University of Technology, Sydney

Cover Page - Type A:

SPRING SEMESTER EXAMINATION 1998

FACULTY OF SCIENCE

PHYSICS 1 (F/T, P/T)

68101

FRIDAY, 20 NOVEMBER, 1998

START 9.30 AM - FINISH 12.40 PM

TIME ALLOWED: 3 HOURS + 10 MINUTES

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

ANSWER QUESTION **1** AND ANY **5** OTHER QUESTIONS

CALCULATORS MAY BE USED.

ANSWER **EACH** QUESTION IN A **SEPARATE** BOOKLET.

CLEARLY MARK THE QUESTION NUMBER ON THE FRONT OF EACH BOOKLET.

FIRST YEAR PHYSICS DATA SHEET

$g = 9.80\ ms^{-2}$

$\sigma = 5.670 \times 10^{-8}\ Wm^{-2}\ K^{-4}$

$R = 8.314\ J\ mole^{-1}\ K^{-1}$

$N_o = 6.022 \times 10^{23}$ molecules $mole^{-1}$

$k = 1.381 \times 10^{-23}\ JK^{-1}$ $molecule^{-1}$

$c = 2.998 \times 10^{8}\ ms^{-1}$

$h = 6.626 \times 10^{-34}\ Js$

$\varepsilon_o = 8.854 \times 10^{-12}\ Fm^{-1}$

$\mu_o = 4\pi \times 10^{-7}\ Hm^{-1}$

$e = 1.602 \times 10^{-19}\ C$

$m_e = 9.110 \times 10^{-31}\ kg = 0.00055\ u$

$m_p = 1.673 \times 10^{-27}\ kg = 1.00728\ u$

$m_n = 1.675 \times 10^{-27}\ kg = 1.00866\ u$

$G = 6.673 \times 10^{-11}\ m^2N\ kg^{-2}$

$1u = 1.661 \times 10^{-27}\ kg$

Rydberg's Constant $= 1.097 \times 10^{7}\ m^{-1}$

Temperature of Ice Point $= 273.15\ K$

1 atmosphere $= 1.013 \times 10^{5}\ Pa$

Mass of earth $= 5.974 \times 10^{24}\ kg$

Radius of earth $= 6.37 \times 10^{6}\ m$

1 Curie $= 3.70 \times 10^{10}$ becquerel

SECTION A

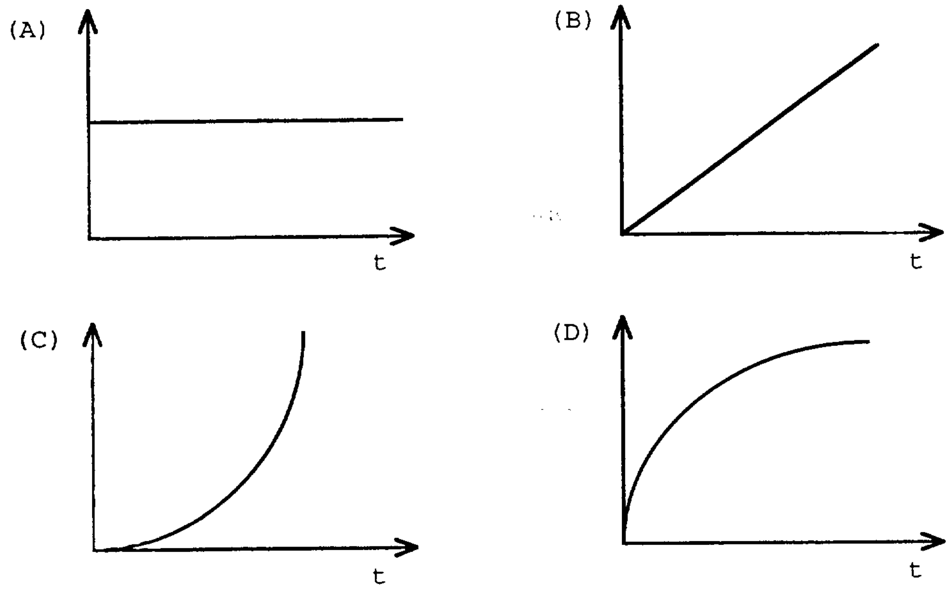
(THIS QUESTION IS COMPULSORY.)

QUESTION 1.

a. Put the answers to the multiple choice question in your examination booklet. Show working where appropriate.

i. An object is dropping under gravity .

Which of the following graphs represents the variation of **distance** with time?



ii. On a boating picnic a child (whose mass is much less than the boat) dives off the back of a stationary boat. What happens to the boat?

A. it does not move

B. it moves in the same direction as the child

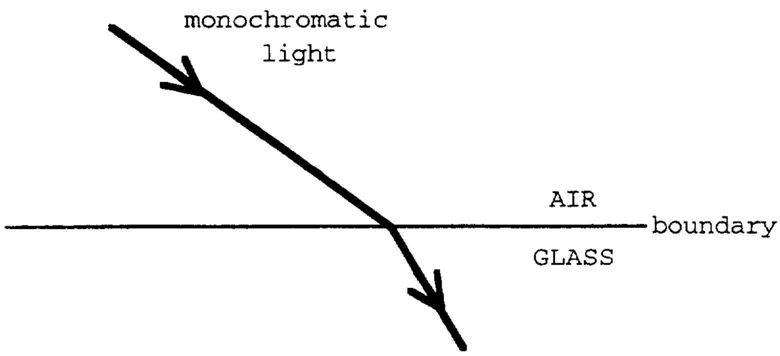
C. it moves in the opposite direction to the child but at the same speed

D. it moves in the opposite direction to the child but at a faster speed

E. it moves in the opposite direction to the child but at a slower speed.

QUESTION 1 (contd.)

iii. The figure below shows a ray of monochromatic light passing from air into glass.



Which of the following best describes the changes that take place when the ray passes from air into glass?

A. Frequency and speed change, wavelength remains the same.

B. Wavelength and frequency change, speed remains the same.

C. Speed and wavelength change, frequency remains the same.

D. Frequency, speed and wavelength all change.

E. Only speed changes.

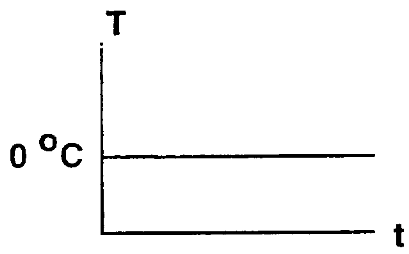
iv. The brakes of a car bring it to rest from 30 m/s in 5 seconds. The distance travelled is:

A. 150 m B. 75 m
C. 225 m D. 6 m

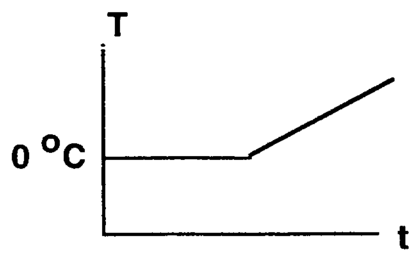
QUESTION 1 (contd.)

v. A cup contains a mixture of ice and water. Heat is transferred to the mixture. Which of the following graphs of temperature (T) against time (t) would be obtained if before the end of the time interval all the ice has melted.

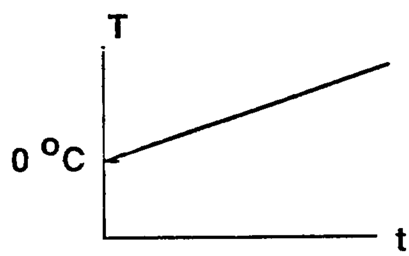
A.



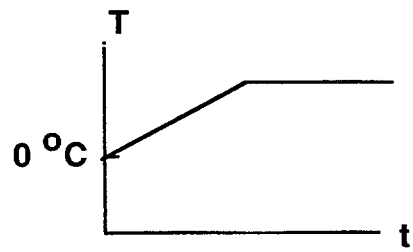
B.



C



D.



E. None of the above

vi. There are 4 identical rods. (All are made of the same metal and have the same shape). The sides of the rods are insulated so that no heat can flow in or out. The temperatures at each end of the rods are as follows:-

A. 0 °C & 50 °C

B. 50 °C & 90 °C

C. -10 °C & 30 °C

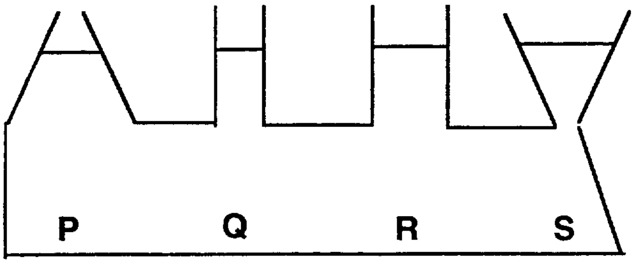
D. 30 °C & 60 °C

Along which rod does heat flow at the <u>greatest</u> rate?

Answer E if you think the heat flows at the same rate for each rod.

QUESTION 1 (contd.) Marks

vii The pressure at the points at the bottom of the vessels will be



A. Greater at P than at Q, R and S

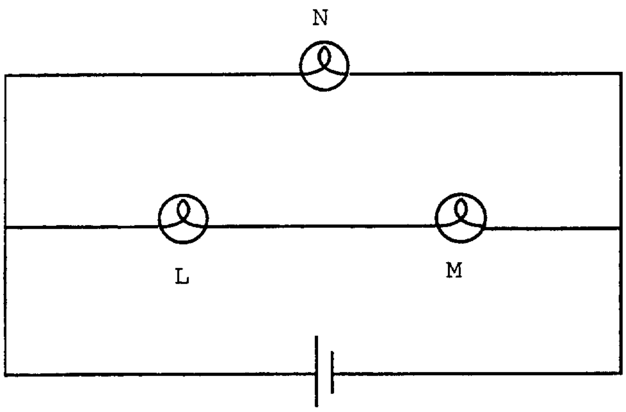
B. Greater at Q than at P, R and S

C. Greater at R than at P, Q and S

D. Greater at S than at P, Q and R

E. The same at P, Q, R and S

viii. In the circuit below there are 3 identical lamps, L, M and N .



M is removed from its socket. What will happen to N?

A. N will go out. B. N will become much brighter.

C. N will remain much the same. D. N will become much dimmer.

10

QUESTION 1 (contd.) | Marks

b. In an experiment to determine the density ($\rho = M/V$) of aluminium a student measured the mass and the volume of 5 aluminium objects of different shapes and obtained the results in the table. An electronic balance and a measuring cylinder was used for the measurements.

object number	shape	M in g (± 0.1g)	V in ml (± 0.5 ml)
1.	sphere	63.5	23.5
2.	cylinder	97.8	35.5
3.	sphere	115.7	43.0
4.	rectangular block	147.2	53.5
5.	irregular shape	188.3	71.0

i. By using the graph paper provided, determine the density of aluminium.

ii. Why do you think the student used 5 objects, when one would have been sufficient to calculate the density of aluminium?

iii. How could the student have obtained a more accurate value for the density of aluminium?

iv. The student also had a large irregular shaped object that wouldn't fit in the measuring cylinder and so she used a spring balance (± 0.1 N) and measured its weight in air and in water (density 1000 kg m^{-3}) and obtained 3.1 N and 2.0 N respectively. Could this object be aluminium? Explain your answer.

10

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Question 2 **Marks**

a Under what conditions can the following Conservation Laws be applied.

i Conservation of Momentum

ii Conservation of Mechanical Energy ?

2

b. A train starts from rest at a station and accelerates at a rate of 2.0 ms^{-2} for 10 s. It then runs at constant speed for 30 s, and decelerates at 4.0 ms^{-2} until it stops at the next station. Find the distance travelled;

i in the first 10 s, and

ii while decelerating to stop at the station.

6

c. An unoccupied car of mass 1400 kg slides down a hill and at the bottom is travelling at 120 km/h.

i If there was no friction between the tyres of the car and the hill, calculate the height of the hill.

ii The car, now on a flat road, collides with another empty car of 980 kg and the two cars become entangled. What is the velocity of the entangled cars immediately after the collision?

iii. If the coefficient of friction between the road and tyres is 0.43, how far will the cars move together before stopping ?

<u>12</u>

<u>20</u>

Marks

QUESTION 3

a. A plane has to travel to a destination 100 km directly north of its present position. It travels at 500 km/h relative to the air but there is a wind of 80 km/h blowing from the south east.

   i. Calculate the direction in which the plane must be pointed in order to travel in a northerly direction.

   ii. Calculate the time it takes for the plane to reach its destination.

5

b. A projectile is fired from ground level with a speed of 200 m/s. 30 s after firing the projectile returns to the ground (which is level).

   i. Calculate the angle at which the projectile is fired.

   ii. Calculate the range of the projectile.

5

c. A car is travelling on a curve in a road. The road is banked at an angle of 10° and the radius of the road is 80 m. Calculate the maximum speed the car can travel at without slipping sideways. Assume that frictional forces are negligible.

5

d. A 0.400-kg block slides along a horizontal surface at 3.0 m/s in the positive x direction and strikes a second block of mass 0.200 kg. The second block is initially stationary. After the collision the first block moves at 2.0 m/s in a direction at 20° to the x direction while the second block at an angle of 40° to the x direction.

   i. Calculate the speed of the second block after the collision.

   ii. Determine whether or not the collision is elastic.

5

20

QUESTION 4. **Marks**

a. A submarine's tanks can be filled with water until it neither sinks nor rises. Explain this in terms of hydrostatic forces and Archimedes' Principle using a drawing.

3

b. i. Calculate the pressure exerted by a 100 mm high column of mercury at its base, and
ii. estimate the height of a column of water which gives the same pressure at its base.
Density of Hg is 13.6×10^3 kg m^{-3} and of water is 1000 kg m^{-3}.

3

c. A hollow cylindrical object of radius 20 mm is held just below the surface of water with the circular end vertically upwards. The thickness of the cylinder wall is 0.5 mm. Estimate the force pulling on it due to surface tension as it tries to break through the surface.

γ (water) = 0.072 N m^{-1}

4

d. Thermal expansion causes a free steel rod to increase its length by 0.20% . What stress (ie external presssure) must be applied to return the rod to its original length ?
Youngs modulus of steel is 2.09×10^{11} N m^{-2}

4

e. Light of wavelength 570.0 nm passes through a container of acetone, which has a refractive index of 1.364. What is the

i. speed of light in acetone?
ii. frequency of the light in aceton?
iii. wavelength of the light in acetone?
iv. critical angle for light passing from acetone to air?

The refractive index of air is 1.000.

6

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QUESTION 5 | Marks

a. 2000 J of heat flows into a block of aluminium of volume 0.002 m^3.

i. Calculate the temperature increase of the block.

ii. Calculate the change in volume of the block.

For aluminium: density = 2.7×10^3 kg/m^3; specific heat = 910 J/kg· K;

coefficient of linear expansion = 2.4×10^{-5} K^{-1}.

4

b. In an experiment to measure the thermal conductivity of an insulating material, a box made of the material is filled with ice at 0 °C. When the outside temperature is 20 °C, it is found that after 1 hour, 0.05 kg of the ice has melted. The thickness of the walls of the box is 4 mm and the total area of all the walls is 0.070 m^2.

i. Calculate the amount of energy needed to melt 0.050 kg of ice.

ii. Calculate the rate at which heat flows into the box.

iii. Calculate the thermal conductivity of the insulating material.

Specific heat of water = 4190 J/kg· K; specific heat of ice = 2110 J/kg· K;

heat of fusion of water = 2.256×10^6 J/kg.

5

c. A new-born baby of mass 3.0 kg has 0.12 m^2 of skin at a temperature of 35.0 °C. Assuming the skin is not covered:

i. calculate the rate at which energy radiates from the baby;

ii. if the temperature of the room is 25.0 °C, calculate the rate at which the baby absorbs radiation;

iii. if the baby is not yet able to regulate its internal temperature, calculate the time it takes for the body temperature to drop by 2.0 °C.

Emissivity of skin = 1; specific heat of body = 4000 J/kg· K.

7

QUESTION 5 (contd.) **Marks**

d. Air in the tyre of a car is at a pressure of 3.0×10^5 Pa when the temperature is 15 °C. After the car has been driven for some time the temperature of the air rises to 35 °C.

i. Calculate the pressure of the air in the tyre at 35 °C.

ii. Calculate the percentage change in the root mean square speed of the molecules in the tyre as a result of the temperature change.

4

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QUESTION 6.

Marks

a. i. Write down the general equation for a particle moving in simple harmonic motion (SHM).

ii. If a SHM has an amplitude of 0.21 m , a period of 3.4 s and a maximum displacement at t = 0, write down its equation.

6

b. The equation of a travelling wave is;

$$y = \sin(0.2x - 60t + \pi/2)$$

where x and y are in metres and t is in seconds. Determine

i. the wavelength of the wave

ii. the speed of the wave.

6

c. A travelling wave is a consequence of elements of the medium oscillating in S.H.M. For the travelling wave in (b) above, determine the total energy for each oscillating element if they have a mass of 0.1 kg.

4

d. Light strikes a glass block at an angle of incidence of 60^0 and part of the beam is reflected and part refracted. If the reflected and refracted portions make an angle of 90^0 with each other, what is the index of refraction of the glass ?

4

20

QUESTION 7 **Marks**

a. An electric heater produces heat at the average rate of 2000 W when it is connected to a power supply with average voltage of 170 V. Calculate the resistance of the heating element. 3

b. A 20-Ω resistor and a 40-Ω resistor are connected in parallel to a power supply. Find the ratios of the following quantities:

i. the current through the resistors;

ii. the potential differences across the resistors;

iii. the power dissipated in the resistors. 4

c. The conductivity (conductivity = 1/resistivity) of a solution is measured by determining the resistance of a conductivity cell filled with the solution. It is found that when the potential difference across the two electrodes of the cell is 5 V the current that flows is 0.01 A. The area of each electrode is $1.5 \times 10^{-4}\ m^2$ and their separation is 35.0 mm. Determine the conductivity of the solution. 3

d. Two large parallel conducting plates are charged using a 20-V battery. The charges on each plate are equal but of opposite sign. The plates are separated by 12 mm. Electrons travelling at high speed enter the region between the plates in a direction parallel to the plates.

i. Sketch the field lines in a region near the centre of the plates, making sure you indicate which is the positive plate and which is the negative.

ii. Sketch the path travelled by the electrons as they move between the plates.

iii. Calculate the electric force experienced by the electrons.

iv. At the point of leaving the region of electric field, the electrons have moved 0.05 mm closer to one of the plates. Calculate the increase in kinetic energy of the electrons as a result of passing between the plates. 6

QUESTION 7 (contd.) Marks

e. A charged particle enters a region containing a uniform magnetic field and a uniform electric field. The particle travels through the fields in a straight line which is perpendicular to the magnetic field.

i. Sketch a diagram showing the directions of the fields and the path taken by the particle.

ii. A second particle of the same mass and charge but travelling at twice the speed enters the region of the fields. By what fraction should the electric field be changed for this particle to travel in the same direction as the first?

4

20

Mechanics Equation Sheet

$\sum F_x = 0$

$\sum F_y = 0$

$\sum M = 0$

$F = ma$

$F = \mu N$

$F = -ks$

$W = Fs$

$W = -\frac{1}{2} ks^2$

$PE = mgh$

$P = Fv$

$KE = \frac{1}{2} mv^2$

$p = mv$

$I = Ft$

$\bar{v}_{ac} = \bar{v}_{ab} + \bar{v}_{bc}$

$s = ut + \frac{1}{2} at^2$

$v = u + at$

$v^2 = u^2 + 2as$

$c^2 = a^2 + b^2 - 2ab \cos C$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$

$\theta = \omega_o t + \frac{1}{2} \alpha t^2$

$\omega = \omega_o + \alpha t$

$\omega^2 = \omega_o^2 + 2\alpha\theta$

$s = R\theta$

$v = R\omega$

$a = R\alpha$

$a_n = \frac{v^2}{R} = \omega^2 R$

$T = Fr$

$I_C = Mk^2$

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

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

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

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

$L = I\omega$

$\Delta L = Tt$

$W = T\theta$

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

$P = T\omega$

Thermal Equation Sheet

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

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

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

$PV = nRT$ $PV = NkT$ $PV^\gamma = \text{constant}$

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

$C_p - C_v = R$ $C_v = \frac{3}{2}R$ (mono-), $\frac{5}{2}R$ (di-), $\frac{6}{2}R$(poly-)

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

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

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

Waves/Optics Equation Sheet

$F = -kx$ $\quad T = 2\pi\sqrt{\frac{l}{g}}$ $\quad \omega^2 = \frac{k}{m}$

$U = \frac{1}{2}kx^2$ $\quad x = A\sin(\omega t + \alpha)$

$y = A\sin(kx - \omega t + \phi)$ $\quad y = 2A\sin kx\cos\omega t$

$c = f\lambda$ $\quad c = \sqrt{\frac{F}{\mu}}$

$n_1\sin i = n_2\sin r$ $\quad n_1c_1 = n_2c_2$ $\quad d_a = \frac{d}{n}$

$P = 2\pi^2A^2f^2\mu c$ $\quad I = 2\pi^2A^2f^2\rho c$

$\sin A + \sin B = 2\sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)$ $\quad c = \sqrt{\frac{\gamma P}{\rho}}$

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

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

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

$m_l = \frac{250}{f} + 1$ $\quad \alpha = \frac{\pi a\sin\theta}{\lambda}$ $\quad \beta = \frac{\pi d\sin\theta}{\lambda}$

$I = \frac{I_{max}\sin^2\alpha\cos^2\beta}{\alpha^2}$ $\quad I = I_0\cos^2\theta$

$m_\theta = \frac{f_o}{f_e}$ $\quad R = \frac{\lambda}{\Delta\lambda} = mN$ $\quad D = \frac{d\theta}{d\lambda}$

Properties of Matter/Fluids Equation Sheet

$$Y = \frac{F/A}{\Delta l/l_0}$$

$$B = \frac{-\Delta p}{\Delta V/V_0}$$

$$S = \frac{F/A}{d/y}$$

$$\sigma = \frac{-\Delta b/b_0}{\Delta l/l_0}$$

$$P = P_0 + \rho g h$$

$$P + \tfrac{1}{2}\rho v^2 + \rho g y = \text{constant}$$

$$v = \sqrt{2gh}$$

$$\gamma = \frac{F}{l} = \frac{W}{\Delta A}$$

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

$$\Delta P = \frac{2\gamma}{R} \text{ or } \frac{4\gamma}{R}$$

$$Q = Av = \text{constant}$$

$$Q = \frac{\pi R^4 \Delta P}{8\eta l}$$

$$v_1^2 = \frac{2(P_1 - P_2)}{\left[\rho\left\{\left(\frac{A_1}{A_2}\right)^2 - 1\right\}\right]}$$

$$\eta = \frac{F/A}{\Delta v/\Delta y}$$

$$F = 6\pi\eta R v$$

$$N_R = \frac{\rho v D}{\eta}$$

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

Electricity and Magnetism Equation Sheet

$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

$V = \frac{q}{4\pi\varepsilon_0 r}$

$E = \frac{q}{4\pi\varepsilon_o r^2}$

$U = \frac{q_1 q_2}{4\pi\varepsilon_o r}$

$E = -\frac{dV}{dx}$

$C = \frac{\varepsilon_o A}{d}$

$U_E = \frac{1}{2}CV^2$

$W = \frac{QV}{2}$

$W = VIt$

$R = \rho\frac{l}{A}$

$\oint \underset{\sim}{E}.d\underset{\sim}{A} = \frac{q}{\varepsilon_o}$

$\underset{\sim}{F} = q\underset{\sim}{v} \text{ x } \underset{\sim}{B}$

$\underset{\sim}{F} = i\underset{\sim}{l} \text{ x } \underset{\sim}{B}$

$\underset{\sim}{M} = i\underset{\sim}{A}$

$\underset{\sim}{\Gamma} = \underset{\sim}{M} \times \underset{\sim}{B}$

$\frac{F}{\ell} = \frac{\mu_o I_1 I_2}{2\pi a}$

$\oint \underset{\sim}{B}.d\underset{\sim}{l} = \mu_0 I$

$dB = \frac{\mu_0 \, i \, dl \sin\theta}{4\pi r^2}$

$\phi_B = \int \underset{\sim}{B}.d\underset{\sim}{A}$

$\varepsilon = -\frac{d}{dt}(N\phi_B)$

$\varepsilon = -L\frac{di}{dt}$

$\varepsilon = -M\frac{di}{dt}$

$U_B = \frac{1}{2}Li^2$

$U_B = \frac{B^2}{2\mu_0}$

$\tau = \frac{L}{R}$

$\tau = RC$

$X_L = \omega L$

$X_C = \frac{1}{\omega C}$

$Z^2 = R^2 + (X_L - X_C)^2$

$\tan\phi = \frac{X_L - X_C}{R}$