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

NOVEMBER EXAMINATION 2019

DATE 14/11/2019 **SESSION: 08:30 – 11:30**

ASSESSOR **DR. J. CHANGUNDEGA**

INTERNAL MODERATOR **PROF. L. REDDY**

DURATION 3 HOURS **MARKS 126**

NUMBER OF PAGES: 20 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. A rather ordinary middle-aged man is in the hospital for a routine check-up. The nurse writes the quantity 200 on his medical chart but forgets to include the units. Which of the following quantities could the 200 represent? (Tick your choice) (1)

(a) his mass in kilograms
(b) his height in metres
(c) his height in centimetres
(d) his height in millimetres
(e) his age in months

Justify your answer. (2)

1.2. How many years older will you be 1.00 gigasecond from now? (Assume that a year has 365 days.) (5)

1.3. According to Albert Einstein, energy can be related to mass through the equation

$$E = \frac{1}{2}mc^2$$

where c is the speed of light in a vacuum.

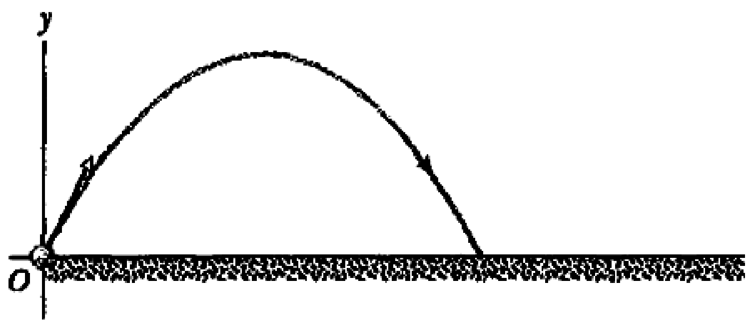
Prove that this equation is dimensionally consistent. (4)

[12]

QUESTION 2: KINEMATICS, VECTORS AND DYNAMICS

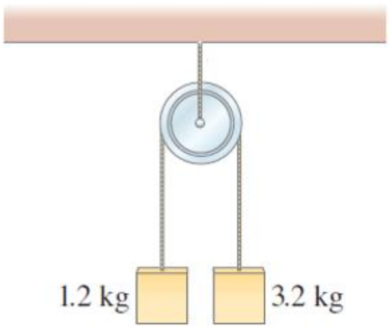
2.1. State Newton's second law of motion. (2)

2.2. The diagram shows the trajectory of a projectile.
Suppose the projectile was fired again from the same starting position and with the same launch angle, but this time, the initial speed of the projectile is increased.
On the same diagram given below, sketch the new trajectory of the projectile. (2)



2.3. A runner accelerates uniformly from rest to 9.00 m/s in 1.28 s. What is her acceleration? (3)

2.4. Suppose the pulley in the diagram is suspended by from the ceiling.



Determine the acceleration of the masses after they are released. Ignore the mass of the pulley and cords. (5)

Additional working space is available on the next page

[12]

QUESTION 3: ENERGY, LINEAR MOMENTUM AND COLLISIONS

3.1. State one difference between a perfectly elastic and a perfectly inelastic collision. (3)

3.2. A bat strikes a 0.145 kg ball. Just before impact, the ball is traveling horizontally to the right at a velocity of 50.0 $\hat{\imath}$ m/s and it leaves the bat traveling to the left at an angle of 30.0^0 above the horizontal with a speed of 65.0 m/s. The ball and bat are in contact for 1.75 milliseconds.

3.2.1. What is the final velocity of the ball? (3)

3.2.2. Determine the average impulse on the ball during this interaction.

(3)

3.3. If one hydrogen atom is located at the origin of the x axis and another hydrogen atom is located at a large positive position x, the potential energy of the pair of hydrogen atoms is given by

$$U(x) = -\frac{C_6}{x^6}$$

where C_6 is a positive constant.

Is the force between the atoms attractive or repulsive? (3)

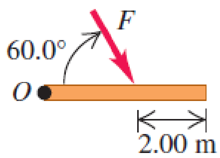
[12]

QUESTION 4: ROTATIONAL DYNAMICS AND ELASTIC PROPERTIES OF SOLIDS

4.1. Explain why concrete with steel reinforcing rods embedded inside it is used in construction rather than plain concrete? (3)

4.2. At t = 0, a wheel (radius 0.200 m), slows down with an angular acceleration of constant magnitude 50 rad/s^2. At t = 3.00 s, a point on the rim of the wheel has an angular speed of 250 rad/s. Through what angular displacement did the wheel turn between t = 0 and t = 3.00 s? (5)

4.3. The rod in the diagram has a length 4.00 m. Calculate the torque (magnitude and direction) on the rod about point *O* due to the force $\vec{F}$ of magnitude is $F = 10.0$ N. (4)



[12]

QUESTION 5: UNIVERSAL GRAVITATION

Constants

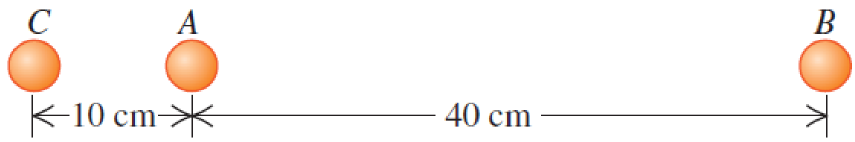
$G = 6.674 \times 10^{-11}$ N m^2 kg^{-2}

5.1. State Kepler's second law. You must include a sketch diagram illustrating the law. (3)

Additional working space is available on the next page.

8/…

5.2. Determine the magnitude and direction of the net gravitational force on mass *A* due to masses *B* and *C* in the diagram. (5)

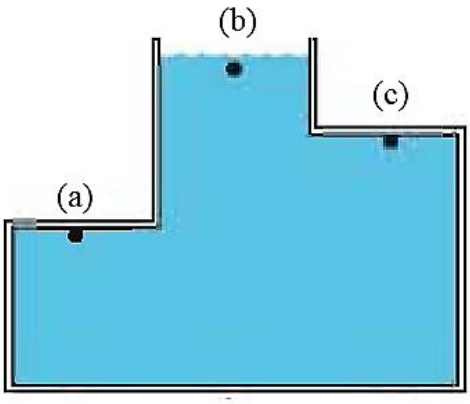


5.3. The mass of the planet Venus is 81.5% that of the Earth, and its radius is 94.9% that of the Earth. Compute the acceleration due to gravity g_{Venus} on the surface of Venus using only this information and $g_{Earth} = 9.8$ m s^{-2}. (4)

[12]

QUESTION 6: FLUID MECHANICS

6.1. The diagram shows a liquid inside a container.



6.1.1. Between positions (a), (b) and (c), where is the fluid absolute pressure greatest? (1)

6.1.2. Between positions (a), (b) and (c), where is the fluid absolute pressure lowest? (1)

Justify your answers above. (1)

6.2. A solid aluminium ingot weighs 89 N in air. The density of aluminium is 2 700 kg m^{-3}. What is the weight of the ingot in water? (5)

6.3. How fast does water flow from a tiny hole at the bottom of a huge 5.3 m deep storage tank filled with water? (4)

[12]

QUESTION 7: OSCILLATIONS AND WAVES

7.1. A box containing a rock is attached to a horizontal spring and is oscillating on a frictionless surface. At one instant while the spring is stretched out to its maximum displacement, the rock is suddenly lifted out of the box without disturbing the box.

Will the following characteristics of the oscillatory motion increase, decrease or remain the same after the rock is lifted out of the box?

7.1.1. Frequency (2)

7.1.2. Amplitude (2)

7.2. A certain transverse wave is described by

$$y(x,t) = (6.50\ mm)\cos 2\pi\left[\frac{x}{28.0\ cm} - \frac{t}{0.0360\ s}\right]$$

Use the information in this wave function to determine the wave's

7.2.1. angular frequency. (3)

7.2.2. wave number. (3)

7.2.3. speed of propagation (in cm/s). (3)

7.2.4. direction of propagation. (1)

[12]

QUESTION 8: THERMODYNAMICS

Constants

$\alpha_{Aluminum} = 24 \times 10^{-6}$ °C^{-1}

8.1. Describe any four characteristics of the ideal gas used for the kinetic theory of gases. (4)

8.2. An aluminium sphere has a diameter of 8.75 cm in diameter at 30°C. Determine its change in volume if it is heated from up to 180°C (6)

8.3. A petrol engine takes in 10 000 J of heat and delivers 2 000 J of mechanical work per cycle. What is the thermal efficiency of this engine? (4)

[12]

QUESTION 9: ELECTRICITY AND MAGNETISM

Constants

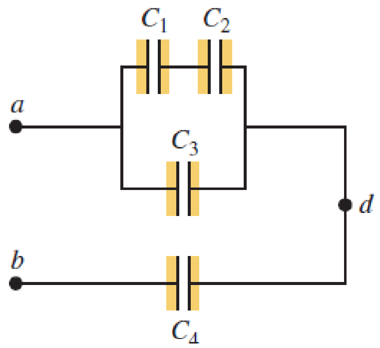
$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

9.1. Draw the electric field around an electric charge of

9.1.1. 2 nC (2)

9.1.2. -2 nC (2)

9.2. Each capacitance in the diagram has a capacitance of $C = 4.00$ μF.



Calculate the equivalent capacitance C_{ab} between points a and b. (5)

9.3. Determine the magnitude and direction of the force between two parallel wires 25 m long and 4.0 cm apart, each carrying 35 A in the same direction. (5)

[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: $y = r\sin\theta$ $x = r\cos\theta$ $\tan\theta = \frac{y}{x}$ $r = \sqrt{y^2 + x^2}$
$v_{x\,avg} = \frac{\Delta x}{\Delta t} = \frac{total\ displacement}{total\ time}$	
$v_{avg} = \frac{d}{\Delta t} = \frac{total\ distance}{total\ time}$	Vector Components: $A_x = A\cos\theta$ $A_y = A\sin\theta$ $A = \sqrt{{A_x}^2 + {A_y}^2}$ $\tan\theta = \left\lvert\frac{A_y}{A_x}\right\rvert$
$v_x = \frac{dx}{dt} = x' = \dot{x}$	
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**
$v_{xf} = v_{xi} + a_x t$ $v_{x\,avg} = \frac{v_{xi} + v_{xf}}{2}$ $\Delta x = v_{xi} t + \frac{1}{2} a_x t^2$ $v_{xf}^2 = v_{xi}^2 + 2a_x(\Delta x)$ $\Delta x = v_{xf} t - \frac{1}{2} a_x t^2$ $\Delta x = \left(\frac{v_{xi} + v_{xf}}{2}\right) t$	Projectile Motion: $t_{total} = \frac{v_i \sin\theta_i}{g}$ $h = \frac{v_i^2 \sin^2\theta_i}{2g}$ $R = \frac{v_i^2 \sin 2\theta_i}{g}$ Uniform Circular Motion: $a_c = \frac{v^2}{r}$ $T = \frac{2\pi r}{v}$ $\omega = \frac{2\pi}{T}$ $v = r\omega$ $a_c = r\omega^2$ $F_r = \frac{mv^2}{r}$
$\Delta v = v_f - v_i = \int_{t_i}^{t_f} a\, dt$	**Forces and Laws of Motion**
$\Delta x = x_f - x_i = \int_{t_i}^{t_f} v\, dt$	$\sum \vec{F} = m\vec{a}$

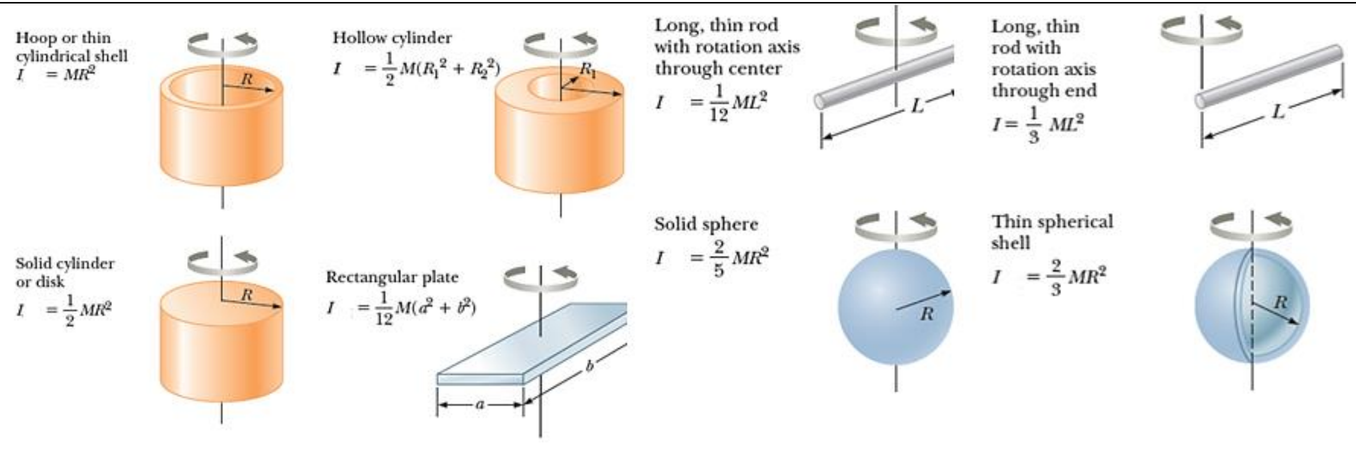
ENERGY, ENEGRY CONSERVATION AND LINEAR MOMENTUM	
Energy	**Energy Conservation**
$W = \vec{F} \cdot \Delta\vec{r} = F\Delta r \cos\theta$ $W = \int F_x\, dx$	$\Delta K + \Delta U_g + \Delta U_S = 0$ (isolated system, no friction)
$K = \frac{1}{2} mv^2$ $U_g = mgy$ $U_S = \frac{1}{2} kx^2$	$\Delta K +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

ROTATIONAL MOTION AND ELASTIC PROPERTIES OF SOLIDS

Rotational Motion

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

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 $F = -kx$ $\quad \frac{d^2x}{dt^2} = -\omega^2 x$ $\quad \omega = \sqrt{\frac{k}{m}}$ $f = \frac{1}{T}$ $\quad T = \frac{2\pi}{\omega}$ $x = A\,cos(\omega t + \phi)$ $E = \frac{1}{2} k A^2$ $v = \pm\omega\sqrt{A^2 - x^2}$	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 $P_i V_i = P_f V_f$ $\quad \frac{V_i}{T_i} = \frac{V_f}{T_f}$ $\quad \frac{P_i}{T_i} = \frac{P_f}{T_f}$ $n = \frac{m}{M}$ $\quad PV = nRT$ $\quad PV = N k_B T$

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

ELECTRICITY AND MAGNETISM
Electrostatics
$F_e = k_e\frac{\|q_1\|\|q_2\|}{r^2}$ $\quad \vec{E} = \frac{\vec{F_e}}{q_0}$ $\quad C = \frac{Q}{\Delta V}$ $\quad U_E = \frac{Q^2}{2C} = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2$ $C = \kappa\frac{\varepsilon_0 A}{d}$
Direct Current Electricity
$I = \frac{dQ}{dt}$ $\quad R = \rho\frac{l}{A}$ $\quad \rho = \rho_0[1 + \alpha(T - T_0)]$ $\quad P = I\Delta V = I^2R = \frac{(\Delta V)^2}{R}$ $\mathcal{E} = I\left[R_{Eq} + r\right]$
Electromagnetism
$\vec{F}_B = q\vec{v} \times \vec{B}$ $\quad r = \frac{mv}{qB}$ $\quad \vec{F}_B = I(\vec{L} \times \vec{B})$ $\quad B = \frac{\mu_0 I}{2\pi r}$ $\quad F_B = \frac{\mu_0 I_1 I_2 L}{2\pi a}$ $\Phi_B = BAN\sin\theta$ $\quad \mathcal{E} = -N\frac{d\Phi_B}{dt}$ $\quad \frac{\Delta V_2}{\Delta V_1} = \frac{N_2}{N_1}$

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