Q1	Q6
Q2	Q7
Q3	Q8
Q4	Q9
Q5	
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FIRST NAMES: ______________________________

SURNAME: ______________________________

STUDENT NUMBER: ______________________________

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED PHYSICS AND ENGINEERING MATHEMATICS

BACHELOR OF ENGINEERING TECHNOLOGY IN EXTRACTION METALLURGY
BACHELOR OF ENGINEERING TECHNOLOGY IN PHYSICAL METALLURGY

MODULE ENGINEERING PHYSICS X 1A (THEORY) PHASED1

CAMPUS DFC

JANUARY EXAMINATION 2020

DATE 07/01/2020	**SESSION: 08:00 – 11:00**
ASSESSOR	**DR. J. CHANGUNDEGA**
INTERNAL MODERATOR	**PROF. L. REDDY**
DURATION 3 HOURS	**MARKS 108**

NUMBER OF PAGES: 21 PAGES, INCLUDING BLANK SPACE AND INFORMATION SPACE

INSTRUCTIONS: CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT)

ANSWER ALL QUESTIONS IN THE SPACES PROVIDED IN THIS QUESTION PAPER

QUESTION 1: PHYSICS AND MEASUREMENT

1.1. Five clocks (A to E) are being tested in a laboratory. For one week, exactly at 12 Noon, as determined by South African Standard Time (SAST), the clocks read shown in the following table.

Clock	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
A	12:36	12:36	12:37	12:37	12:37	12:37	12:38
B	11:59	12:00	11:59	12:00	12:00	11:59	12:00
C	15:50	15:51	15:52	15:53	15:54	15:55	15:56
D	12:03	12:02	12:01	12:00	11:59	11:58	11:57
E	12:03	12:02	12:01	12:01	12:01	12:01	12:01

1.1.1. Define precision. (1)

1.1.2. Which clock is most accurate? (1)

1.1.3. Which clock is most precise? (1)

1.2. According to Stokes' formula, the viscous force is given by

$$F_r = 6\pi r\eta v$$

Where r is a radius, η is the coefficient of viscosity of the fluid and v is velocity.

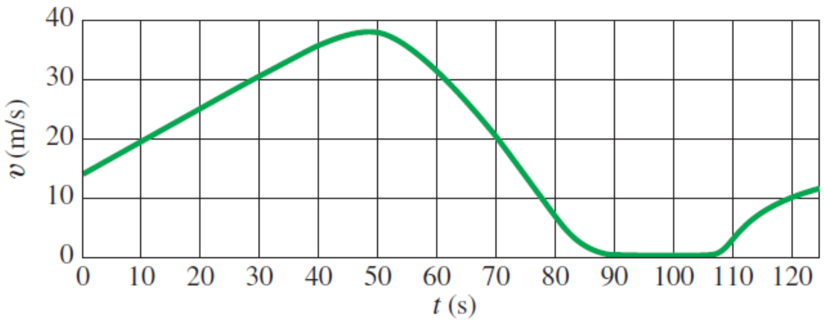
1.2.1. Use the above equation to determine the dimensions of viscosity η. (5)

1.3. A multivitamin tablet can contain 3.0 mg of vitamin B_2 (riboflavin) and the recommended daily allowance is 0.003 g/day.
How many such tablets should a person take each day to get the proper amount of this vitamin, assuming that this is his only source of the vitamin? (4)

[12]

QUESTION 2: KINEMATICS, VECTORS AND DYNAMICS

2.1. The graph shows the velocity of a train as a function of time.



2.1.1. At what time was its velocity greatest? (1)

2.1.2. During what time interval, was the velocity constant? (2)

2.2. A fire hose held near the ground as illustrated in the diagram, shoots water at a speed of 6.5 m/s.

What is the launch angle θ_i if the water lands 2.5 m away? (4)

2.3. Two crates, of mass 65 kg and 125 kg are in contact and at rest on a horizontal surface as shown in the diagram. A 650 N force is exerted on the 65 kg crate.

If the coefficient of kinetic friction is 0.18, calculate the acceleration of the system. (5)

Additional working space is available on the next page

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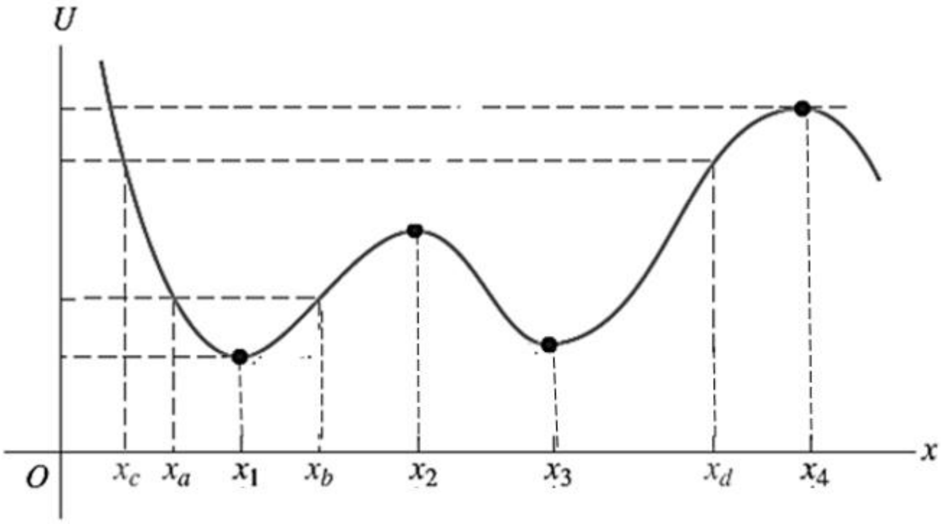
QUESTION 3: ENERGY, LINEAR MOMENTUM AND COLLISIONS

3.1. A particle is acted upon by a conservative force. The graph shows the variation of the potential energy of a particle with position along the x axis.

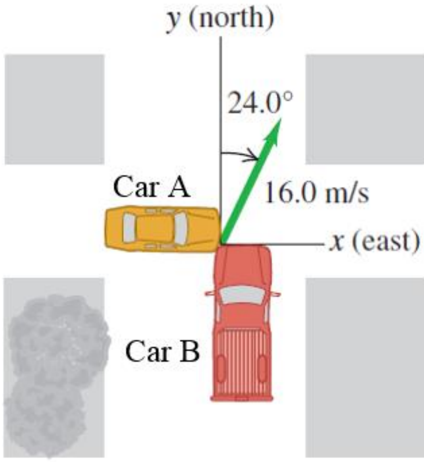


3.1.1. Using the labelled positions along the x axis, identify a position of stable equilibrium. (1)

3.1.2. Using the labelled positions along the x axis, identify a position of unstable equilibrium. (1)

3.1.3. At what position is the kinetic energy a minimum? (1)

3.2. At an intersection, car A with mass 950 kg traveling East on collides with car B with mass 1900 kg that is traveling North as illustrated in the diagram.



The two vehicles stick together as a result of the collision, and the wreckage slides at 16.0 m/s in the direction 24^0 East of North. Calculate the speed of each car before the collision. The collision occurs during a heavy rainstorm therefore you can ignore friction forces between the vehicles and the wet road. (6)

3.3. The linear momentum of a particle is given by

$\vec{p} = \left[4.8t^2\hat{\imath} - 8.0\hat{\jmath} - 8.9t\hat{k}\right]$ kg m s^{-1}

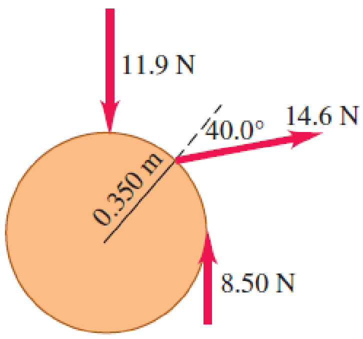
What is the net force acting on the particle (in terms of time t)? (3)

[12]

<u>QUESTION 4: ROTATIONAL DYNAMICS AND ELASTIC PROPERTIES OF SOLIDS</u>

4.1. A helicopter has large main rotor blades that rotate above it in order to provide lift. There is also a set of rotating small tail blades. Explain the purpose of the tail blades? (3)

4.2. A wheel of radius 0.350 m is pivoted about an axis through point *O* at its centre, as shown in the diagram. Calculate the net torque about this axis due to the three forces indicated. The 11.9 N force acts downwards while the 8.5 N force acts at a upwards and the 14.6 N force acts at an angle of 40^0 to the radius of the wheel as shown. (7)



4.3. A sample of oil having an initial volume of 600 cm^3 is subjected to a pressure increase of 3.60×10^6 Pa and the volume is found to decrease by 0.45 cm^3. What is the bulk modulus of the material? (4)

[12]

QUESTION 5: UNIVERSAL GRAVITATION

Constants

$G = 6.674 \times 10^{-11}$ N m^2 kg^{-2}
$M_{Eath} = 5.97 \times 10^{24}$ kg
$R_{Earth} = 6.37 \times 10^6$ m

5.1. The Earth is closer to the sun in November than in May. In which of these two months does the Earth move faster in its orbit? (1)

Justify your answer. (2)

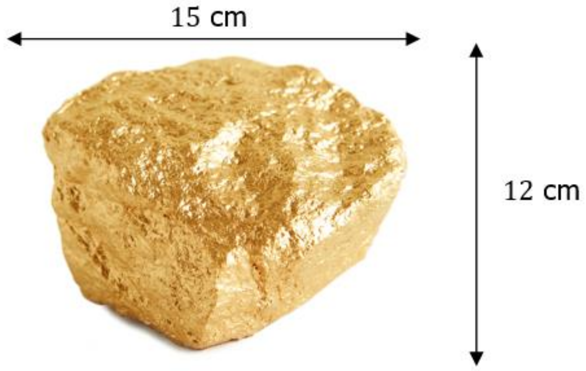
5.2. Deimos, a moon of Mars, is about 12 km in diameter with a mass of 2.0×10^{15} kg. Determine the magnitude of the mean acceleration of gravity on the surface of Deimos. (5)

5.3. Assume that the Earth and its Moon are isolated and uninfluenced by the Sun. The mean distance of the Moon from the Earth is 3.84×10^8 m.
What is the gravitational potential energy of a 1 kg object that is located midway between the Earth and Moon? (5)

[12]

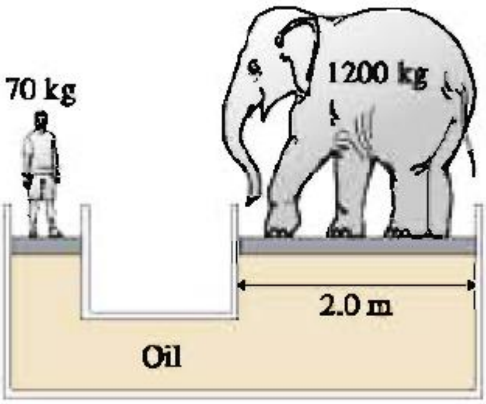
QUESTION 6: FLUID MECHANICS

6.1. A student found the block of metal shown in the diagram and she believes that it is a piece of gold. The distances are given so that you have an idea of the size of the block.



To test if this is truly pure gold, she weighed the metal in air ($W_{in\ air}$) and then she weighed it in water ($W_{in\ water}$).
Use equations to show how she would calculate the block's density without having to take any more measurements. (4)

6.2. The 70.0 kg student in the diagram balances a 1 200 kg elephant on a hydraulic lift.



Both the large and small pistons have a circular cross-sectional area and the diameter of the large piston is 2.0 m as indicated in the diagram. What is the diameter of the piston that the student is standing on? (4)

6.3. Coca-Cola (which is mostly water) flows in a pipe at a beverage plant with a flow rate that fills 220 cans per minute.
Each can holds 355 mL of soft drink.
At one point X along the pipe, the cross-sectional area of the pipe is 2.00 cm^2.

Determine

6.3.1. the volume flow rate of the Coca-Cola in the pipe (in m^3/s). (3)

6.3.2. the speed of the Coca-Cola at point X in the pipe. (3)

[12]

QUESTION 7: OSCILLATIONS AND WAVES

7.1. You are captured by Martians (inhabitants of Mars), taken into their ship, and put to sleep. You awake some time later and find yourself locked in a small room with no windows. The only items that the Martians have left you with are your digital watch, your school ring, your ruler, your calculator and your long silver-chain necklace. Explain how you could use the simple pendulum to determine whether you are still on the Earth.

(4)

7.2. What is the intensity (in W m^{-2}) of a sound whose level is at the human threshold of pain (120 dB)? The threshold of hearing is at an intensity of 1.0 pW m^{-2} (4)

7.3. A musician is tuning her instrument to one musical sound (note) called ‘concert A’ which has a frequency of 440 Hz. She plays the note on her instrument while listening to tuning device sounding a perfect ‘concert A’. She hears beats of frequency 3 Hz. She then tightens her instrument’s string slightly (for a higher frequency) and now hears beats at 4 Hz. What was the frequency of the sound she played when she heard the 3 Hz beats? (4)

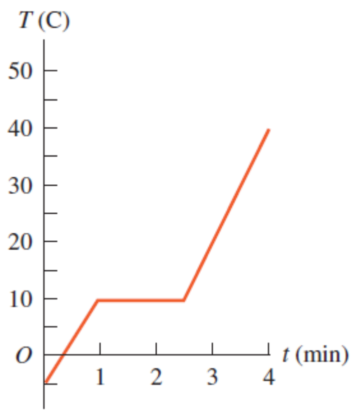
[12]

QUESTION 8: THERMODYNAMICS

8.1. We are very lucky that the Earth is not in thermal equilibrium with the Sun (which has a surface temperature of 5 800 K) but why are the two bodies not in thermal equilibrium? (2)

8.2. State the second law of thermodynamics. (2)

8.3. Heat is added to a 500 g solid sample at the rate of 10.0 kJ/min while recording its temperature as a function of time. The data is plotted in the graph below.



8.3.1. What is the latent heat of fusion for this solid? (4)

8.3.2. What is the specific heat of the solid state of this material? (4)

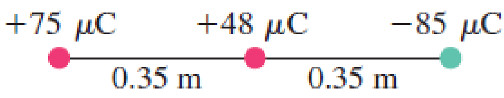
[12]

QUESTION 9: ELECTRICITY AND MAGNETISM

Constants
$k_e = 8.99 \times 10^9$ N m^2 C^{-2}

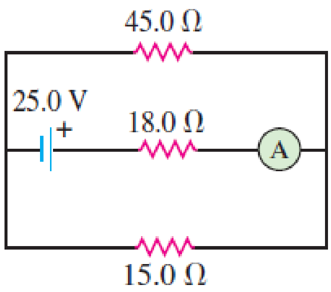
9.1. What is a ferromagnetic material and explain briefly how it can be magnetised. A diagram is not necessary.
(4)

9.2. The particles in the diagram are located along one line. The distances between the charges are shown.



Calculate the net electric force on the +75 μC charge, assuming that the three charge system is isolated. (5)

9.3. Determine the current reading of the ammeter in the diagram if the battery has an internal resistance of 3.26 Ω. (5)



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[12]

TOTAL [108]

INFORMATION SPACE

Plane Geometry, Areas and Volumes of Geometric Figures			
Shape	Perimeter	Area	Volume
Square	$P = 4s$	$A = s^2$	
Rectangle	$P = 2l + 2w$	$A = l\,w$	
Circle	$C = 2\pi r$	$A = \pi r^2$	
Sector of a circle		$A = \frac{1}{2}\theta r^2$	
Triangle		$A = \frac{1}{2}\,b\,h$	
Trapezoid		$A = \frac{1}{2}(b_2 + b_1)h$	
Parallelogram	$P = 2a + 2b$	$A = b\,h$	
Cube		$A = 6s^2$	$V = s^3$
Rectangular solid		$A = 2(l\,w + l\,h + w\,h)$	$V = l\,w\,h$
Circular cylinder		$A = 2\pi r h$ (without top and bottom)	$V = \pi r^2 h$
Non-circular cylindrical prisms			$V = A\,h$
Sphere		$A = 4\pi r^2$	$V = \frac{4}{3}\pi r^3$
Right Circular Cone		$A = \pi r l$	$V = \frac{1}{3}\pi r^2 h$

KINEMATICS, VECTORS AND DYNAMICS

1D Motion	Vectors
$\Delta x = x_f - x_i$	Polar Coordinates: $y = r\sin\theta$ $\quad x = r\cos\theta$ $\quad \tan\theta = \frac{y}{x}$ $\quad r = \sqrt{y^2 + x^2}$
$v_{x\,avg} = \frac{\Delta x}{\Delta t} = \frac{total\ displacement}{total\ time}$	
$v_{avg} = \frac{d}{\Delta t} = \frac{total\ distance}{total\ time}$	Vector Components: $A_x = A\cos\theta$ $\quad A_y = A\sin\theta$ $\quad A = \sqrt{{A_x}^2 + {A_y}^2}$ $\quad \tan\theta = \left\|\frac{A_y}{A_x}\right\|$
$v_x = \frac{dx}{dt} = x' = \dot{x}$	
Constant velocity: $v_x = v_{x\,avg} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t}$	$\vec{v} = \frac{d\vec{r}}{dt}$
$a_{x\,avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$	$\vec{a} = \frac{d\vec{v}}{dt}$
$a_x = \frac{dv_x}{dt} = v_x' = \dot{v}_x$	
$a_x = \frac{dv_x}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2} = x'' = \ddot{x}$	

1D Motion Continued	**2D Motion**
$v_{xf} = v_{xi} + a_x t$ $v_{x\,avg} = \dfrac{v_{xi} + v_{xf}}{2}$ $\Delta x = v_{xi} t + \dfrac{1}{2} a_x t^2$ $v_{xf}{}^2 = v_{xi}{}^2 + 2a_x(\Delta x)$ $\Delta x = v_{xf} t - \dfrac{1}{2} a_x t^2$ $\Delta x = \left(\dfrac{v_{xi} + v_{xf}}{2}\right) t$	Projectile Motion: $t_{total} = \dfrac{v_i \sin\theta_i}{g}$ $h = \dfrac{v_i{}^2 \sin^2\theta_i}{2g}$ $R = \dfrac{v_i{}^2 \sin 2\theta_i}{g}$ Uniform Circular Motion: $a_c = \dfrac{v^2}{r}$ $T = \dfrac{2\pi r}{v}$ $\omega = \dfrac{2\pi}{T}$ $v = r\omega$ $a_c = r\omega^2$ $F_r = \dfrac{mv^2}{r}$
$\Delta v = v_f - v_i = \int_{t_i}^{t_f} a\, dt$	**Forces and Laws of Motion**
$\Delta x = x_f - x_i = \int_{t_i}^{t_f} v\, dt$	$\sum \vec{F} = m\vec{a}$

ENERGY, ENEGRY CONSERVATION AND LINEAR MOMENTUM

Energy	**Energy Conservation**
$W = \vec{F} \cdot \Delta\vec{r} = F\Delta r \cos\theta$ $\quad W = \int F_x\, dx$	$\Delta K + \Delta U_g + \Delta U_S = 0$ (isolated system, no friction)
$K = \dfrac{1}{2} mv^2$ $\quad U_g = mgy$ $\quad U_S = \dfrac{1}{2} kx^2$	$\Delta K + \Delta U_g + \Delta U_S + f_k d = 0$ (isolated system with friction)
$F_s = -kx$	$\Delta K + \Delta U_g + \Delta U_S = W_{\sum F}$ (non-isolated system, no friction)
$F_x = -\dfrac{dU}{dx}$	$\Delta K + \Delta U_g + \Delta U_S + f_k d = W_{\sum F}$ (non-isolated system with friction)
$P = \dfrac{dE}{dt} = \dfrac{dW}{dt}$ $\quad P_{avg} = \dfrac{E}{\Delta t} = \dfrac{W}{\Delta t}$ $P = \vec{F} \cdot \vec{v} = Fv\cos\theta$	

Linear Momentum

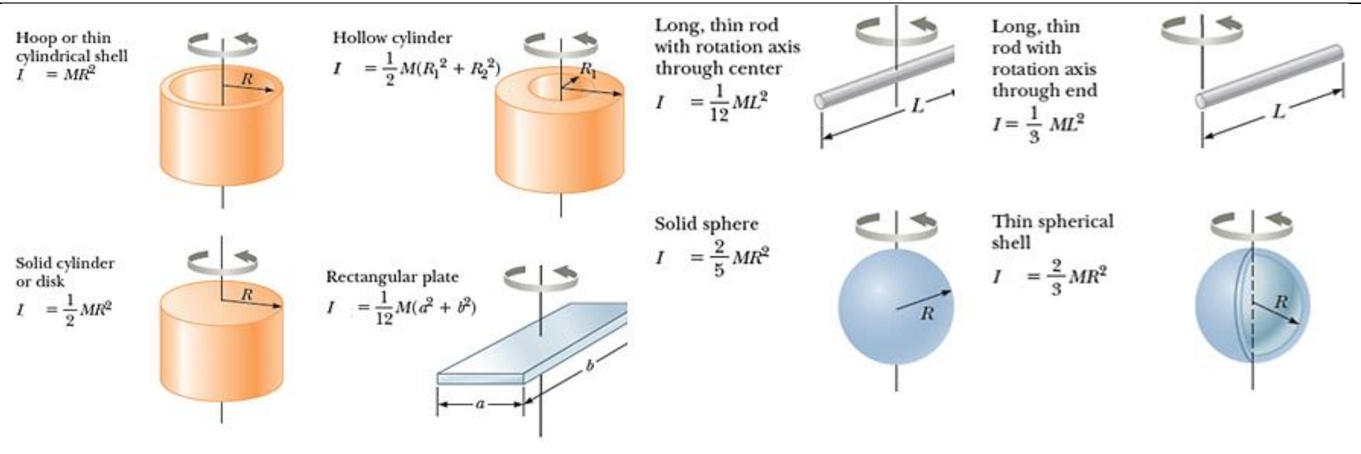
$\vec{p} = m\vec{v}$	$\sum \vec{F} = \dfrac{d\vec{p}}{dt}$	$\Delta\vec{p} = \vec{I} = \vec{F}\Delta t$

ROTATIONAL MOTION AND ELASTIC PROPERTIES OF SOLIDS

Rotational Motion

$s = r\theta$ $v = r\omega$ $a_t = r\alpha$	$\theta(rad) = \pi\left[\frac{\theta(deg)}{180°}\right]$
$\omega_{avg} = \frac{\Delta\theta}{\Delta t}$ $\omega = \frac{d\theta}{dt}$	$a = \sqrt{{a_t}^2 + {a_r}^2} = \sqrt{r^2\alpha^2 + r^2\omega^4}$
$\alpha_{avg} = \frac{\Delta\omega}{\Delta t}$ $\alpha = \frac{d\omega}{dt}$	$\vec{\tau} = \vec{r} \times \vec{F}$ $\tau = Fr\sin\theta$
$\omega_f = \omega_i + \alpha t$ $\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$ ${\omega_f}^2 = {\omega_i}^2 + 2\alpha(\Delta\theta)$ $\Delta\theta = \left(\frac{\omega_i + \omega_f}{2}\right)t$	$K_R = \frac{1}{2}I\omega^2$ $\sum \tau = I\alpha$
$\vec{L} = \vec{r} \times \vec{p}$ $L = I\omega$	

Rotational Inertia



Elastic Properties of Solids

$Y = \frac{F/A}{\Delta L/L_i}$ $S = \frac{F/A}{\Delta x/h}$ $B = -\frac{\Delta P}{\Delta V/V_i}$

UNIVERSAL GRAVITATION

$F_g = G\frac{m_1 m_2}{r^2}$	$g = G\frac{M_E}{{R_E}^2}$
$\left(\frac{F_g}{m}\right) = G\frac{M_{Planet}}{r^2}$	$T^2 = \left[\frac{4\pi^2}{GM_{Sun}}\right]a^3$
$U_g = -\frac{GM_E m}{r}$	

FLUID MECHANICS	
Fluid Pressure and Archimedes' Principle	
$P = \frac{F}{A}$ $\quad P = P_{atm} + \rho g h$ $\quad \frac{F_1}{A_1} = \frac{F_2}{A_2}$ $\quad Fraction\ submerged\ = {\rho_{body}}/{\rho_{fluid}}$	
Fluids in Motion	
Continuity Equation $Av =$ constant	Bernoulli's Equation $P + \frac{1}{2}\rho v^2 + \rho g y = constant$
Venturi meter $Q = A_1 A_2 \sqrt{\frac{2(P_1 - P_2)}{\rho({A_1}^2 - {A_2}^2)}} = A_1 A_2 \sqrt{\frac{2\rho_{mano} g h}{\rho({A_1}^2 - {A_2}^2)}}$	Torricelli's Theorem $v_1 = \sqrt{2gh}$
Viscocity $F = \eta \frac{Av}{d}$	*Poiseuille's law* $Q = \frac{V}{t} = \frac{\pi r^4 \Delta P}{8 \eta L}$
Stokes' Formula $F_f = 6\pi\eta r v$ $\quad \eta = \frac{2}{9} r^2 \frac{(\rho - \sigma) g}{v_T}$	Reynolds number $Re = \frac{2\rho v r}{\eta}$

OSCILLATIONS AND WAVES	
Simple Harmonic Motion	
Block-Spring Oscillator $F = -kx$ $\quad \frac{d^2x}{dt^2} = -\omega^2 x$ $\quad \omega = \sqrt{\frac{k}{m}}$ $f = \frac{1}{T}$ $\quad T = \frac{2\pi}{\omega}$ $x = A\cos(\omega t + \phi)$ $E = \frac{1}{2}kA^2$ $v = \pm\omega\sqrt{A^2 - x^2}$	Simple Pendulum $\frac{d^2\theta}{dt^2} = -\omega^2\theta$ $\quad \omega = \sqrt{\frac{g}{L}}$ Physical Pendulum $\frac{d^2\theta}{dt^2} = -\omega^2\theta$ $\quad \omega = \sqrt{\frac{mgd}{I}}$ Torsional Pendulum $\frac{d^2\theta}{dt^2} = -\omega^2\theta$ $\quad \omega = \sqrt{\frac{\kappa}{I}}$
Waves	
Travelling Sinusoidal Waves $k = \frac{2\pi}{\lambda}$ $\quad \omega = \frac{2\pi}{T} = 2\pi f$ $\quad v = f\lambda$ $\quad v = \frac{\omega}{k}$ $y(x,t) = A\sin(kx \mp \omega t + \phi) = A\sin\left[\frac{2\pi}{\lambda}(x \mp vt) + \phi\right]$	Sound Waves $\beta\ (in\ dB) = 10\log\frac{I}{I_0}$ $f' = \left[\frac{v \mp v_O}{v \pm v_S}\right] f$ $f = (f_1 + f_2)/2$ $\quad f_{Beat} = f_1 - f_2$

THERMODYNAMICS	
Temperature $T_{\circ C} = T - 273.15$ $\alpha = \frac{\Delta L}{L_i\,\Delta T}$ $\quad \beta = \frac{\Delta A}{A_i\,\Delta T}$ $\quad \beta = \frac{\Delta V}{V_i\,\Delta T}$	Ideal Gas Laws $P_i V_i = P_f V_f$ $\quad \frac{V_i}{T_i} = \frac{V_f}{T_f}$ $\quad \frac{P_i}{T_i} = \frac{P_f}{T_f}$

	$n = \dfrac{m}{M}$ $\quad PV = nRT \quad PV = Nk_B T$
	$Q = mc\Delta T \quad L = \dfrac{Q}{m}$

Thermodynamic Processes

PV diagram $W = -\left[\int_{V_i}^{V_f} PdV\right]$ First Law $\Delta E_{int} = Q + W$ Isothermal Process $W = nRT \ln\left(\dfrac{V_i}{V_f}\right)$	Conduction $P = \dfrac{Q}{\Delta t} = kA\left\|\dfrac{dT}{dx}\right\|$ Stefan's Law $P = \sigma AeT^4$ Wien's Displacement Law $\lambda_{max} = \left[\dfrac{2.898\times 10^{-3}}{T}\right]$ $metres$
Kinetic Theory of Gases $P = \dfrac{2}{3}\left(\dfrac{N}{V}\right)\left(\dfrac{1}{2}m_0\overline{v^2}\right)$ $\quad \dfrac{1}{2}m_0\overline{v^2} = \dfrac{3}{2}k_B T$ $E_{int} = \dfrac{3}{2}nRT \quad C_V = \dfrac{Q}{n\Delta T} \quad C_P = \dfrac{Q}{n\Delta T}$ Monoatomic Gas $\Delta E_{int} = nC_V\Delta T \quad C_V = \dfrac{3}{2}R \quad C_P = \dfrac{5}{2}R$ Adiabatic Process $PV^\gamma =$ constant $TV^{\gamma-1} =$ constant	Heat Engine $W_{eng} = Q_h - Q_c$ $e = \dfrac{W_{Eng}}{Q_h} = 1 - \dfrac{Q_c}{Q_h}$ Heat Pump $COP = \dfrac{Q_c}{W}$ $W_{pump} = Q_h - Q_c$

ELECTRICITY AND MAGNETISM

Electrostatics

$$F_e = k_e\frac{|q_1||q_2|}{r^2} \qquad \vec{E} = \frac{\vec{F}_e}{q_0} \qquad C = \frac{Q}{\Delta V} \qquad U_E = \frac{Q^2}{2C} = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2$$

$$C = \kappa\frac{\varepsilon_0 A}{d}$$

Direct Current Electricity

$$I = \frac{dQ}{dt} \qquad R = \rho\frac{l}{A} \qquad \rho = \rho_0[1+\alpha(T-T_0)] \qquad P = I\Delta V = I^2R = \frac{(\Delta V)^2}{R}$$

$$\mathcal{E} = I[R_{Eq} + r]$$

Electromagnetism

$$\vec{F}_B = q\vec{v}\times\vec{B} \qquad r = \frac{mv}{qB} \qquad \vec{F}_B = I(\vec{L}\times\vec{B}) \qquad B = \frac{\mu_0 I}{2\pi r} \qquad F_B = \frac{\mu_0 I_1 I_2 L}{2\pi a}$$

$$\Phi_B = BAN\sin\theta \qquad \mathcal{E} = -N\frac{d\Phi_B}{dt} \qquad \frac{\Delta V_2}{\Delta V_1} = \frac{N_2}{N_1}$$

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