Cover Type A

University of Technology, Sydney

THIS PAPER MAY BE REMOVED FROM THE EXAM CENTRE.

AUTUMN SEMESTER, 2002

FACULTY OF SCIENCE

FOUNDATIONS OF PHYSICS

68101

FRIDAY, 21 JUNE, 2002

START 6:00 PM - FINISH 9:10 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

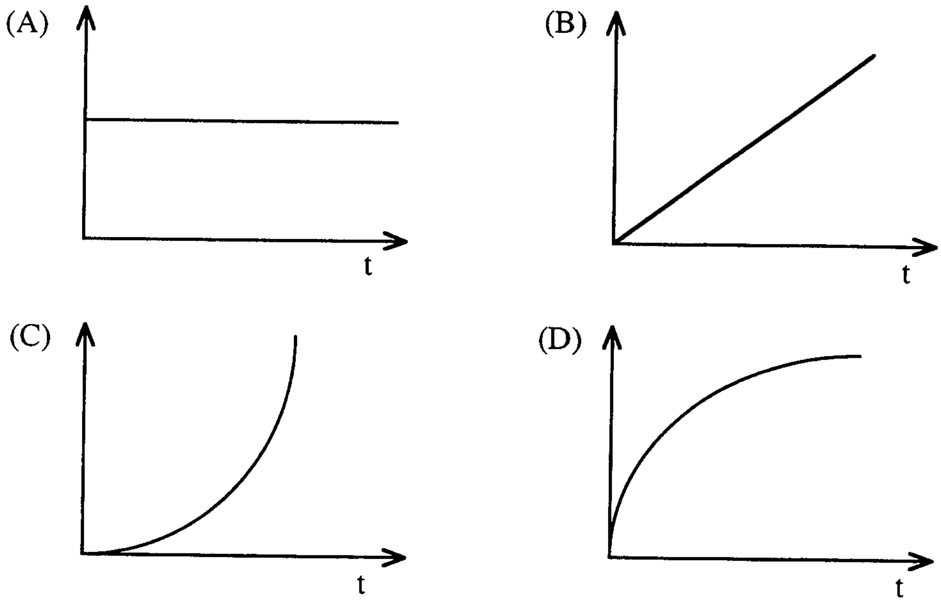
1 Curie $= 3.70 \times 10^{10}$ becquerel

SECTION A.
(THIS QUESTION IS COMPULSORY)

QUESTION 1.

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

i. An object is dropping under gravity. Which of the following graphs represents the variation of **velocity** with time?



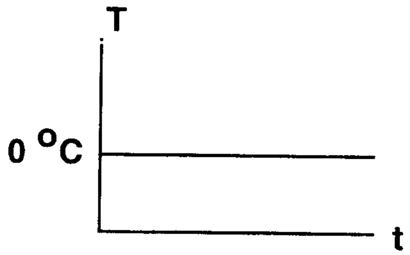
ii. There are 2 spheres made of the same material; one has twice the radius of the other. If they are both at the same temperature, and the smaller one loses heat, by radiation, at a rate of 20 J s^{-1}, at what rate does the larger one loose its heat energy by radiation?

A. 5 J s^{-1} B. 10 J s^{-1} C. 20 J s^{-1}

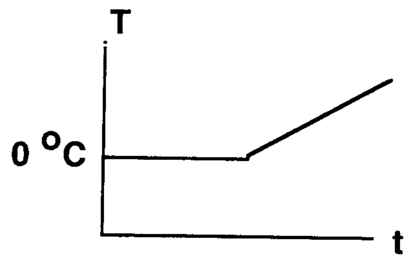
D. 40 J s^{-1} E. 80 J s^{-1} F. none of A - E

iii. 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 part of the way through the time interval all the ice has melted?

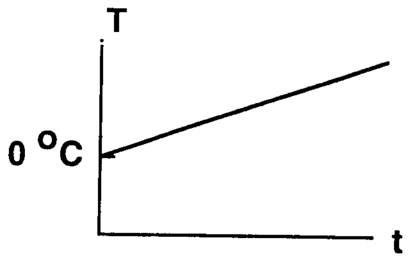
A.



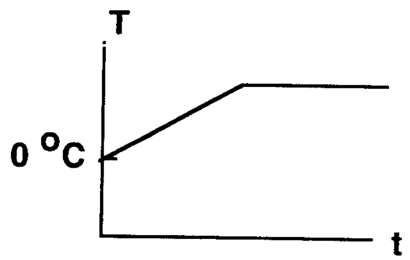
B.



C

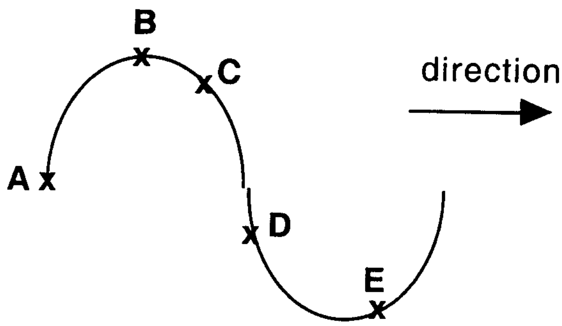


D.



E. None of the above

iv. The diagram shows a travelling wave



At the instant shown:

A. Particle A is moving the fastest.

B. Particle B is moving the fastest.

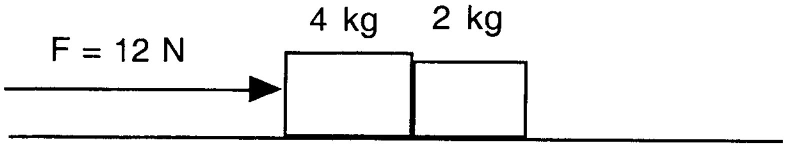
C. Particle C is moving the fastest.

D. Particle D is moving the fastest.

E. Particle E is moving the fastest.

F. All particles are moving at the same speed

v. A force of 12N is applied to two blocks of mass 4 kg and 2 kg on a frictionless horizontal surface as shown in the diagram.



What is the magnitude of the force exerted by the 4 kg block on the 2 kg block?

A. 2 N B. 4 N C. 6 N D. 12 N

vi. The buoyancy (or upthrust) force on an immersed body has the same magnitude as

A. the weight of the body

B. the weight of the fluid displaced by the body

C. the difference between the weights of the body and the displaced fluid

D.. the average pressure of the fluid times the surface area of the body.

vii. Two steel balls, one of which weighs twice as much as the other, roll off a horizontal table with the same speed. Compare the horizontal distances from the base of the table where they land.

A. both balls hit the floor at approximately the same horizontal distance from the base of the table.

B. the heavier ball hits the floor at about half the distance than does the lighter one

C. the heavier ball hits the floor at about twice the distance of the lighter one

D. the heavier ball hits the floor at a considerably smaller distance than does the lighter one but not half the distance.

E. the heavier ball hits the floor at a considerably larger distance than does the lighter one but not twice the distance

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b.

i. A student wants to determine the density of Brass (density equals mass/volume). She collects the following six objects and measures their volume and their mass;

	Volume	Mass
brass cylinder	7.92 ml	59.9 grams
brass sphere number 1	3.26 ml	25.0 grams
brass sphere No. 2	11.8 ml	89.5 grams
brass sphere number 3	21.0 ml	164.3 grams
Odd shaped brass object	27 ml	224.1 grams
Brass rectangular block	18.6 ml	151.3 grams

Use as many of these results as you can and the graph paper provided to determine the density of brass.

ii. How would you have measured the volume of the odd shaped object?

iii. What is the uncertainty in the final answer?

iv. How could you improve the accuracy of the final answer?

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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 in some cases videos. Choose one of those topics, give the name of research topic, and briefly (in one or two paragraphs) describe the area of research and discuss its importance.

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SECTION B.

Attempt any 5 questions in this Section

QUESTION 2.

(a) A student observes that a block suspended from a spring vibrates with a period, T. When the vibrations eventually die away, he notices that the stretched spring is a length, s, greater than in the unstretched state. On doing some calculations, he comes up with the result that

$$T = \sqrt{\frac{s}{g}}$$

where g is the acceleration due to gravity.
Using the method of dimensions, decide whether or not his result is plausible.

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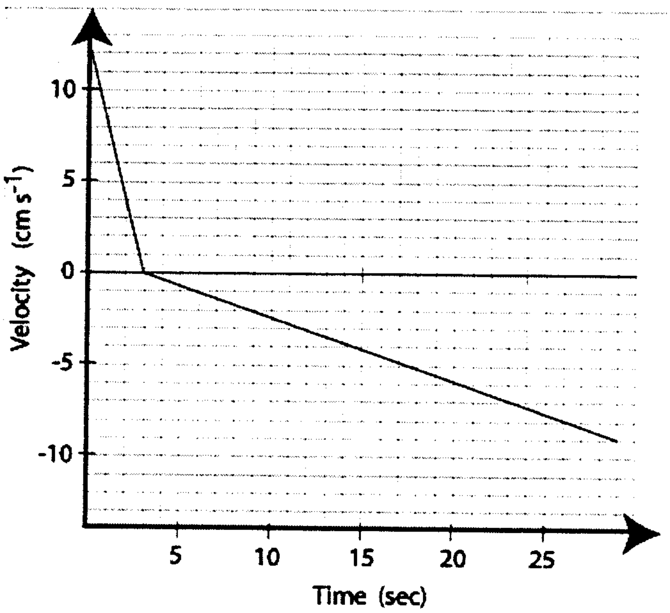
(b) The graph below represents a rolling ball bouncing off a brick wall.



i. At what time does the ball return to the location it had at t = 0?

ii. What is the acceleration of the ball after the collision? 5

(c) A motorist in a 60 kph zone is travelling at a constant speed of 100 kph when he passes a waiting police car, which immediately sets off (from rest) in pursuit with a constant acceleration of 2.5 m/s^2.

i. How long will it take the police car to catch the motorist?

ii. How far will the police car have travelled in this time?

7

(d) A boat sets off to cross a river, hoping to arrive at a pier 1km away and directly opposite its starting point. The river is flooded, with a dangerous current of 10 kph flowing. In still water the boat is capable of travelling at 20 kph.

i. Find the direction in which the boat must be steered in order to arrive directly at the pier.

ii. How long will the journey take?

5

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QUESTION 3.

(a) A 600 N Physics student stands on a bathroom scale in a lift. As the lift starts moving, the scale reads 680 N.

i. Find the acceleration of the lift (magnitude and direction).

ii. What is the acceleration when the scale reads 580 N?

iii. What is the tension in the supporting cable when the scale reads zero? Explain.

8

(b) A box resting on the floor is kicked, giving it an initial velocity of 2 m/s. It slides across the (rough) floor, coming to a stop 1 m from its initial position. Find the coefficient of friction between the box and floor.

5

(c) A person of mass, M, stands in the middle of a tightrope, which is fixed at the ends to two buildings separated by a horizontal distance, L. The rope sags in the middle, stretching slightly.

i. The tightrope walker wants the rope to sag vertically by no more than a distance h. Find the minimum tension, T, that the rope must be able to withstand without breaking, in terms of h, g, M, and L. Be sure to draw a diagram!

ii. Based on your result to (i) above, explain why it is not possible for h to be equal to zero.

<u>7</u>

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QUESTION 4.

a. A metal block which has a volume of 20.00 ml at 20 ^{o}C is in a glass beaker with 180.00 ml of water at 20 ^{o}C. The glass beaker holds 200.00 ml at 20 ^{o}C. When the beaker with the water and the metal block are both at 50 ^{o}C, how much water would spill out of the flask?

(α_{metal} = 1.1 x 10^{-5} K^{-1}, β_{water} = 7.3 x 10^{-5} K^{-1} , α_{glass} = 0.8 x 10^{-5} K^{-1})

4

b. The original temperature of the water (0.18 kg) and the beaker (0.12 kg) in part a. was 20 ^{o}C. The metal block (0.16 kg) was at a higher temperature and when placed in the water the final temperature of the mixture was 50 ^{o}C. What was the initial temperature of the metal block? (Ignore any water that spills out.)

(c_{metal} = 660 J kg^{-1} K^{-1}, c_{glass} = 460 J kg^{-1} K^{-1}, c_{water} = 4190 J kg^{-1} K^{-1})

4

c. If the metal block in part b had been at 280 ^{o}C, how much ice would melt if it was placed in a large block of ice?

($L_{f\ ice}$ = 3.35 x 10^{5} J kg^{-1})

4

d. In a room, heat is transferred by conduction through a sheet of material 0.7 metres by 0.5 metres by 7 mm at a rate of 20.1 J s^{-1}. If the temperature of the outside surface of the material is 16 ^{o}C, what is the temperature of the inside surface? (k = 0.11 in W K^{-1} m^{-1})

4

e. Heat is lost by radiation from the outside surface in part d (at 16 ^{o}C) at a rate of 20.1 J s^{-1}. If the temperature of the surrounding air is 3 ^{o}C, calculate the emissitivity of the material.

4

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QUESTION 5.

a. i. What is the root mean square speed of a molecule of nitrogen (molecular weight = 28) at 20 ^{o}C?

ii. What is the internal energy of a mole of nitrogen gas at 20 ^{o}C? (NB nitrogen is diatomic.)

4

b. A metallic cylinder has a fixed volume of 8.7 litres and contains nitrogen (molecular weight = 28) at 20 ^{o}C and at a pressure of 5.3 x 10^5 Pa. If the pressure reaches 1.5 x 10^6 Pa, the cylinder will burst.

i. At what temperature will the cylinder burst?

ii. How many moles of gas are in the cylinder at 20 ^{o}C?

4

c. A ride at an amusement park consists of a cabin (mass 120 kilograms) attached vertically to a large spring. The cabin is pulled down and let go when the displacement is 3.5 metres, resulting in a vertical oscillating motion.
It is found that with two passengers (70 kilograms each) in the cabin, the force on the spring is 850 Newtons when the displacement is 3.5 metres. Calculate:

i the force constant of the spring

ii the angular frequency of the motion

iii the period of the motion.

5

d. i. Which of the following equations represents the motion of a wave? (In these equations x and y are in metres and t is in seconds.)

α $y = 10t - 4.9\,t^2$

β. $y = 5.0 \sin (3.0\,x + \pi/2)$

γ. $y = 5.0 \sin (3.0\,x - 10t + \pi/2)$

For the wave represented by that equation, determine:

ii the wavelength

iii the frequency

iv. the wave speed

v. the amplitude

vi. the equation of a second wave that when combined with the original wave produces a standing wave.

7

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QUESTION 6.

a. An observer at a particular location sees a stroke of lightning and three seconds later hears the associated thunder. How far from the observer was the lightning?
(Speed of light = 3.0×10^8 ms^{-1} speed of sound = 340 m s^{-1})

3

b. Light, of wavelength 550 nm, travelling in air (n=1) is incident on a block of glass whose refractive index is 1.55. Determine:

i. the frequency of the incident light (in air)
ii. the speed of light in the glass
iii. the wavelength of light in the glass
iv. the frequency of light in the glass
v. the angle of refraction if the angle of incidence was 25°

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

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

7

c. A 5mm object is placed 40 mm in front of a convex lens of focal length 25 mm.

i. Sketch a ray diagram showing the image formation.
ii. Use the lens equation to determine the nature, position and size of the image.

6

d. Explain with the aid of ray diagrams

i. an optical instrument involving a mirror , and
ii. an optical instrument involving two lenses

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QUESTION 7.

(a) i. What is meant by the term "stress" when referred to a solid object?

ii. Distinguish between "compressive stress" and "tensile stress".

iii. Physicists often refer to "strain" when discussing stressed objects. Briefly explain the meaning of this term, and name at least two types of strain.

iv. A copper wire 1mm in diameter and 2 m long is used to support a pot plant of mass 5kg.

Young's modulus for copper, $Y_{Cu} = 12.3 \times 10^{10}$ N/m^2.

Poisson's ratio for copper, $\sigma_{Cu} = 0.32$

α) By how much does the wire stretch under the load?

β) What is the change in width of the wire?

11

(b) Water pressure to a small town is maintained by a 30m high water tower which is covered at the top but still open to the atmosphere.

The density of water is 1000 kg/m^3.

i. What is the gauge pressure at ground level, in atmospheres?

ii. A 17mm diameter garden hose in this town is open at one end and is spilling water. What force is necessary to stop the leak?

3

(c) While enjoying a canteen lunch at Alice's before your Physics lecture, you notice that a wonton in your noodle soup is floating two-thirds submerged. What is its density? (It is only a light soup, so we can assume a density equal to that of water.)

4

(d) In a brief paragraph and using a suitable diagram, describe how lift in an aircraft wing can be explained by Bernoulli's equation.

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

$L = I\omega$

$\Delta L = Tt$

$W = T\theta$

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

$P = T\omega$

Properties of Matter/Fluids Equation Sheet

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

$$P = P_0 + \rho g h$$ $$P + \tfrac{1}{2}\rho v^2 + \rho g y = \text{constant}$$ $$v = \sqrt{2gh}$$

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

$$Q = Av = \text{constant}$$ $$Q = \frac{\pi R^4 \Delta P}{8\eta l}$$ $$v_1^2 = \frac{2(P_1 - P_2)}{\left[\rho\left\{\left(\frac{A_1}{A_2}\right)^2 - 1\right\}\right]}$$

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

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

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

$F = -kx$

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

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

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

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

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

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

$c = f\lambda$

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

$n_1 \sin i = n_2 \sin r$

$n_1 c_1 = n_2 c_2$

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

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

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

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

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

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

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

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

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

$d \sin\theta = m\lambda$

$a \sin\theta = m\lambda$

$a \sin\theta = 1.22\lambda$

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

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

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

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

$I = I_0 \cos^2\theta$

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

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

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