Cover Type A

UTS

University of Technology, Sydney

THIS PAPER MAY BE REMOVED FROM THE EXAM CENTRE.

AUTUMN SEMESTER, 2003

FACULTY OF SCIENCE

FOUNDATIONS OF PHYSICS

68101

FRIDAY, 20th JUNE, 2003

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

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

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

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

$N_o = 6.022 \times 10^{23}$ 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

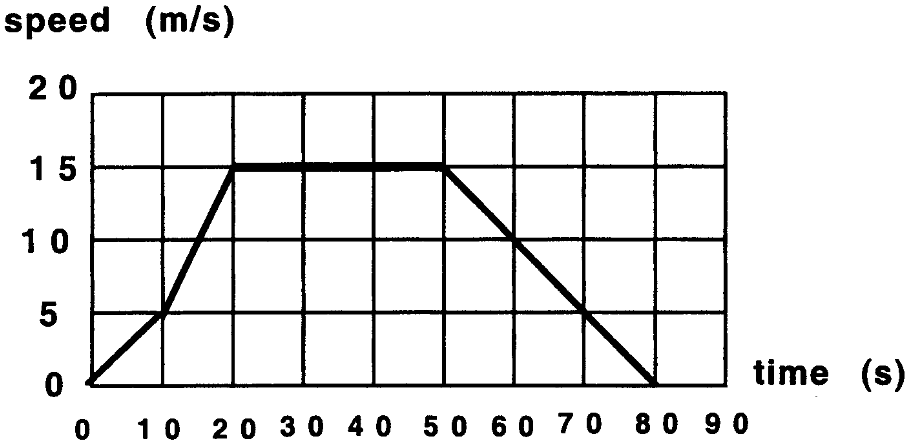
SECTION A

(THIS QUESTION IS COMPULSORY.)

QUESTION 1.

a. 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

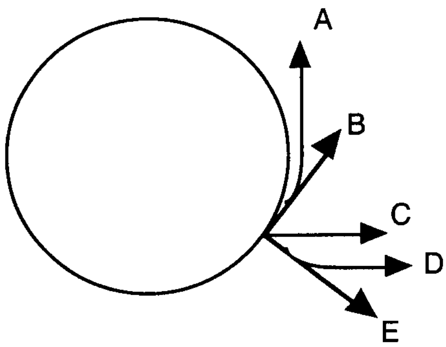
C. it moves in the opposite direction to the child but at the same speed

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

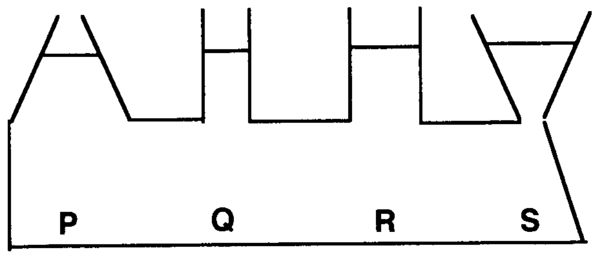
E. it moves in the opposite direction to the child but at a slower speed.

iii. A heavy ball is attached to a string and swung in a circular path in a horizontal plane as shown in the diagram. At the point indicated the string suddenly breaks. If these events are viewed from directly above, which is the path followed by the ball?

A B C D E



iv. The pressure at the points at the bottom of the vessel filled with water 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.

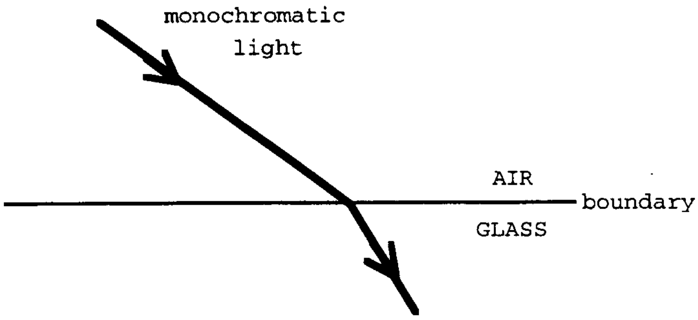
v. A mirror produces an image that is magnified and upright. The mirror and the image are:

A. mirror - concave and image - real
B. mirror - concave and image - virtual
C. mirror - convex and image - real
D. mirror - convex and image - virtual

vi. To what temperature must a gas be heated so that the root mean square speed of its molecules is doubled if its initial temperature is 300 K?

A. 424 K B. 600 K C. 846 K D. 1200 K

vii. 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.

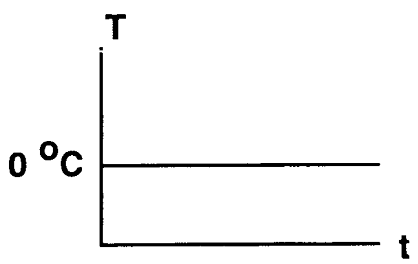
C. Speed and wavelength change, frequency remains the same.

D. Frequency, speed and wavelength all change.

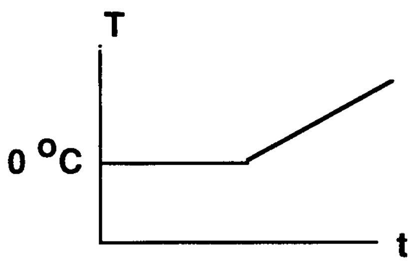
E. Only speed changes.

viii. A cup contains water at 0 °C but no ice. 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 had started to boil?

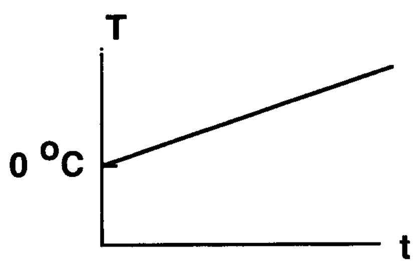
A.



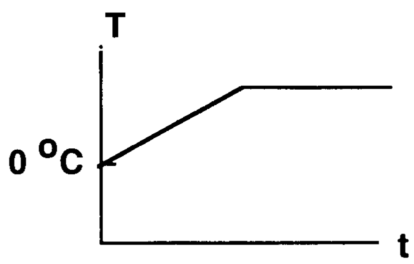
B.



C



D.



E. None of the above

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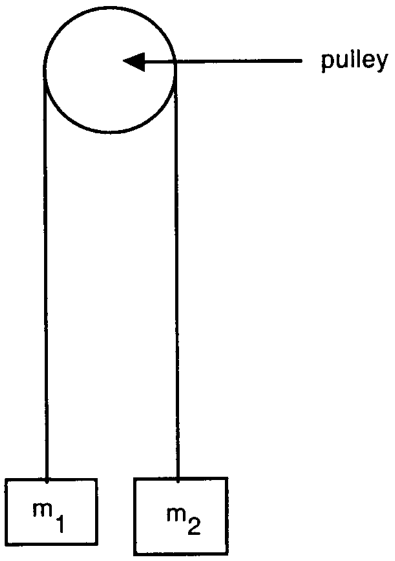
b. In an experiment to measure the acceleration due to gravity, g, a laboratory group set up the following experiment and recorded the following values for m_2 and a, the acceleration of both blocks. In each case m_1 = 100 grams. The two masses are joined by a piece of string over a pulley.



According to theory the equation for the motion is

$$a = \frac{m_2 - m_1}{m_2 + m_1} g$$

	m_2	a (m s^{-2})
1	120 grams	0.90
2	140 grams	1.63
3	160 grams	2.24
4	180 grams	2.80
5	200 grams	3.20

i. Choose one value on m_2 and determine g using the equation given.

ii. Use the graph paper provided to obtain a value of g.

iii. What is the advantage of drawing a graph?

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c. Discuss in one or two paragraphs the following:

During the semester, there have been a number of talks on special research topics by visiting lecturers, and possibly videos. Choose one of these topics, give the name of the research topic, and briefly (in one or two paragraphs) describe the area of research and discuss its importance.

3

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SECTION B.

Attempt any 5 questions in this section

Question 2

a. A track and field coach trains an athlete to throw a javelin so that it leaves the athlete's hand at a height 'h' above the ground, moving at a speed of $\sqrt{\frac{25gh}{8}}$ and at an angle of 36.9° above the horizontal. The javelin continues in flight until it strikes the ground.

Answer the following questions assuming h = 1.5 m.

i. On ONE graph plot the javelin's horizontal velocity component versus time AND the javelin's vertical velocity component versus time

ii. From the graph, determine the time at which the maximum height is reached by the javelin

iii. Determine the maximum height reached by the javelin

iv. Find the horizontal distance that the javelin travels from where it leaves the athlete's hand to where it strikes the ground.

7

b. The compass of a aeroplane indicates that it is pointing in a due north direction and its airspeed indicator shows that it is moving through the air at 240 km h^{-1}. If there is a wind of 100 km h^{-1} blowing from west to east what is the velocity of the plane relative to the earth. (i.e what is the speed and direction of travel.) (Include an appropriate vector equation and vector diagram as part of your answer)

4

c. A motorbike stunt rider takes off from the edge of a 15 m cliff, leaving the cliff in a horizontal direction with a velocity of 35 km h^{-1}. Determine the rider's

i. location

ii. velocity

at 0.50 seconds after takeoff.

6

d. The excess pressure, Δp, at the centre of a soap bubble is experimentally found to depend only 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, suggest the relationship which might exist between these quantities.

3

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Question 3

a. Why is it that Newton's First Law might be thought of as a special case of Newton's Second Law?

2

b. To improve the acoustics in a theatre a sound reflector with a mass of 200 kg is suspended by a chain hanging vertically from the ceiling. (Assume that the mass of the chain is negligible.)

i. What is the weight of the reflector?

ii. What force (magnitude and direction) does the chain exert on it?

iii. What is the tension in the chain?

4

c. Fred is trying to move a 150 kg crate full of equipment across a rough horizontal floor by tying a rope around it and pulling it. The rope is at an angle of 30° above the horizontal. The coefficient of friction is 0.40.

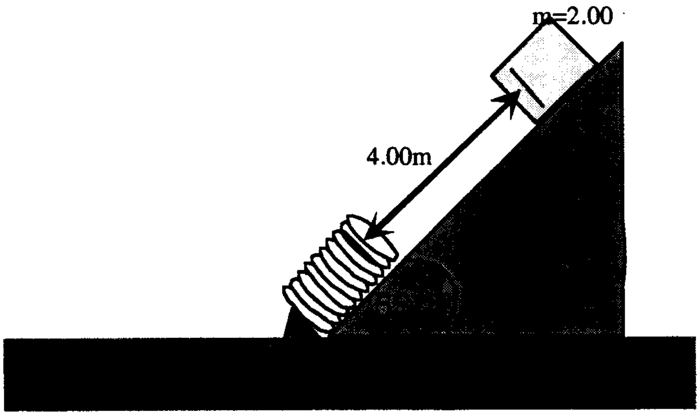
i. Draw a freebody diagram of the crate in motion.

ii. What force does Fred need to apply to move the crate at constant velocity?

iii. Is the force required less if the crate is pulled horizontally? Why?

6

d. A 2.00 kg package is released on a 53.1° incline, 4.00 metres from a long spring with force constant 1.20 N/m, attached at the bottom of the incline. The coefficients of friction between package and incline are $\mu_s = 0.40$ and $\mu_k = 0.20$. The mass of the spring is negligible.



i. Will the 2.00 kg package slide down the incline? Show working.

ii. Assuming it does slide, what would be the speed of the package just before it reaches the spring?

iii. What would then be the maximum compression of the spring?

iii. After the spring expands, how close would the package get to its initial position on its return?

<u>8</u>

<u>20</u>

QUESTION 4.

a. i. Steel railway tracks of length 8.3 m are laid at a temperature of 18 °C. (α_{steel} = 1.2 x 10^{-5} K^{-1}) If the maximum temperature in the location is 50 °C, what distance must be left between the rails in order that the rails don't touch at 50 °C?

ii. What is the distance between the rails on a cold winter's morning at - 2.0 °C?

5

b. Calculate the total energy radiated per second from the sun if its emissivity is 1.0. (radius of the sun = 6.96 x 10^{8} m, temperature of the sun = 5800 K)

3

c. A water heater of dimensions 1.2 m x 0.8 m x 0.4 m is covered by 18 mm of insulation (k = 0.34 in J s^{-1} m^{-1} K^{-1}) on all sides. Calculate:

i. the total mass of water in the tank (density of water = 1000 kg m^{-3}).

ii. the total surface area of the tank

iii. the rate at which heat flows from the tank, by conduction, if the water temperature is 80 °C and the room temperature is 18 °C.

iv. the amount of heat energy lost from the tank when the temperature of the hot water drops from 80 °C to 78 °C? (specific heat of water = 4200 J kg^{-1} K^{-1})

v. the time taken for the temperature to fall from 80 °C to 78 °C.

8

d. i. At what rate must heat flow into 2.36 kg of ice if it is to melt in 1 hour? (heat of fusion for ice = 3.35 x 10^{5} J kg^{-1})

ii. If the heat is supplied by solar radiation falling onto a 0.5 m x 0.5 m surface of ice, what is the intensity (energy/second/square metre) of the solar radiation?

4

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QUESTION 5.

a. $0.6\ m^3$ of oxygen (molecular weight = 32) is in a balloon at a pressure of 9.8×10^4 Pa and a temperature of 18 °C.

If the pressure decreases to 7.3×10^4 Pa and the temperature drops to 4 °C,

i. what is the new volume of the balloon?

ii. what is the number of molecules present?

iii. what is the root mean square speed of a molecule of oxygen at 18 °C?

iv. what is the internal energy of a mole of oxygen gas at 18 °C? (NB oxygen is diatomic.)

7

b. 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, or stiffness factor, of the spring

iii. Calculate the period of the motion.

7

b. A ripple (wave) on the lake's surface in part b. 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 in the form of $y = f(x,t)$ [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 a standing wave.

6

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QUESTION 6.

a. i. A student relaxing by a lake turns on the radio to a station, which broadcasts at 96.9 M Hz. Calculate the wavelength of the signals being transmitted.

ii. Music from the radio travels across the lake and is reflected from a cliff on the other side of the lake resulting in an echo being heard by the student 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 transmitted radio signal (part i.) and the sound wave (part ii.).

6

b. Light, of wavelength in air of 575 nm, is incident on a block of glass whose refractive index is 1.53. The refractive index of air is 1.0. Determine:

i. the wavelength of light in the glass

ii. the angle of refraction if the angle of incidence was 20^{0}

The light passes through the glass block and returns to air. Determine

vi. the critical angle for light passing from the glass to air.

4

c. An object is placed 450 mm in front of a concave mirror whose radius of curvature is 600 mm. Draw a rough ray diagram to show the position of the image.

2

d. i. An object is placed 10.0 mm to the left of a biconvex lens of focal length 8.0 mm.

α. Draw a rough ray diagram showing formation of the image.

β. Determine the position, nature and magnification of the image using the lens equation

ii. If another biconvex lens of focal length 20.0 mm is placed 55.0 mm behind the first lens, determine the final position, nature and magnification of the image.

iii. What optical instrument has this arrangement of lenses and ray diagram?

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QUESTION 7.

a. i. Archimedes' principle has been known for over 2200 years. What does it tell us about floating or submerged objects?

ii. A large stone is connected to a spring balance by a string of negligible mass. In air, the balance reads 90 N, but when the stone is completely submerged into a tank of water the balance shows 50 N.

<u>Data</u>: Density of Water = 1000 kg/m^3

α Draw a free-body diagram for the case when the stone is submerged. Be sure to label all forces for this system.

β Determine the volume of the stone

γ Determine the density of the stone (assumed uniform).

8

b. A pipe of diameter 30 cm carries crude oil to a refinery at the rate of 2000 litres per minute. This pipe later reduces to 15 cm in diameter.

i. What is the volume rate of flow of oil in the smaller pipe?

ii. What is the velocity of oil in the two pipes?

4

c. A service lift of mass 600 kg hangs from a metal cable 3.00 m long. The cable has a cross-sectional area of 0.25 cm^2, and with this load the cable stretches 0.42 cm beyond its normal (unloaded) length. For the cable, calculate:

i. the stress

ii. the strain

iii. Young's modulus of the metal.

iv. If the breaking stress of the cable is 7×10^8 Pa, what is the maximum load the lift can carry?

8

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

$L = I\omega$

$\Delta L = Tt$

$W = T\theta$

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

$P = T\omega$

Mechanics Equation Sheet

$\Sigma F_x = 0$

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

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

$\Sigma F_y = 0$

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

$\omega = \omega_o + \alpha t$

$\Sigma M = 0$

$v = u + at$

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

$F = ma$

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

$s = R\theta$

$F = \mu N$

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

$v = R\omega$

$F = -ks$

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

$a = R\alpha$

$W = Fs$

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

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

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

$T = Fr$

$PE = mgh$

$I_C = Mk^2$

$P = Fv$

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

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

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

$p = mv$

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

$I = Ft$

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

$L = I\omega$

$\Delta L = Tt$

$W = T\theta$

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

$P = T\omega$

Properties of Matter/Fluids Equation Sheet

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

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

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

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

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

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

$$v = \sqrt{2 g h}$$

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

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

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

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

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

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

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

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

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

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

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-)

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

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

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

Waves/Optics Equation Sheet

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

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

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

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

$n_1 \sin i = n_2 \sin r$ $\qquad n_1 c_1 = n_2 c_2$ $\qquad d_a = \frac{d}{n}$

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

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

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

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

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

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

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

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