Cover Type A

University of Technology, Sydney

THIS PAPER MAY BE REMOVED FROM THE EXAM CENTRE.

AUTUMN SEMESTER EXAMINATION 2001

FACULTY OF SCIENCE

FOUNDATIONS OF PHYSICS

68101

TUESDAY, 26 JUNE, 2001

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.

PHYSICS DATA SHEET

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

OVER/2

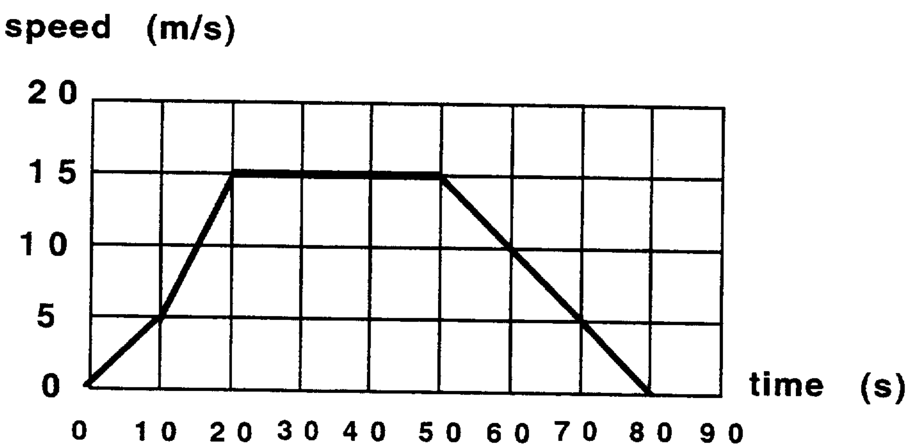
SECTION A

(THIS QUESTION IS COMPULSORY.)

QUESTION 1.

a. Write the answers to the following multiple choice questions in your examination booklet. Show working where appropriate.

i. The following graph represents the motion of a car along a straight road.



During which interval was the acceleration of the car a maximum

A. 0 – 10 seconds B. 10 –20 seconds C. 20 – 50 seconds

D. 50- 80 seconds E. none of A - D

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

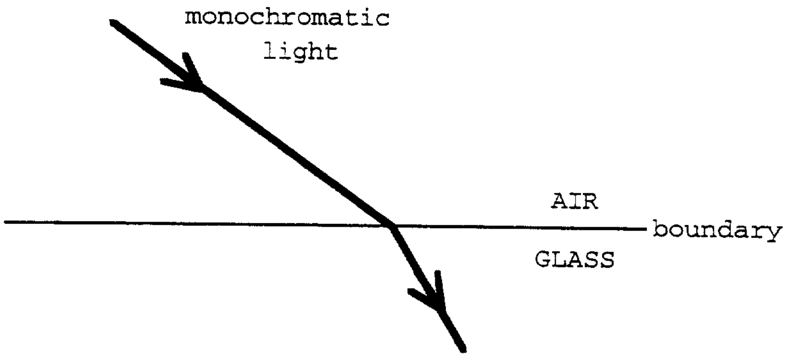
B. it moves in the same direction as the child

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.

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 uniformly to rest from 20 m/s in 5 seconds. The distance travelled is:

A. 4 m
B. 50 m
C. 100 m
D. 150 m

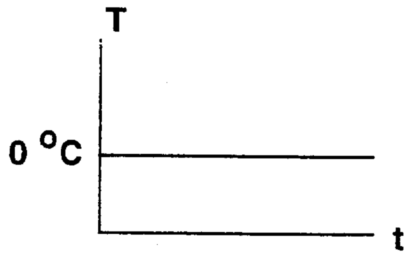
v. There are 4 identical rods. (All are made of the same metal and have the same shape). The walls of the rods are insulated so that no heat can flow in or out radially. The temperatures at each end of the rods are as follows:-

A. 0 ^{o}C & 50 ^{o}C
B. 50 ^{o}C & 90 ^{o}C
C. -10 ^{o}C & 30 ^{o}C
D. 30 ^{o}C & 60 ^{o}C

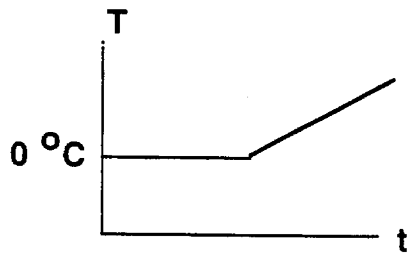
Along which rod does heat flow at the greatest rate?
Answer E if you think the heat flows at the same rate for each rod.

vi. A cup contains water at 0 °C. Heat is transferred uniformly to the water. Which of the following graphs of temperature (T) against time (t) would be obtained if before the end of the time interval the water has started to boil.

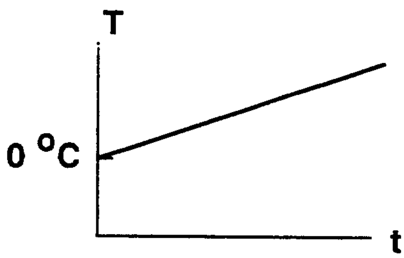
A.



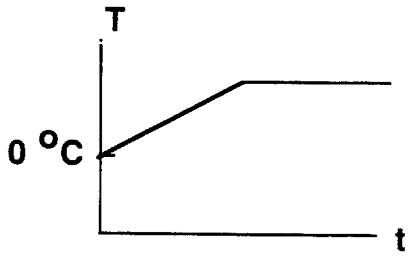
B.



C

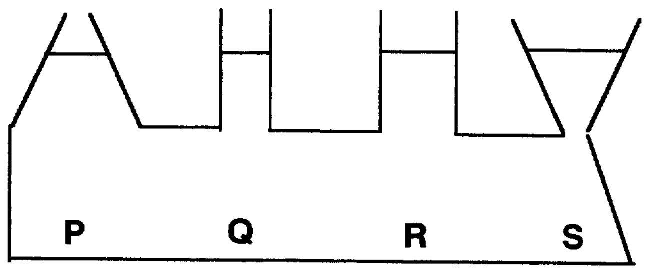


D.



E. None of the above

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



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

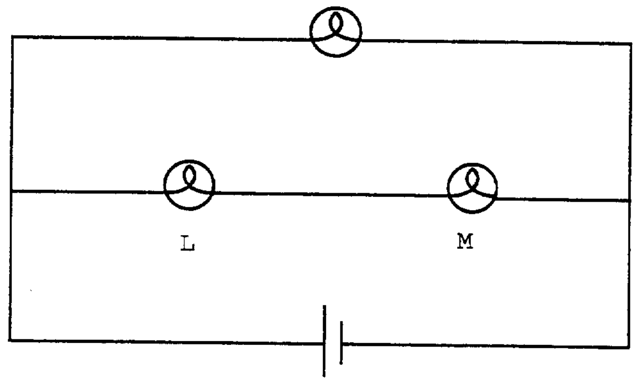
B. Greater at Q than at P, R and S

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 powered by an ideal battery.



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.

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b. In an experiment to measure the coefficient of linear expansion, α, of a metal rod of length 1.8 m and originally at a temperature of 20 °C, the following readings were obtained. By plotting a suitable graph on the graph paper provided and using the formula ($\Delta L = L_o \alpha \Delta T$), determine α.

T (°C)	ΔL (mm)
40	0.9
60	1.9
80	2.9
100	4.0
120	4.8

ii. A student is given a 5 m tape measure, a stopwatch, a 1.2 m length of string and a 50 gram mass. She is to measure the acceleration due to gravity by two different methods. Describe two methods, along with the equations you could use, to measure the acceleration due to gravity.
(Hint the following equations may be helpful:
$v = u + at$, $s = ut + 0.5\,at^2$, $v^2 = u^2 + 2\,as$, and $T = 2\pi\sqrt{\frac{l}{g}}$).
Which measurement would be the more accurate? Explain.

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SECTION B.

Attempt any 5 questions in this section

QUESTION 2.

a. The period, T, of a pendulum is thought to depend on the length of its string, l, the mass at the end of the string, m, and the acceleration due to gravity, g. Using dimensional analysis derive an expression relating the period to l, m and g.

4

b. A stunt car is to drive off a cliff (whose face is vertical) and crash into a house 20.0 m below and 20.0 m from the face of the cliff. If the stunt car leaves the cliff travelling horizontally:

i) What speed must it travel at, as it leaves the top of the cliff, if it is to hit the house?

ii) What is the speed of the car when it hit the house?

iii) At what angle does the car strike the house?

7

c. A 30 kg block is pushed from rest up a plane surface that is inclined at 30° to the horizontal, by a force of 500 N. The coefficient of sliding (kinetic) friction is 0.25. Find:

i) The acceleration of the block

ii) The speed of the block after it has moved 10 m up the plane.

5

d. A bucket of water is swung in a circle of radius 1.00 m in the vertical plane. What is the minium speed that the bucket can have at the highest point of its path for no water to spill? Explain all reasoning.

4

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QUESTION 3.

a. A pair of ice skaters are skating in a straight line at 1.5 m/s. The female ice skater (mass 59 kg) pushes the male skater (mass 58 kg) away from her and in the same direction in which they are already travelling so that his speed is now 1.9 m/s. What is the female skater's velocity?

4

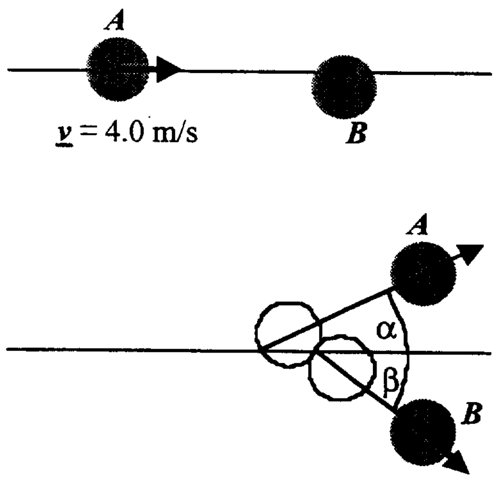
b. A ball of mass 0.150 kg is dropped from a height of 2.00 m. After bouncing once it returns to a height of 1.80 m

i. what is the speed of the ball just before it hits the ground on the way down?

ii. what is the impulse of the force exerted by the floor on the ball?

4

c. Disc A (mass $m_A = 0.500$ kg) is shot at disc B (mass $m_B = 0.500$ kg) and makes an elastic collision with it, as shown below. If the initial speed of disc A is 4.00 m/s and disc B is stationary find the velocities (as specified by the angles α and β shown below) of the discs after the collision, given that angle β is 30°. Assume no friction.



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d. A swing is made of two hanging ropes of equal length. Alfred, whose mass is 35 kg, is sitting motionless on the 2.0 kg swing. His friend throws a watermelon of mass 10 kg so that Alfred catches it when it is moving horizontally at 1.0 m/s.

i. What is the speed of Alfred just after he catches the watermelon

ii. Given that the maximum angle the swings reaches is 2° what is the length of the ropes?

<u>6</u>

<u>20</u>

QUESTION 4.

a. i. At the bottom of a mountain lake the total pressure is 2.246×10^5 Pa. If air pressure is 0.90×10^5 Pa and the density of the water is $1000\ \text{kg m}^{-3}$ calculate the depth of the lake.

ii. The pressure inside a bubble at the bottom of the lake in part i. is 2.253×10^5 Pa, what is the radius of the bubble, if the surface tension of water is $7.2 \times 10^{-2}\ \text{N m}^{-1}$?

5

b. The temperature of the water at the bottom of the lake in part a. is 2 °C, and the temperature of the water at the surface of the lake is 19 °C. If the bubble in part a. rises from the bottom of the lake to the top:
Calculate the ratio of the volume of the bubble at the surface to its volume at the bottom (assume the pressure in the bubble at the top is 0.90×10^5 Pa.)

3

c. A block of metal is lowered into the lake. When it is 9.53 m below the surface it only appears to be 7.11m below the surface.

i. Explain this by means of a ray diagram.

ii. Calculate the refractive index of the water.

4

d. Draw a stress-strain diagram for a metal and indicate the:
elastic limit; fracture point; ultimate strength; and proportional limit

3

e. The block of metal in part d., which has a mass of 7.83 kg and a volume of 8.76×10^{-4} m^3, is lowered into the lake by a metal cable of cross sectional area 1.35×10^{-5} m^2.

i. What is the tension in the cable when the block is 9.53 m below the surface (i.e length of cable is 9.53 m)?

ii. If Young's Modulus for the metal cable is 12.3×10^{10} N m^{-2}, how far does the cable stretch at this depth?

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QUESTION 5.

a. A circular mountain lake has a diameter of 453 m and a constant depth of 12.714 m at 0 °C.. (The average coefficient of volume expansion for water = $2.1 \times 10^{-4}\ K^{-1}$.)

i. What is the volume of water in the lake at 0 °C?

ii. What would be the volume of water in the lake if the temperature rose from 0 °C to 25 °C?

iii. If the diameter of the lake remained exactly the same, what is the rise in the depth of the lake as the temperature rose from 0 °C to 25 °C

7

b. i. If the density of water in part a. was 1000 kg m^{-3}, what mass of water does the lake contain?

ii. In winter the top 60 mm layer of the lake freezes. What is the mass of ice on the lake if the density of ice is 900 kg m^{-3}?

iii. How much heat energy is required to melt the ice (at 0 °C) in Spring, if the heat of fusion of water is 3.35×10^5 J kg^{-1} and the specific heat of water is 4200 J kg^{-1} K^{-1}?

iv. After the ice has melted, how much heat energy is required to raise the temperature of all the water in the lake (part i.) from 0 °C to 25 °C?

8

c. i. If the coefficient of thermal conductivity for ice is 1.1×10^{-1} W K^{-1} m^{-1}, what is the rate of flow of heat across the 60 mm layer of ice in part b. when the temperature of the water below the ice is 0 °C and the air temperature is 15 °C?

ii. How long would it take for 2.92×10^{12} J of heat to flow across the 60 mm ice layer?

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QUESTION 6.

a. At a picnic beside a lake, a child has a toy spring. The child places a 0.50 kg mass on the end of the spring held vertically and it stretches 63 mm to a new "equilibrium" position. She then pulls it down a further 50 mm and lets it go.

i. Sketch a rough graph of the motion of the 0.50 kg mass (i.e extension from "equilibrium" position against time).

ii. Calculate the force constant for the spring

iii. Calculate the period of the motion.

7

b. A ripple (wave) on the lake's surface in part a. has an amplitude of 5.2 mm, a wavelength of 48 mm and a speed of 0.28 ms^{-1}.

i. What is the frequency of the ripple?

ii. Write down an equation that describes this progressive wave (if at t=0, x=0 and y=0).

iii. Write down the equation of a wave which when combined with the equation in part ii. would produce destructive interference.

6

c. i. Someone at the picnic in part a. turns on the radio to Sydney's new FM radio station, which broadcasts at 96.9 M Hz. Calculate the wavelength of the signals.

ii. Music from the radio travels across the lake reflects from a cliff on the other side of the lake and an echo is heard 2.8 seconds later. If the speed of sound is 338 ms^{-1}, how wide is the lake?

iii. Explain the main differences between the radio signal (part i.) and the sound wave (part ii.).

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QUESTION 7.

a. A potential difference of 21 V is placed across a 47 kΩ resistor. How many electrons pass through the resistor in one minute?

3

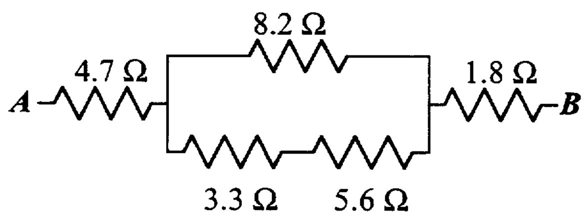
b. The resistance of the tungsten filament of a light bulb is 2.5 Ω when the bulb is not on and at 20 °C, and 25 Ω when it is on. The temperature coefficient of tungsten in 4.5×10^{-3} $(C°)^{-1}$. What is the temperature of the filament when it is on?

3

c. A copper wire 2.0 mm in diameter and 2.0 m in length is stretched until its length triples. Given that the resistivity of copper is 1.72×10^{-8} Ω·m what is the resistance of the stretched wire?

4

d. What is the resistance between the points *A* and *B* in the following circuit?



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e. A battery with an emf of 9.0 V and an internal resistance of 2.2 Ω is connected to a resistance of 4.7 Ω.

i. Find the current flowing in the 4.7 Ω resistor
ii. Find the voltage drop across the 4.7 Ω resistor
iii. Find the power dissipated in the 4.7 Ω resistor
iv. The external resistance is to be changed - show that the maximum power occurs when the external resistance is equal to 2.2 Ω.

6

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Mechanics Equation Sheet

$\Sigma F_x = 0$

$\Sigma F_y = 0$

$\Sigma M = 0$

$F = ma$

$F = \mu N$

$F = -ks$

$W = Fs$

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

$PE = mgh$

$P = Fv$

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

$p = mv$

$I = Ft$

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

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

$v = u + at$

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

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

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

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

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

$\omega = \omega_o + \alpha t$

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

$s = R\theta$

$v = R\omega$

$a = R\alpha$

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

$T = Fr$

$I_C = Mk^2$

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-)

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

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

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

Properties of Matter/Fluids Equation Sheet

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Waves/Optics Equation Sheet

$F = -kx$

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

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

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

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

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

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

$c = f\lambda$

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

$n_1 \sin i = n_2 \sin r$

$n_1 c_1 = n_2 c_2$

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

$P = 2\pi^2 A^2 f^2 \mu c$

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

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

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

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

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

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

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

$d \sin\theta = m\lambda$

$a \sin\theta = m\lambda$

$a \sin\theta = 1.22\lambda$

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

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

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

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

$I = I_0 \cos^2\theta$

$m_\theta = \frac{f_o}{f_e}$

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

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

Electricity and Magnetism Equation Sheet

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

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

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

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

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

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

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

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

$W = VIt$

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

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

$\underset{\sim}{F} = q\underset{\sim}{v} \times \underset{\sim}{B}$

$\underset{\sim}{F} = i\underset{\sim}{l} \times \underset{\sim}{B}$

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

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

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

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

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

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

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

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

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

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

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

$B = \mu_o I/(2\pi r)$

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

$\tau = RC$

$X_L = \omega L$

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

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

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