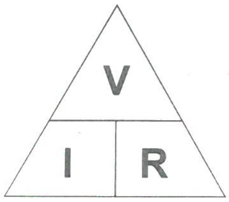
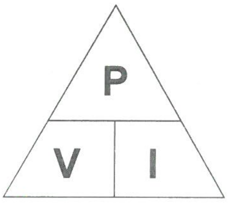
Equations for C&G 2365 Level 2

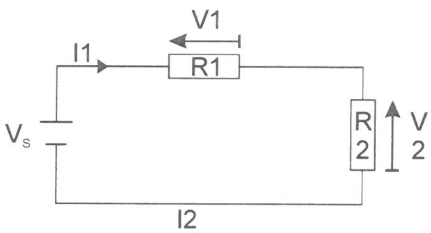
<table>
<tr>
<td rowspan="1">Ohm's Law</td>
<td>

Where: V = Voltage (Volts (V))
I = Current (Amps (A))
R = Resistance (Ohms (Ω))</td>
<td>R = V / I
I = V / R
V = I x R

17.69Ω = 230V / 13A
13A = 230V / 17.69Ω
230V = 13A x 17.69Ω</td>
</tr>
<tr>
<td rowspan="2">Power</td>
<td>

Where: P = Power (Watts (W))
V = Voltage (Volts (V))
I = Current (Amps (A))</td>
<td>P = V x I
V = P / I
I = P / V

3kW = 230V x 13A
230V = 3kW / 13A
13A = 3kW / 230V</td>
</tr>
<tr>
<td>Combined with Ohm's Law:

$P = I^2 R$
$P = V^2 / R$</td>
<td>$3kW = 13A^2 \times 17.69\Omega$
$3kW = 230V^2 / 17.69\Omega$</td>
</tr>
<tr>
<td>Series Circuits</td>
<td>

V_S = Voltage at Source

$V_S = V1 + V2$

I = I1 = I2
(current remains same throughout circuit)

V1 = R1 x I

R2 = V2 / I

I = V1 / R1

$R_{TOT} = R1 + R2$</td>
<td>230V (V_s) = 110V (V1) + 120V (V2)

I = 13A

110V (V1) = 8.46Ω (R1) x 13A

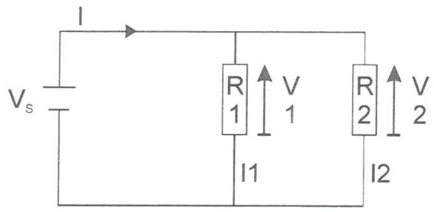
9.23Ω (R2) = 120 / 13A

13A = 110 / 8.46Ω

R_{TOT} = 8.46 + 9.23 = 17.69Ω</td>
</tr>
</table>

Equations for C&G 2365 Level 2

Parallel Circuits



$V_S = V1 = V2$
(voltage remains same throughout circuit)

$I = I1 + I2$

$I1 = V1 / R1$

$V2 = I2 \times R2$

$R2 = V2 / I2$

$$R_{TOT} = \frac{R1 \times R2}{R1 + R2}$$ (Only usable for 2 loads)

$$\frac{1}{R_{TOT}} = \frac{1}{R1} + \frac{1}{R2}$$ (Usable for multiple loads)

$V_S = 230V$

$I1 = 230V / 12\Omega\ (R1) = 19.167A$

$R2 = 230V / 16A\ (I2) = 14.375\Omega$

$$R_{TOT} = \frac{12\Omega \times 14.375\Omega}{12\Omega + 14.375\Omega} = 6.54\Omega$$

$I = 19.167 + 16 = 35.167A$

$$\frac{1}{R_{TOT}} = \frac{1}{12\Omega} + \frac{1}{14.375\Omega}$$

$$= \frac{1.198}{14.375\Omega} + \frac{1}{14.375\Omega}$$

$$= \frac{2.198}{14.375\Omega}$$

$$\therefore R_{TOT} = \frac{14.375}{2.198} = 6.54\Omega$$

Resistance in length of cable

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

Where:

ρ = Specific resistivity of material (Ω m)

l = Length of material (m)

A = Cross-sectional area of material (m^2)

$1mm^2 = 1 \times 10^{-6} m^2$

Specific resistivities:

Silver = 16.4×10^{-9}
Copper = 17.5×10^{-9}
Aluminium = 28.5×10^{-9}
Brass = 75.0×10^{-9}
Iron = 100.0×10^{-9}
Stainless Steel 690×10^{-9}

$R \propto l$

α = proportional

$$R \propto \frac{1}{A}$$

Resistance of 10m of $2.5mm^2$ Copper cable:

$$R = \frac{17.5 \times 10^{-9} \times 10}{2.5 \times 10^{-6}}$$

$$R = \frac{17.5 \times 10^{-3} \times 10}{2.5}$$

$$R = \frac{0.0175 \times 10}{2.5}$$

$$R = \frac{0.175}{2.5}$$

$R = 0.07\Omega$

Equations for C&G 2365 Level 2

Frequency

$$F = \frac{1}{T}$$

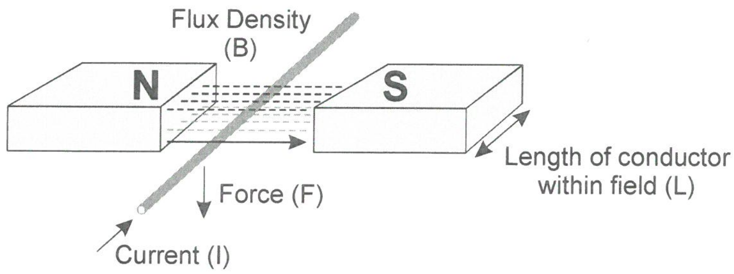
Where:

F = Frequency (Hz)

T = Time of single cycle (s)

$$50\text{Hz} = \frac{1}{0.02\text{s}}$$

Motor Action



$$F = B\,I\,L$$

Where:

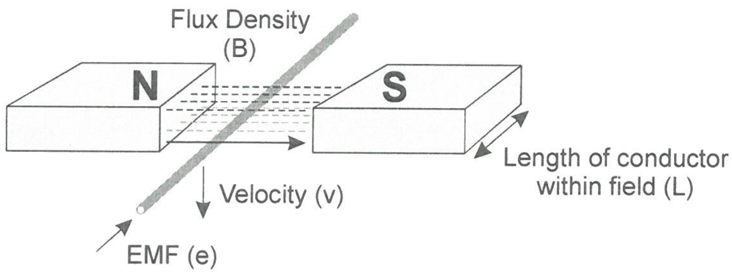
F = Force (N)

B = Flux Density (Tesla (T))

I = Current (A)

L = Length of conductor (m)

Generator Action



$$e = B\,L\,v$$

Where:

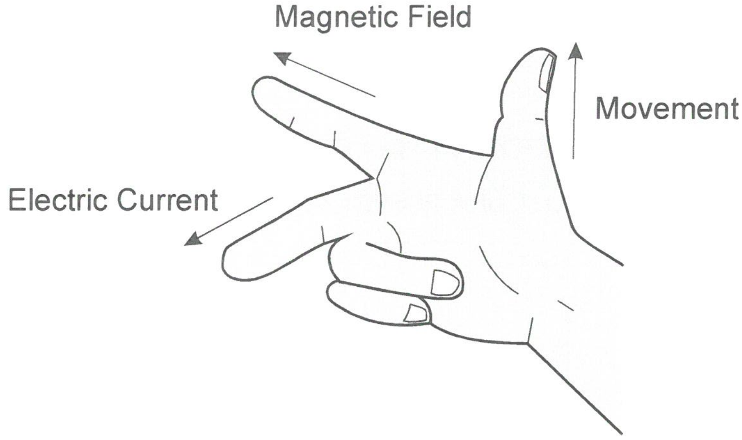
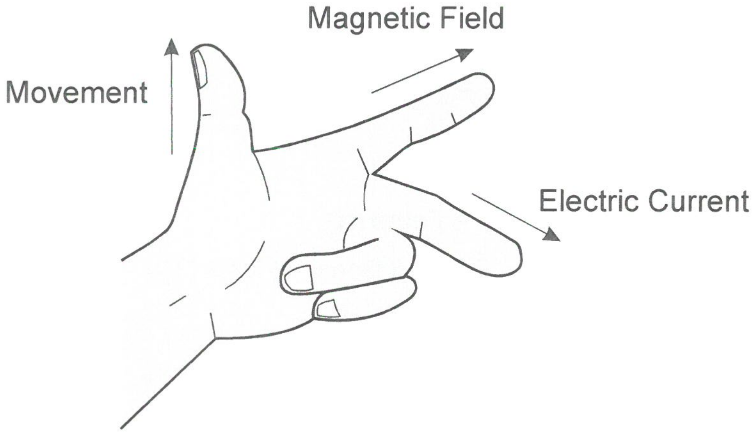
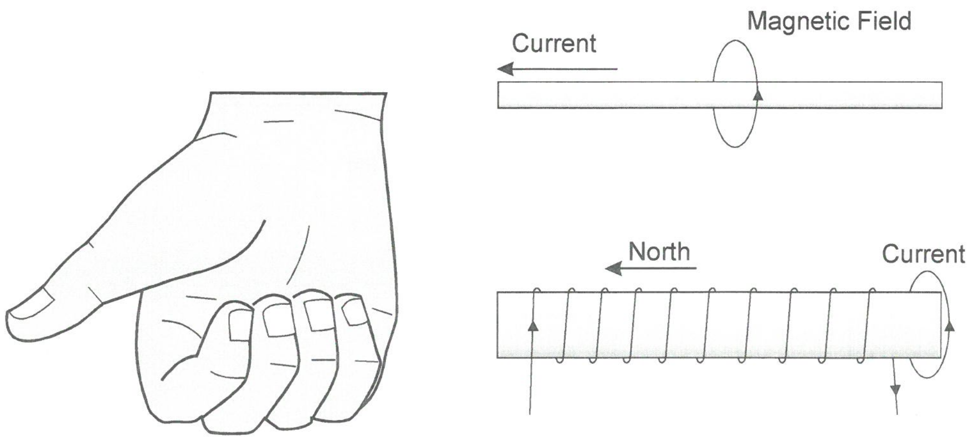
e = EMF (V)

B = Flux Density (Tesla (T))

L = Length of conductor (m)

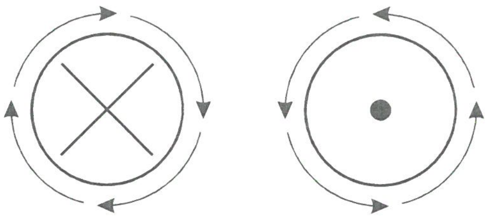
v = Velocity (m/s)

Equations for C&G 2365 Level 2

Flemming's Right Hand Rule **(Generator)**	
Flemming's Left Hand Rule **(Motor)**	
Flemming's Right Hand Grip Rule	

Equations for C&G 2365 Level 2

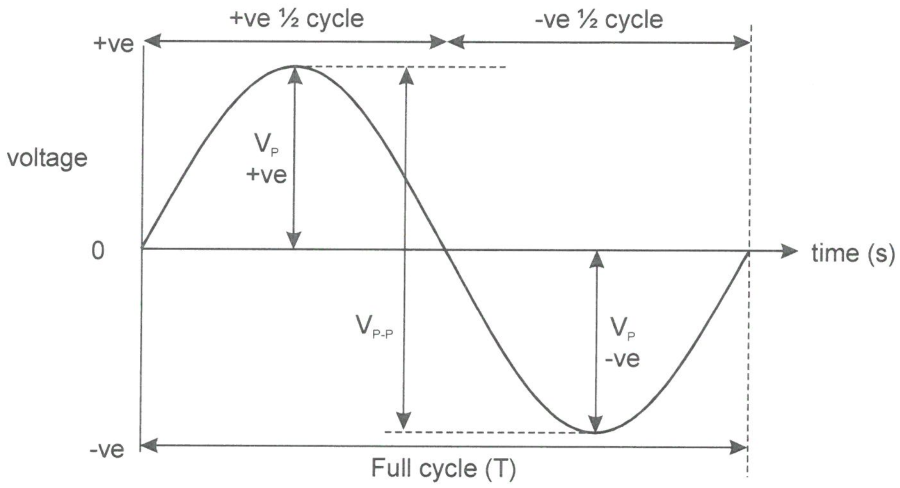
Direction of magnetic fields produced by cables



× = Current flowing away (dart flights)

● = Current flowing towards (dart point)

AC Sine Wave



V_P = Voltage Peak

$V_{P\text{-}P}$ = Voltage Peak to Peak

$$V_{RMS} = \frac{V_P}{\sqrt{2}}$$

$1\text{ms} = 1 \times 10^{-3}\text{s}$

$$F(\text{Hz}) = \frac{1}{T(\text{s})}$$

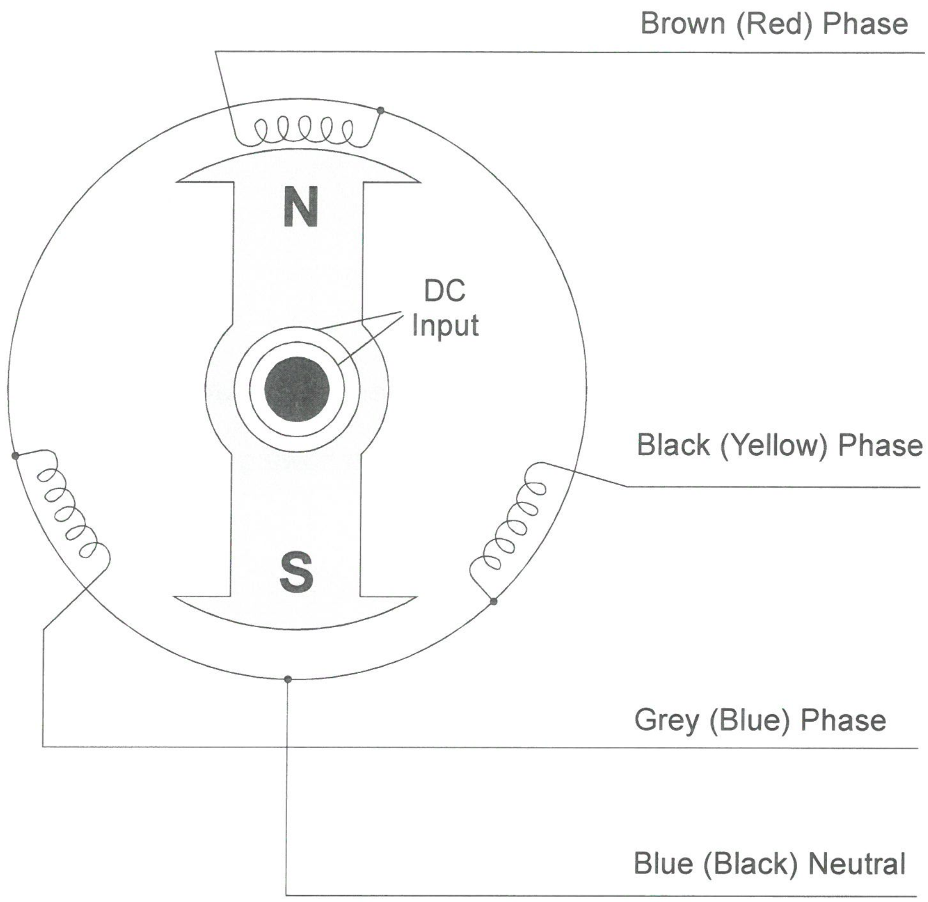
T = 20ms

$$230\text{V} = \frac{325\text{V}}{\sqrt{2}}$$

$$50\text{Hz} = \frac{1}{20 \times 10^{-3}}$$

Equations for C&G 2365 Level 2

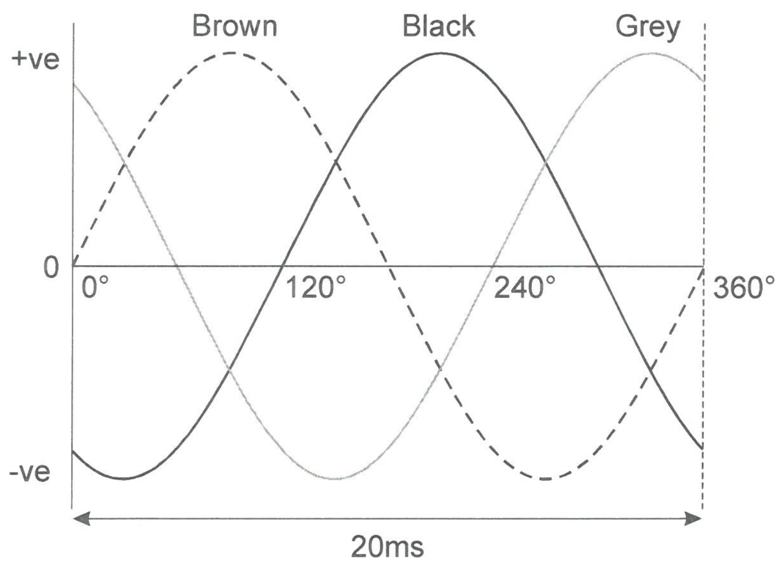
AC Power Generation (Alternator)



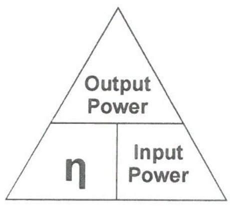
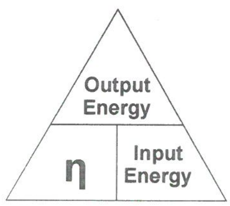
Windings are evenly spaced at 120°

DC electro magnet in centre

Generator speed = 50Hz x 60 seconds = 3000RPM

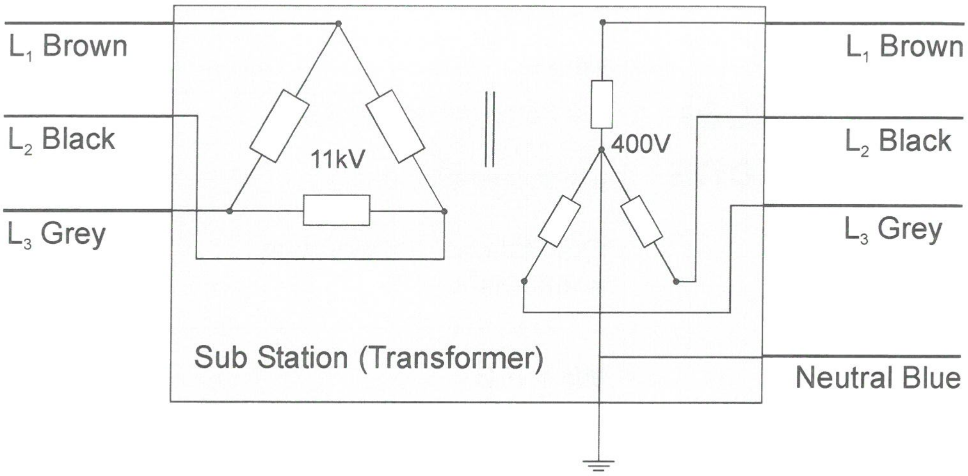


Equations for C&G 2365 Level 2

Mechanical Calculations	$F = m\,a$ Where: F = Force (Newtons (N)) m = mass (kg) a = acceleration (ms^{-2}) Gravitational acceleration $= 9.81ms^{-2}$	$981N = 100kg \times 9.81ms^{-2}$
	$Wd = F\,D$ Where: Wd = Work done (Nm) F = Force (N) D = Distance (m) 1Nm = 1 Joule(J)	$9810J = 9810Nm = 981N \times 10m$
	$P = \frac{Wd}{t}$ Where: P = Power (W) Wd = Work done (J) t = Time (s) 1W = 1 Joule per second (Js)	$16.35W = \frac{9810J}{600s}$
Efficiency	  Where: η = Efficiency (as ratio) Efficiency as % = Efficiency ratio x 100	$\eta = \frac{9810W}{14010W} = 0.7$

Equations for C&G 2365 Level 2

230V Single Phase & 400V 3 Phase Supplies

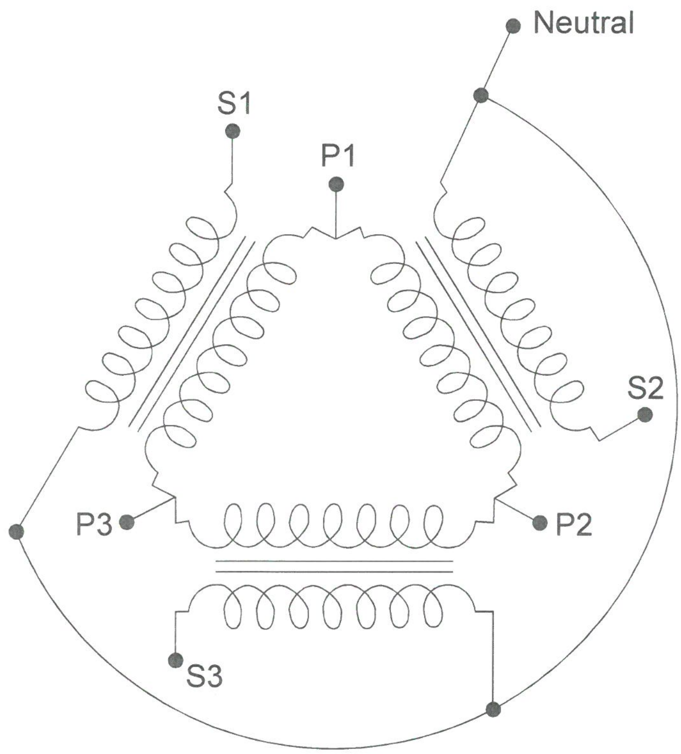


Input Line to line on the input side will give you 11kV

Output Line to line (or Phase to Phase) on the output side will give you 400V
Any line to neutral will give you 230V

Domestic supplies will use one phase to neutral at 230V, protected by a 100A fuse.

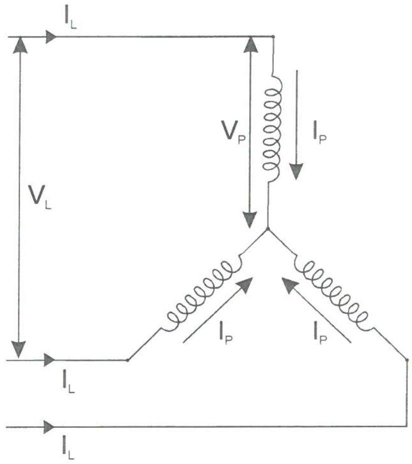
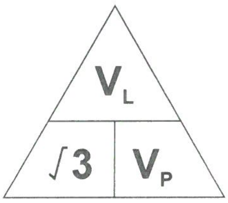
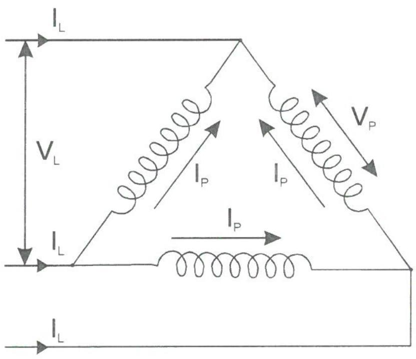
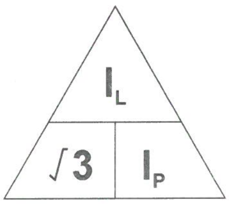
Delta-Star (or Delta-Wye) Transformer



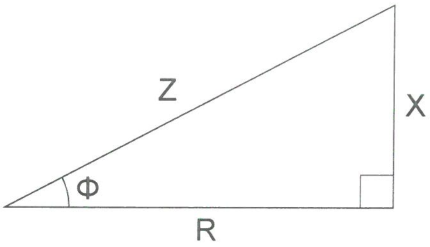
Equations for C&G 2365 Level 2

UK Power Generation & Distribution Voltages	**25kV**	**Generation** Electricity is generated as 25kV as we do not have a useful insulator beyond that voltage.
	275kV or 400kV	**National Grid & Super Grid** Used for long distance distribution
	132kV	**Supply to local distribution companies**
	33kV	**Regional distribution & heavy industry**
	11kV	**Towns, villages & small industry**
	400V	**Commercial**
	230V Single phase	**Domestic & Commercial**

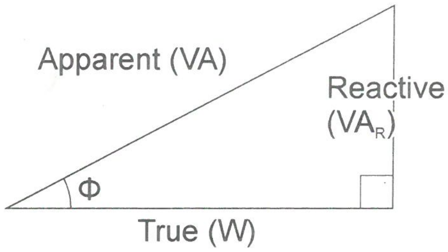
Equations for C&G 2365 Level 2

Star 3 Phase Circuits	 I_L (I Line) = I_P (I Phase) 	$400V = \sqrt{3} \times 230V$
Delta 3 Phase Circuits	 V_L (V Line) = V_P (V Phase) 	$22.6A = \sqrt{3} \times 13A$
Power (3 Phase Circuits) **Balanced Load(Ω)**	Power (W) = $\sqrt{3} \times V_L \times I_L \times \cos\Phi$ Where: V_L = Line Voltage (V) I_L = Line Current (A) $\cos\Phi$ = Power Factor (p.f.) Load(Ω) in each phase must be identical otherwise power for each phase must be calculated individually.	$P_{TOT} = \sqrt{3} \times 400 \times 23 \times 0.7$ $P_{TOT} = 11.2kW$

Equations for C&G 2365 Level 2

Impedance Triangle	 Where: X = Reactance (Ω) R = Resistance (Ω) Z = Impedance (Ω) cos Φ = Power Factor (p.f.) From Pythagoras: $Z = \sqrt{R^2 + X^2}\ \Omega$ From Trigonometry: $\cos \Phi = \frac{R}{Z}$ $X = \lvert X_C - X_L \rvert$ (Modulus meaning difference between) Where: X_C = Capacitive Reactance X_L = Inductive Reactance	$X = \lvert 10 - 12 \rvert = 2\Omega$ $Z = \sqrt{15^2 + 2^2}\ \Omega = 15.133\Omega$ $\cos \Phi = \frac{15}{15.133} = 0.99$
Inductive Reactance (X_L)	$X_L = 2\pi fL\ \Omega$ Where: f = Frequency (Hz) L = Inductance (Henris)	$L = 50mH = 50 \times 10^{-3} = 0.05H$ $X_L = 2 \times \pi\ 50Hz \times 0.05H\ \Omega$ $X_L = 15.708\Omega$
Capacitive Reactance (X_C)	$X_C = \frac{1}{2\pi fC}\ \Omega$ Where: f = Frequency (Hz) C = Capacitance (Farads (F))	$C = 50\mu F = 50 \times 10^{-6} = 0.00005F$ $X_C = \frac{1}{2 \times \pi \times 50Hz \times 0.00005F}$ $X_C = 63.662\Omega$

Equations for C&G 2365 Level 2

<table>
<tr>
<td>Power Triangle</td>
<td>

Apparent = Source Power
True = Useful Power
Reactive = Waste Power

$VA_R = \sqrt{VA^2 - W^2}\ \Omega$

$\cos \Phi = \frac{W}{VA}$</td>
<td></td>
</tr>
<tr>
<td>CIVIL</td>
<td>C Capacitive Reactance
I Current
V Voltage
I Current
L Inductive Reactance

Capacitive Reactance
I leads V (CIV)

Inductive Reactance
I lags V (VIL)</td>
<td></td>
</tr>
</table>