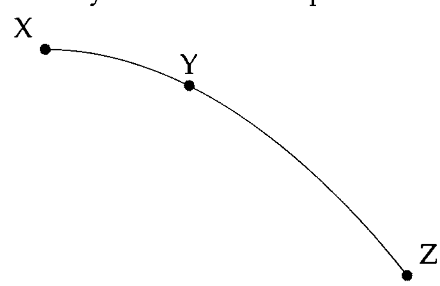
Write you answers in a separate answer booklet, NOT on this question paper.

Question 1 (20 marks)

(a) i. The area of a square patch of lawn is measured to be $121 \pm 5\,\text{m}^2$. It follows that each side has a length of

A. $11.0 \pm 2.2\,\text{m}$
B. $11.0 \pm 0.2\,\text{m}$
C. $11.0 \pm 0.04\,\text{m}$
D. $11.0 \pm 0.5\,\text{m}$
E. $11.0 \pm 2.5\,\text{m}$ [1]

ii. A stone is thrown horizontally and follows the path XYZ shown below.



The direction of the acceleration of the stone at point Y is:

A. ↗
B. ↓
C. →
D. ↘
E. ↙ [1]

iii. A vector of magnitude 20 is added to a vector of magnitude 25. The magnitude of their sum could be:

A. 0
B. 3
C. 12
D. 47
E. 50

iv. A ballon is filled with cold air and placed in a warm room. It is NOT in thermal equilibrium with the air of the room until:

A. it rises to the ceiling
B. it sinks to the floor
C. it stops expanding
D. it starts to contract
E. none of the above [1]

Q1 continues on next page ...

v. Two different samples have the same mass and temperature. Equal quantities of energy are absorbed as heat by each. Their final temperatures may be different because the samples have different:

A. thermal conductivities
B. coefficients of expansion
C. densities
D. volumes
E. heat capacities [1]

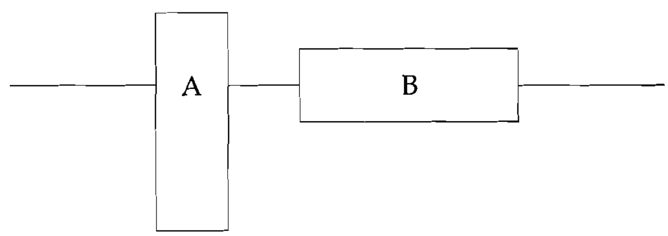
vi. A 3 kg block, attached to a spring, executes simple harmonic motion according to $x = 2\cos(50t)$ where x is in meters and t is in seconds. The spring constant of the spring is:

A. 1 N/m
B. 100 N/m
C. 150 N/m
D. 7 500 N/m
E. none of these [1]

vii. In order for two sound waves to produce audible beats, it is essential that the two waves have:

A. the same amplitude
B. the same frequency
C. the same number of harmonics
D. slightly different amplitudes
E. slightly different frequencies [1]

viii. Two identical blocks of ice flooat in water as shown below (not drawn to scale).



Which one of the following statements is correct?

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]

Q1 continues on next page ...

(b) Some student set out to identify an unknown material by measuring the rate at which heat is conducted through it. They start off by writing down the thermal conduction equation,

$$P_{\mathrm{cond}} = kA\frac{T_{\mathrm{H}} - T_{\mathrm{C}}}{L}$$

A heater supplying energy at a constant rate of $170 \pm 0.5\,\mathrm{mW}$ is available. They cut 8 different lengths of the material, each with the same cross-sectional area $A = 25.0 \pm 0.1\,\mathrm{mm}^2$. Next they heat one end of each material for 10 minutes and measure the temperature difference across their ends. Their results are tabulated below.

Sample	Length $\pm 20\,\mathrm{mm}$	Temperature difference $\pm 1°\mathrm{C}$
1	100	15
2	150	25
3	200	30
4	300	60
5	400	65
6	500	75
7	600	89
8	700	105

i. Rearrange the equation above to describe the expected temperature difference between the ends, $\Delta T = T_{\mathrm{H}} - T_{\mathrm{C}}$, as a function of sample length. [1]

ii. Use one of the readings to obtain an estimate of the likely value of k for the material (and its units); do not calculate the uncertainty in this estimate. [2]

iii. The students decide to use a graphical method to find k, rather than a simple calculation as in part (ii). Why is this a preferred experimental technique? [1]

iv. Tear off the sheet of graph paper provided on page 13 of this examination paper and plot on it an appropriate graph to determine k. [4]

v. Using the graph, estimate the value of k and its uncertainty. [3]
Write your name on the graph paper and put it inside your Q1 answer booklet.

vi. To identify the unknown material, the students consult a table of k values for different materials, as shown below.

Material	Fe	Steel	Al	Cu	Ag	Au	Pt	Brass
k (SI units))	73	46	210	386	406	293	70	85

Are they able to identify the material? Explain. [1]

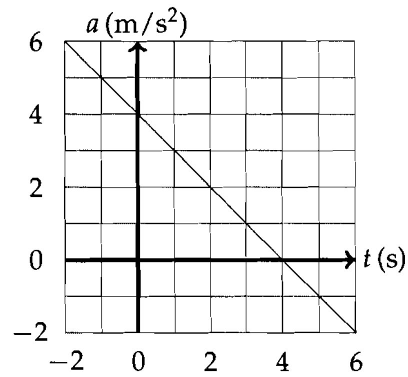
Total Q1= 20

Question 2 (20 marks)

(a) i. The excess pressure, Δp, at the centre of a soap bubble is found experimentally to depend on the radius of the bubble, R, and the surface tension, γ (a quantity whose units are energy per unit area).
Using the method of dimensions, determine the relationship which may exist between these quantities. [3]

ii. The surface tension of mercury is $\gamma = 487\,\mathrm{J/m^2}$. Convert this value to $\mathrm{mJ/cm^2}$. [2]

(b) A particle moves along an x-axis. Its acceleration as a function of time is plotted below.



At $t = -2.0\,\mathrm{s}$ the particle's velocity is $8.0\,\mathrm{m/s}$. Calculate its velocity at $t = 6.0\,\mathrm{s}$. [3]

(c) A goanna (type of Australian lizard), startled by an approaching kangaroo, dashes over the flat sand of the Simpson desert.
The x and y components of its dashes, all in metres, are:
$(3.00, 4.00)$, $(b_x, -7.00)$, $(-2.00, c_y)$, $(-8.00, -7.00)$.
The resulting displacement of the goanna has (x, y) components $(-14.0\,\mathrm{m}, -2.00\,\mathrm{m})$.
Calculate:

i. b_x [1]

ii. c_y [1]

iii. the magnitude of the goanna's overall displacement [3]

iv. the angle, relative to $+x$, of the overall displacement [2]

(d) A car travelling at $52.5\,\mathrm{km/h}$ is $28.5\,\mathrm{m}$ from a barrier when the driver slams on the brakes. The car hits the barrier $2.93\,\mathrm{s}$ later.

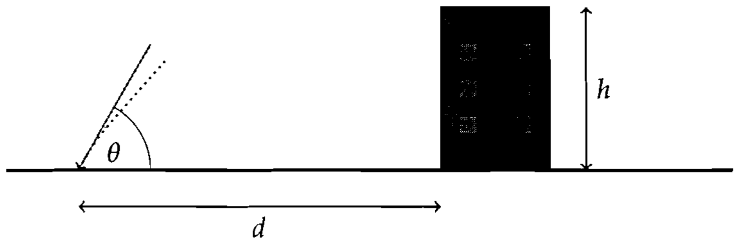
i. What is the magnitude of the car's (constant) deceleration before impact? [3]

ii. How fast is the car travelling at impact? [2]

Total Q2= 20

Question 3 (20 marks)

(a) A ball is thrown leftward (not necessarily horizontally!) from the roof of a building, at a height h above the ground. The ball hits the ground 2.00 s later, at a distance $d = 25.0\,\text{m}$ from the building and an angle $\theta = 60^\circ$ with the horizontal.



i. Determine the horizontal component of the initial velocity. [1]

ii. Find h. [2]

iii. Calculate the magnitude of the velocity at which the ball is thrown. [1]

iv. Determine the angle relative to the horizontal of the velocity at which the ball is thrown and state whether it is above or below the horizontal. [1]

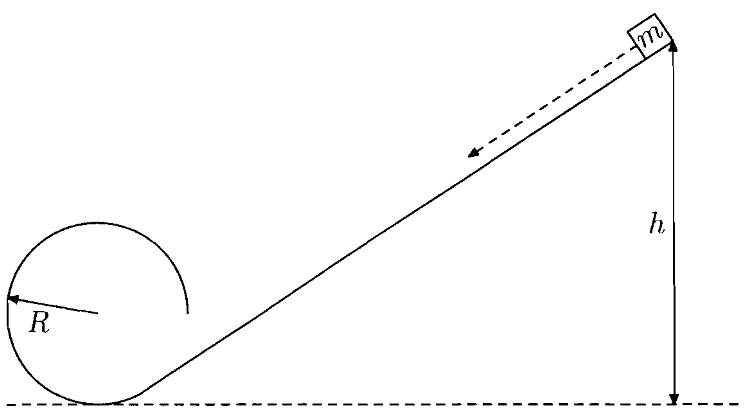
(b) A car travelling at 52.0 km/h hits a bridge abutment (i.e. supporting structure). A passenger in the car moves forward a distance of 54.0 cm (with respect to the road), while being brought to rest by an inflated air bag.

i. Explain, using the relevant Newton's law(s), how airbags minimize injury to the occupants in car accidents. [2]

ii. What magnitude of force (assumed constant) acts on the passenger's upper torso, which has a mass of 50 kg? [3]

(c) A 640.0 kg cable car hanging from a vertical cable starts down a mine shaft with an acceleration of 1.50 m/s^2. Determine the tension in the cable during the start. [3]

(d) A block of mass m slides from rest, without friction, down an inclined plane as shown below.



i. Under what circumstancs will the block complete the loop? [2]

ii. If $m = 0.500\,\text{kg}$ and $R = 0.75\,\text{m}$, determine the minimum height, h, from which the block must start in order to complete the loop. [5]

Total Q3= 20

Question 4 (20 marks)

(a) In a common, but dangerous prank, a chair is pulled away as a person is moving downward to sit on it, causing the victim to land hard on the floor. Suppose the victim falls by 0.70 m, the mass that moves downward is 62.0 kg, and the collision on the floor lasts 0.0760 s.

i. Calculate the magnitude of the impulse acting on the victim from the floor during the collision. [2]

ii. Calculate the magnitude of the average force acting on the victim from the floor during the collision. [3]

(b) i. Distinguish between elastic and inelastic collisions. Give an example of each. [2]

ii. An object of mass 7.0 kg travelling in the positive direction of the x-axis at 15 m/s collides elastically head-on with a stationary object of mass 4.0 kg. Calculate the velocity of each object immediately following the collision. [3]

(c) The kinetic theory of gases links the macroscopic properties of a gas to microscopic properties of the gas molecules. In this theory, what is the microscopic interpretation of the following macroscopic properties?

i. temperature, T [1]

ii. pressure, P [2]

(d) Consider equal volumes, at 22°C, of Ne, O_2 and CO_2, whose molar masses are listed below:

$$\text{Ne} = 20\,\text{g} \qquad O_2 = 32\,\text{g} \qquad CO_2 = 44\,\text{g}$$

i. In which gas do the molecules have the largest rms speed? [1]

ii. For each gas write down the number of degrees of freedom of its molecules. [2]

iii. Calculate the constant-volume molar heat capacity of each gas. [2]

iv. How much energy is needed to increase the temperature of 3 moles of CO_2 by 5°C? [2]

Total Q4= 20

Question 5 (20 marks)

DATA: Specific heat capacity of water $= 4\,180\,\text{J}/(\text{kg}\cdot\text{K})$
Latent heat of fusion of ice $= 333\,\text{kJ}/\text{kg}$

(a) It is possible to freeze water under a clear, moonless night sky even if the surrounding air temperature is above freezing.

i. In order to cool and freeze, the water must be losing energy to its surroundings. What is the heat transfer mechanism with the night sky that allows this to happen? [2]

ii. Name two mechanisms leading to the tranfer of heat to the water from its environment? [2]

iii. How can heat transfer to the water be minimised? [1]

(b) A novel 'sky cooler' for cooling at night consists of a 100.0 g container. The top surface, of area $0.500\,\text{m}^2$, has a special thin film that allows the container, on a cloudless night, to see the sky as a blackbody radiator at a temperature of $-30.0°\text{C}$.

i. If the temperature of the sky cooler is 2.00°C (the same as its surroundings), and the emissivity of the top surface is 1.00, calculate the power that the sky cooler radiates into the night sky. [3]

ii. If the heat capacity of the sky cooler is 840 J/(kg·K), calculate the energy it must radiate to cool to 0°C. [3]

iii. Calculate the amount of energy the sky cooler would have to radiate to freeze 1.00 litre of water if the water is initially at 2.00°C. [4]

iv. Calculate the amount of water the sky cooler could freeze overnight (i.e. in 8 hours), assuming the power radiating from the cooler is given by the answer to part (i). [4]

v. Briefly explain what the effect of a full-moon in the night sky has on the rate of cooling. [1]

Total Q5= 20

Question 6 (20 marks)

(a) An object of mass 0.400 kg is attached to a spring, the force constant of which is 5.00 N/m. The mass is displaced so that the spring is compressed 0.080 m and then released from rest.

i. On a graph sketch how the position of the particle varies with time. [2]

ii. On a second graph, immediately below the first and using the same scale for the time, show how the velocity of the mass varies with time. [2]

iii. On the graphs indicate the time scale i.e. mark values of time at certain points along the horizontal axis. [1]

iv. On the graphs indicate values of position or velocity on the vertical axes. [1]

(b) The equation describing a pressure wave in a tube filled with a gas is $p(x,t) = 0.012 \sin(12x - 3000t)$, where position x is measured in metres and time t is measured in seconds. p is the amount the pressure deviates from average pressure and is measured in pascals.

i. Determine the speed of the wave in the gas. [1]

A second wave is introduced into the tube and a standing wave pattern results.

ii. Write down the equation for the second wave. [2]

iii. Determine the amplitude of the pressure deviation at an antinode in the standing wave pattern. [2]

iv. Determine the distance between the nodes in the standing wave pattern. [1]

(c) i. A particular type of glass has an index of refraction of 1.48. Light of wavelength 640 nm as measured in the glass is travelling in the glass.
Determine its frequency. [2]

ii. Describe what occurs when light travelling in the glass is incident on a flat boundary between the glass and air if the angle of incidence is 52°. [2]

iii. Describe what occurs when light travelling in the glass is incident on a flat surface which is covered with a thin layer of water of refractive index 1.33. The angle of incidence is 52° and the water is in contact with air. [2]

(d) Two sounds differ in loudness by 31.0 dB. Find the ratio of their intensities. [2]

Total Q6= 20

Question 7 (20 marks)

(a) A converging lens has a focal length of 40.0 mm. Draw ray diagrams, approximately to scale, showing how images are formed for the following situations.

  i. The object is 70 mm in front of the lens. [2]

  ii. The object is 20 mm in front of the lens. [2]

  iii. Determine the magnification of the image for situation (ii) above. [2]

(b) Two converging lenses are assembled to form a telescope which is used to view distant objects.

  i. Draw a ray diagram to show how the image, suitable for relaxed vision, of a distant object is formed. [2]

  ii. Use the diagram to show how angular magnification is defined. [2]

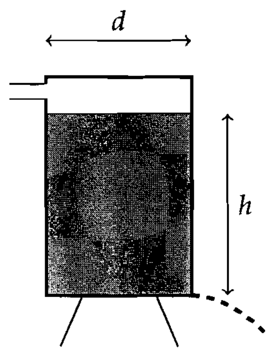
(c) i. State Archimedes' principle. [1]

  ii. A gas pipeline is to be laid on the ocean floor. The mass per unit length of the pipe is 210 kg/m, and its outside diameter is 1.2 m. The mass of the gas can be ignored. The density of sea water is 1 025 kg/m^3.

    α) Draw a free-body diagram for a length of the pipe, showing the possible forces acting on the pipe. [1]

    β) Determine whether the pipe will remain on the sea bed or float. If it floats, what force would be required to hold the pipe on the sea bed? If it does not float, what new diameter would cause it to float, assuming the mass per unit length does not change? [3]

(d) A hole of radius $r = 0.5$ mm develops in the side at the bottom of a water tank whose diameter is $d = 2.00$ m. The hole is $h = 1.50$ m below the surface of the water. The density of water is 1 000 kg/m^3.



  i. Calculate the initial speed of the water emerging from the hole. [3]

  ii. Calculate the initial volume rate of flow from the tank. [1]

  iii. Comment on whether there are any changes in the volume rate of flow as the tank empties. [1]

Total Q7= 20

Mechanics Equations

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

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

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

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

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

$F = -kx$ $\quad$ $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\quad$ $a_\mathrm{t} = R\alpha$

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

$W = \int \mathbf{F} \cdot d\mathbf{s}$ $\quad$ $U = mgy$ $\quad$ $U = \frac{1}{2}kX^2$ $\quad$ $\vec{T} = \vec{r} \times \vec{F}$ $\quad$ $\vec{v} = \vec{\omega} \times \vec{r}$

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

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

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

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

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

$T = I\alpha$ $\quad$ $W = T\theta$

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

$P = T\omega$

Thermal Equations

$$\Delta L = L\alpha\Delta T \qquad \Delta V = V\beta\Delta T$$

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

$$P_{\text{cond}} = kA\frac{T_{\text{H}} - T_{\text{C}}}{L} \qquad P_{\text{rad}} = \sigma\varepsilon AT^4 \qquad P_{\text{abs}} = \sigma\varepsilon AT_{\text{env}}^4$$

$$\frac{dT}{dt} = -k(T_0 - T_{\text{S}}) \qquad N = nN_A$$

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

$$PV = \frac{Nmv_{\text{rms}}^2}{3} \qquad \tfrac{1}{2}mv_{\text{rms}}^2 = \tfrac{3}{2}kT \qquad v_{\text{rms}} = \sqrt{\frac{3kT}{m}} \qquad v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

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

$$Q = W + \Delta E_{\text{int}} \qquad \Delta E_{\text{int}} = nC_{\text{v}}\Delta T \qquad W = P\left(V_{\text{f}} - V_{\text{i}}\right)$$

Waves / Optics Equations

$$F = -kx \qquad a = -\omega^2 x \qquad \omega = \sqrt{\frac{k}{m}}$$

$$\omega = 2\pi f \qquad x = A\cos(\omega t + \alpha) \qquad U = \frac{1}{2}kx^2$$

$$T = \frac{2\pi}{\omega} \qquad T = 2\pi\sqrt{\frac{\ell}{g}} \qquad T = 2\pi\sqrt{\frac{m}{k}}$$

$$y = A\sin(kx - \omega t + \phi) \qquad v = f\lambda \qquad k = \frac{2\pi}{\lambda} \qquad v = \sqrt{\frac{F}{\mu}}$$

$$y = 2A\sin(kx)\cos(\omega t) \qquad v = \sqrt{\frac{\gamma P}{\rho}} \qquad v = \frac{\omega}{k}$$

$$v_{\text{max}} = \omega A \qquad P = 2\pi^2\mu v A^2 f^2 \qquad I = 2\pi^2\rho v A^2 f^2$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad n = \frac{c}{v} \qquad n_1 v_1 = n_2 v_2$$

$$d_{\text{app}} = \frac{d}{n} \qquad \beta = 10\log_{10}\frac{I}{I_0} \qquad I = \frac{P}{A}$$

$$\frac{1}{P} + \frac{1}{i} = \frac{1}{f} \qquad m = -\frac{i}{P} \qquad \frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$m_\theta = -\frac{f_\text{o}}{f_\text{e}} \qquad d = f_\text{o} + f_\text{e} \qquad m_\theta = \frac{250}{f}$$

$$d\sin\theta = m\lambda \qquad a\sin\theta = m\lambda \qquad a\sin\theta = 1.22\lambda$$

Properties of Matter / Fluids Equations

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

$$R_\text{V} = Av = \text{const.}$$

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