Candidate Handbook answers

ELTK 04a: Understanding the principles of planning and selection for the installation of electrotechnical equipment and systems in buildings, structures and the environment

Page 12: Progress check

1. Explain the difference between the following supply earth terminals.

- TN-S
- TN-C-S
- TT

Answers should include:

TN-S
The earth connection is usually through the sheath or armouring of the supply cable and then by a separate conductor within the installation. As a conductor is used throughout the whole system to provide a return path for the earth-fault current, the return path should have a low value of impedance.

TN-C-S
In a TN-C-S system, the supply uses a common conductor for both the neutral and the earth. This combined conductor is commonly known as the Protective Earthed Neutral (PEN) or also sometimes as the Combined Neutral and Earth (CNE) conductor.

TT
This system is used where the customer installation hasn't been provided with an earth terminal by the Electricity Supply Company. As such it is most commonly used in rural areas where it is invariably easier to provide an overhead supply.

2. Briefly state where single- and three-phase supplies are utilised.

Answers could include:

Single-phase supply
In general terms, we can say that domestic installations in the UK will be provided with a single-phase supply, the most modern ones being rated at 80 A where there is no electric heating or 100 A where there is.

This capacity will normally be more than adequate to meet the lighting and small power needs of a domestic consumer or small commercial user. By single-phase we mean that the premises are supplied by a 2-core (1 x line plus neutral) cable at 230 V.

Three-phase supply
Where commercial or industrial installations require a larger capacity, it is normal for a three-phase supply to be provided. By three-phase we mean 3 x line plus neutral and this would normally be supplied at 400 V for the average premises of this type.

3. Identify the types of switching classified in BS7671.

Answers should include:

- **Switching for isolation**
- **Switching for mechanical maintenance**
- **Emergency switching**
- **Functional switching**

Page 30: Progress check

1. Describe the component parts of the earth-fault loop.

Answer should include the following (starting from the point of the fault):

- **circuit protective conductor (cpc)**
- **consumer's main earth terminal (MET) and earth conductor**
- **return path (may be via electrodes or the cable armouring/sheath)**
- **earthed neutral of the supply transformer and then the transformer winding (phase)**
    - **line conductor**

2. Explain the difference between an exposed - conductive part and an extraneous - conductive part.

Answers should include:

- **Exposed-conductive-part – these are the conductive parts of an installation that can be touched and, although not normally live, could become live under fault conditions. Examples of these are metal casings of appliances such as kettles and ovens or wiring enclosures such as steel conduit, trunking or tray plate.**
- **Extraneous-conductive-part – these are the conductive parts within a building that don't form part of the electrical installation, but they could become live under fault conditions. Examples of these are copper water and gas pipes and metal air conditioning system ductwork.**

3. What are the requirements for additional protection for a socket-outlet rated at less than 20A for use by ordinary persons?

'Additional protection' (411.3.3) on a.c. systems is afforded by the use of a 30 mA RCD that must operate within 40ms (415.1.1).

4. In relation to protective devices explain the term discrimination.

Discrimination is the ability of protective devices to operate selectively to ensure that, in the event of a fault, only the faulty circuit is isolated from the system, therefore allowing healthy circuits to remain in operation. So, for example in a house, a fault on an appliance should cause the fuse in the plug top connected to the appliance to operate before the protective device in the consumer unit.

Similarly, a fault on a lighting circuit should only result in the mcb in the consumer unit for that circuit to trip; all other mcbs in the consumer unit and the main DNO fuse should remain intact and energised.

Page 65: Progress check

1. What is the purpose of applying ratings to cables during the design stage?

Answer should include:

To take account of the heating effect, that may occur which could lead to damage to a cables insulation. This is because most insulation utilised is of a plastic nature with a relatively low melting point when compared to that of the conductors.

2. What is meant by the term voltage drop and how does this occur in electrical installations? What is the maximum voltage drop allowed for a single-phase lighting circuit?

Answer should include:

- **Voltage drop is the reduction in voltage between the supply and point of utilisation.**
- **Voltage drop occurs, when a current is passed through a cable as the cable has resistance. From ohm's law V = I x R.**
- **Maximum voltage drop for a single-phase lighting circuit is 6.9 V.**

3. What is meant by the term diversity and why is this not allowed for heating circuits?

Diversity is an allowance based upon the fact a circuit will not be drawing full load current all the time. Therefore during the design stage an allowance is made (diversity). Heating circuits may be drawing, full load current for a considerable period of time, before the temperature is reached hence no allowance is allowed.

Page 74: Check your knowledge

1. The supply earthing system having a combined neutral and earth in part of the system is designated as what?

a) TT
b) TN
c) TN-S
d) TN-C-S

2. Why are three-phase supplies usually provided?

a) Client requests is
b) A large capacity is required
c) Site engineer thinks it is a good idea
d) Wiring is easier on three-phase systems

3. Which of the following would **not** be regarded as an extraneous-conductive part?

a) Gas service pipe
b) Water service pipe
c) Metallic trunking
d) Metal radiator

4. What is the formula used to calculate earth-loop impedance?

a) $Z_S = Z_e + (R_1 + R_2)$
b) $Z_E = Z_S + (R_1 + R_2)$
c) $Z_S = Z_e - (R_1 + R_2)$
d) $Z_S = Z_E + (R_1 - R_2)$

5. What is an RCD used to provide?

a) Overload protection
b) Short circuit protection
c) Thermal protection
d) Additional protection

6. What gives the rated current of a protective device?

a) I_b
b) I_Z
c) I_n
d) I_2

7. The maximum permitted time a fault current can be allowed, before permanent damage is done to cable insulation is given in the formula. What does **S** represent in this formula?

$$t = \frac{k^2S^2}{I^2}$$

a) Time in seconds
b) Fault current
c) Conductor CSA
d) Factor for insulation, resistivity and heat capacity

8. The coordination of protective device rating, design current of a circuit and the current-carrying capacity of conductors is given by which formula?

a) $I_n \leq I_b \leq I_Z$
b) $\mathbf{I_b \leq I_n \leq I_Z}$
c) $I_Z \leq I_b \leq I_n$
d) $I_n \leq I_Z \leq I_b$

9. Diversity would **not** be applied to which of the following circuits?

a) Cooker
b) Immersion heater
c) Ring
d) Lighting

10. What is the calculated full load current of an 8.5 kW single-phase shower unit?

a) 35.4 A
b) 36.9 A
c) 40 A
d) 45 A

ELTK 06: Understanding the principles, practices and legislation for the inspection, testing, commissioning and certification of electrotechnical systems and equipment

Page 82: Progress check

1. The site supervisor has requested an apprentice, to carry out the inspection and test alone on the area he has been working, as he had to leave site and pick up more equipment. Should the apprentice carry out the inspection?

Regulation 16 of the EAWR states that no person shall engage in work that requires technical knowledge or experience to prevent danger or injury, unless he or she has that knowledge or experience, or is under appropriate supervision.

That would preclude the apprentice unless working under supervision, as his mentor was providing before the request.

2. Explain the purpose of the initial inspection on an electrical installation.

An initial inspection should be carried out to verify:

- **All equipment and material is of the correct type and complies with applicable British Standards or acceptable equivalents.**
- **All parts of the fixed installation are correctly selected and erected.**
- **No part of the fixed installation is visibly damaged or otherwise defective.**
- **The equipment and material used are suitable for the installation relative to the environmental conditions.**

Page 98: Progress check

1. During the inspection process, checks are needed on the routing of cables. When would that normally be done and what are the checks to ascertain?

Checks would normally take place during construction. Largely because many cables, are obscured by building fabric once installed.

Cables should be routed out of harm's way and protected against mechanical damage where necessary. Permitted cable routes are clearly defined (note the RCD situation) or alternatively cables should be installed in earthed metal conduit or trunking.

2. Effective means of isolation and switching suitably positioned and ready to operate are required. What inspection checks should be made?

Switches and/or isolating devices of the correct rating must be installed as appropriate to meet the requirements of BS7671. It is advisable where practicable to carry out an isolation exercise to check that effective isolation can be achieved. This should include switching off, locking-off and testing to verify that the circuit is dead and no other source of supply is present.

3. On completion of an installation labelling and information should all be present, what would you check during inspection.

Notices are required to be suitably located and give warnings relative to voltage, isolation, periodic inspection and testing, RCDs and earthing and bonding connections.

All distribution boards should be provided with a distribution board schedule that provides information regarding types of circuits, number and size of conductors, type of wiring etc. These should be attached within or adjacent to each distribution board.

Page 145: Progress check

1. What is the sequence of tests to be carried out on a new installation?

Initial tests should be carried out in the following sequence, where applicable, before the supply is connected or with the supply disconnected as appropriate:

- **Continuity of protective conductors including main and supplementary bonding (612.2.1)**
- **Continuity of ring final circuit conductors (612.2.2)**
- **Insulation resistance (612.3)**
- **Protection by SELV, PELV or electrical separation (612.4)**
- **Protection by barriers/enclosures provided during erection (612.4.5)**
- **Insulation resistance/impedance of non-conducting floors and walls (612.5)**
- **Polarity (612.6)**
- **Earth electrode resistance (612.7)**
- **Protection by Automatic Disconnection of Supply (ADS) (612.8)**
- **Earth fault loop impedance (612.9)**
- **Additional protection (612.10)**
- **Prospective fault current (612.11)**
- **Phase sequence (612.12)**
- **Functional testing (612.13)**
- **Verification of voltage drop (612.14).**

2. What precautions would be taken before conducting an insulation resistance test?

Before testing we need to ensure that:

- **Pilot or indicator lamps and capacitors are disconnected from circuits to avoid an inaccurate test value being obtained.**
- **Voltage sensitive electronic equipment such as dimmer switches, delay timers, power controllers, electronic starters for fluorescent lamps, emergency lighting, Residual Current Devices etc. are disconnected so that they are not subjected to the test voltage.**
- **There is no electrical connection between any line and neutral conductor (e.g. lamps left in).**

3. Describe how a measurement of Z_e is made and explain the significance of this test.

The value of Z_e can be measured using an earth fault loop impedance tester at the origin of the installation. However, as this requires the removal of covers and the exposure of live parts, extreme care must be taken and the operation must be supervised at all times.

The instrument is connected using approved leads and probes between the phase terminal of the supply and the means of earthing with the main switch open or with all sub-circuits isolated. In order to remove the possibility of parallel paths, the means of earthing must be disconnected from the equipotential bonding conductors for the duration of the test.

With the instrument correctly connected and the test button pressed, the instrument will give a direct reading of the value of Z_e. It must be remembered to re-connect all earthing connections on completion of the test.

A low resistance test result would indicate the presence of a means of earthing.

4. What considerations should be made when deciding upon the frequency of inspection and testing?

Answer should include:

- **Type of installation**
- **Use and operation of installation**
- **External influences affecting the installation**
- **Frequency and quality of any maintenance activity**

Page 145: Progress check

1. For what purpose should an Electrical Installation Certificate be issued and who to?

Answer should include:

- **The Electrical Installation Certificate is to be used only for the initial certification of a new installation or for an addition or alteration to an existing installation where new circuits have been introduced.**
- **It is not to be used for a Periodic Inspection, for which an Electrical Installation Condition Report form should be used.**
- **It should be issued to the person ordering he work.**

2. Explain briefly when a Minor Electrical Installation Certificate should be issued.

The Minor Works Certificate is intended to be used for additions and alterations to an installation that do not extend to the provision of a new circuit.

3. What is the main function of an Electrical Condition Report and could it be issued to cover the addition of lighting to a property?

Answer should include:

- **The purpose of this condition report is to confirm, so far as reasonably practicable, whether or not the electrical installation is in a satisfactory condition for continued service. The report should identify any damage, deterioration, defects and/or conditions which may give rise to danger.**
- **No as it is a report, on the condition of an existing installation and is not intended to certify new work.**

Page 162: Check your knowledge

1. What is the minimum value of insulation resistance on a lighting circuit?
a) 0.5 Ω
b) 0.5 MΩ
c) 1 Ω
d) 1 MΩ

2. An item of equipment has an IP code of IP56, what does the second digit (6) apply to?
a) Size of test finger to apply
b) Protection against the ingress of solids
c) Protection against the ingress of water
d) Type of coating on the equipment surface

3. Which of the following is unacceptable as an earth electrode?
a) Earth rod
b) Water service pipe
c) Earth plate
d) Underground structural metalwork

4. Where a 30 mA RCD is being used to provide additional protection against contact with live parts, then what must the operating time must not exceed?
a) 40 ms when tested at 1 × 30 mA
b) 40 ms when tested at 5 × 30 mA
c) 100 ms when tested at 1 × 30 mA
d) 100 ms when tested at 5 × 30 mA

5. What is the maximum period between inspection and testing of a domestic property as shown in IET guidance note 3?
a) 3 months
b) 1 year
c) 5 years
d) 10 years

6. What is the maximum period between inspection and testing of a construction site as shown in IET guidance note 3?
a) 3 months
b) 1 year
c) 5 years
d) 10 years

7. Which document lays down the safety requirements of test equipment leads?
a) HSG 85
b) HSE GS38
c) BS 7671
d) BS 5266

8. Which of the following instruments is used for carrying out continuity tests?
a) RCD tester
b) High resistance ohmmeter
c) Low resistance ohmmeter
d) Earth-fault loop impedance tester

9. Who should an Electrical Installation Certificate be issued to?
a) Architect
b) Electrician
c) Site Engineer
d) Person ordering the work

10. Which of these should a Minor Electrical Installation Works Form **not** be issued for?
a) New circuit
b) Moving a light position
c) Adding a new lighting point to an existing circuit
d) Adding an extra socket outlet to an existing circuit

ELTK 07: Understanding the principles, practices and legislation for diagnosing and correcting electrical faults in electotechnical systems and equipment

Page 168: Progress check

1. You have been asked to attend one of your customer's factory complexes to repair a fault. Who are the possible personnel you may need to refer to when checking the technical details of the installation?

Answer could include:

- **the electrician who may have previously worked on the system**
- **design engineer**
- **works engineer**
- **shift engineer**
- **maintenance electrician**
- **machine operator**

2. List the usual sources of information held, that may assist you when diagnosing faults on site.

Answers could include:

- **Operating manuals**
- **Wiring and connection diagrams**
- **Manufacturer's product data/information**
- **Maintenance records**
- **Inspection and test results**
- **Installation specifications**
- **Drawings**
- **Design data**
- **Site diary**

3. What are the main considerations when completing a handover to a customer following the rectification of faults?

Good communication is essential. Involving the customer throughout can assist the process and enable them to work around you.

Take the time to explain what has been done and handover all relevant paperwork such as test results or manufacturer instructions should equipment have been replaced.

Remember that the time spent developing a good relationship may have not only been useful in assisting to find the fault, but may also have been key in gaining your employer future business from a customer who feels their problem was dealt with in a caring and efficient manner.

Page 201: Progress check

1. Identify the logical sequence of events that should be undertaken during fault diagnosis and rectification.

Answers should include:

- **Identify the symptoms**
- **Gather information**
- **Analyse the evidence**
- **Check supply**
- **Check protective devices**
- **Isolation and test**
- **Interpret information and test results**
- **Rectify the fault**
- **Carry out functional tests**
- **Restore the supply**
- **Carry out life and functional tests**

Answers could include UNITE the union and the Joint Industry Board (JIB)

2. What are the common symptoms to be considered with electrical faults?

Answer should include:

- **position of faults (complete loss of supply at the origin of the installation and localised loss of supply)**
- **operation of overload and fault current devices**
- **transient voltages**
- **insulation failure**
- **plant, equipment or component failure**
- **faults caused by abuse, misuse and negligence**
- **prevention of faults by regular maintenance.**

3. There are a number of common faults in electrical installations attributed to misuse by both users and installation personnel. Identify some of these.

User misuse

- **Using an MCB as a switch where constant use could lead to breakdown.**
- **Unplugging on-load portable appliances thus damaging socket terminals.**
- **Damp accessories, for instance, due to hosing walls in dry areas.**
- **MCBs' nuisance-tripping caused by connecting extra load to circuits.**

Installer misuse

- **Poor termination of conductors – overheating due to poor electrical contact.**
- **Loose bushes and couplings – no earth continuity – electric shock risk!**
- **Wrong size conductors used – excessive voltage drop – excess current which could lead to an inefficient circuit and overheating of conductors.**
- **Not protecting cables when drawing them in to enclosures – causing damage to insulation.**
- **Overloading conduit and trunking capacities – causing overheating and insulation breakdown.**

4. The checking of termination of cables and conductors is an integral part of an inspection. List the main areas to be covered during such an inspection.

Answer could include:

- **connection of conductors**
- **identification of conductors**
- **routing of cables in safe zones, or protection against mechanical damage, in compliance with section 522**
- **selection of conductors for current carrying capacity and voltage drop, in accordance with the design**
- **correct connection of accessories and equipment**
- **presence of fire barriers, suitable to seals and protection against thermal effects**
- **methods of protection against electric shock**
- **selection of equipment and protective measures appropriate to external influences.**

Page 208: Progress check

1. What are the main considerations, before deciding upon repair or replacement of faulty equipment?

Answer should include:

- **Cost of replacement**
- **Availability of replacement**
- **Downtime whilst arranging replacement**
- **Cost of low production**
- **Availability of resource and staff**

2. Most companies involved with fault finding at a customers premises, usually have an agreed procedure for its staff to follow, to ensure consistency. What would be included in such a procedure?

Answer should include:

- **Signing in**
- **Wearing identification badges**
- **Locating supervisory personnel**
- **Locating data drawings etc.**
- **Liaising with the client and office before commencing any work**
- **Following safe isolation procedures**

Page 234: Progress check

1. Which of the following is **unnecessary** to familiarise an operative with before fault rectification work commences?

a) Nominal voltage
b) Cost of repair
c) Type of earthing supply system
d) Distribution baord schedules

2. Which one of the following would **not** be included in a sequence of fault finding?

a) Identifying symptoms
b) Checking the supply
c) Isolation and testing
d) Length of time it will take

3. Which of the following tests is carried out during non-live testing?

a) Insulation resistance
b) RCD
c) Functional
d) Earth-fault loop impedance

4. Identify which instrument is used to carry out an insulation resistance test.

a) Bell/buzzer
b) High resistance ohmmeter
c) Low resistance ohmmeter
d) Earth-fault loop impedance tester

5. Which of the following would **not** be regarded as a transient fault?

a) Heavy current switching
b) Earth-fault loop impedance
c) Lightning strikes
d) Overload

6. A mechanical and electrical connection when joining two conductors together relies on good practice by the installer. What should a terminating device for use on conductors have?

a) Current rating lower than that of the conductor
b) Temperature rating lower than the conductor
c) Cross-sectional area smaller than that of the conductor
d) Suitability for the environment and that of the conductor

7. What would the most likely outcome at a loose termination under load conditions be?

a) Overheating
b) Normal running
c) Cooling of the conductor
d) Protective device operating

8. Which of the following faults would an RCD protect against?

a) Overcurrent
b) Excess heat in conductors
c) Short circuits between live conductors
d) Earth-faults between live conductors and earth

9. Which of the following would **not** be regarded as a fault in a flexible cable?

a) Oversized conductor
b) Incorrect type installed
c) Incorrect size of conductor
d) Poor termination into an accessory

10. Antistatic precautions to avoid ignition or explosion are usually required in which of the following installation environments?

a) Office
b) School
c) Flour mill
d) Shopping mall

ELTK 08: Understanding the electrical principles associated with the design, building, installation and maintenance of electrical equipment and systems

Page 245: Progress check

1. Identify the SI units for the following:

- Length
- Mass
- Time
- Electric current
- Temperature
- Luminous intensity

Answer should include:

Base quantity	Base unit
Length	Metre
Mass	Kilogram
Time	Second
Electric current	Ampere
Temperature	Kelvin
Luminous intensity	Candela

2. Convert the following quantities:

- 6 km into metres
- 3500 mm into metres
- 1 MΩ into ohms

Answers should be:

- **6000 metres**
- **3.5 metres**
- **1 000 000 ohms**

3. Your supervisor tells you to leave 10% extra cable at the end of a run to allow for terminations. If the cable run is 34.7 m long what will the overall length be?

Answer should be:
We have a cable run of 34.7m and want to add 10% for terminations.

10% is 10 ÷ 100 = $\frac{1}{10}$ **or 0.1**

0.1 x 34.7 is 3.47 for terminations. Total cable length required is 34.7 + 3.47 = 38.17 m.

Page 256: Progress check

1. Calculate the amount of power required if a load requires 5000 joules of energy and takes 20 seconds to move to its final position.

$$\text{Power (P)} = \frac{\text{Energy used (E)}}{\text{Time taken to do that work (t)}}$$

P = 5000 Joules ÷ 20 seconds

P = 250 W – Power is measured in joules per second (J/s), also known as watts (W)

2. Calculate the output power if 2 kW of input power is used and the efficiency is 85%.

$$\text{\% efficiency} = \frac{\text{Output Power}}{\text{Input Power}} \times 100$$

Transposing the formula to make output power the subject would give:

Output power = Input power x % efficiency

Output power = 2000 x 0.85

Output power = 1700 Watts or 1.7 kW

3. Identify the units for the following:

- Power
- Force
- Energy
- Mass
- Weight

Answer should include:

- **Power = Watt**
- **Force = Newton**
- **Energy = Joule**
- **Mass = Kilogram**
- **Weight = Newton**

Page 287: Progress check

1. In terms of electron movement what is the major difference between a conductor and an insulator?

Conductors have a molecular/atomic structure that allows electrons to move freely through them. Copper is the most common conductor material used.

Insulators are poor conductors of electricity. They do not allow free passage of electrons through them. One common insulator that is used in cable manufacture is PVC (poly Vinyl Chloride).

2. What are the essential components of a practical circuit?

For practical purposes a working circuit should:

- **have a source of supply (such as the battery)**
- **have a device (fuse/MCB) to protect the circuit**
- **contain conductors through which current can flow**
- **be a complete circuit**
- **have a load (such as a lamp) that needs current to make it work**
- **have a switch to control the supply to the equipment (load).**

3. One of the most important formulas for electricians, named after German physicist G.S. Ohm is Ohm's law. State Ohm's law and identify the quantities involved.

Ohm's Law is expressed as:

$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}}$$

4. Calculate the resistance of 100 m of cable where the cross sectional area is 2.5 mm² and has a resistivity of 7.41 mΩ/m.

$$\text{Resistance} = \frac{\text{Resistivity x Length}}{\text{Cross Sectional Area}} \qquad R = \frac{0.00741 \times 100}{2.5}$$

Resistance = 0.296 Ω

5. Calculate the total current in a circuit and the power dissipated, where three resistors of 20 Ω, 40 Ω and 50 Ω are connected in parallel with a 200 V supply.

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_t} = \frac{1}{20} + \frac{1}{40} + \frac{1}{50}$$

$$\frac{1}{R_t} = \frac{10 + 5 + 4}{200}$$

$$\frac{1}{R_t} = \frac{19}{200}$$

$$\frac{R_t}{1} = \frac{200}{19}$$

$$R_t = 10.52\ \Omega$$

Circuit current is

$$I = \frac{V}{R}$$

$$I = \frac{200}{10.52}$$

I = 19A

$$P = \frac{V^2}{R}$$

$$P = \frac{200^2}{10.52}$$

P = 3802 W or 3.8 kW

Page 303: Progress check

1. Describe briefly the difference between a permanent magnet and an electromagnet.

A permanent magnet is a material that, when inserted into a strong magnetic field, will exhibit a magnetic field of its own and continue to exhibit a magnetic field once it has been removed from the original field.

An electromagnet is produced where there is an electric current flowing through a conductor, as a magnetic field is produced around the conductor. This magnetic field is proportional to the current being carried, since the larger the current, the greater the magnetic field.

2. Describe briefly what is meant by alternating current.

Alternating current (a.c.) is a flow of electrons, which rises to a maximum value in one direction and then falls back to zero before repeating the process in the opposite direction. In other words, the electrons within the conductor do not drift (flow) in one direction, but actually move backwards and forwards.

The journey taken, i.e. starting at zero, flowing in both directions and then returning to zero, is called a cycle. The number of cycles that occur every second is said to be the frequency and this is measured in hertz (Hz).

Page 364: Progress check

1. Describe briefly the main problems of having a low power factor.

The lower the power factor of a circuit, then the higher the current will need to be to supply the load's power requirement.

It therefore follows that if power factor is low, then it will be necessary to install larger cables, switchgear etc. to be capable of handling the larger currents. There will also be the possibility of higher voltage drop due to the increased current in the supply cables.

Consequently, local electricity suppliers will often impose financial penalties through tariffs on premises operating with a low power factor

2. Explain the difference between peak values and average values when discussing a.c. sine waves.

Average value

Using equally spaced intervals in our cycle (say every 30°) we could take a measurement of current as an instantaneous value. To find the average we would add together all the instantaneous values and then divide by the number of values used. As with the average of anything, the more values used, the greater the accuracy will be. For a sine wave only, we say that the average value is equal to the maximum value multiplied by 0.637. As a formula:

$$\text{Average current} = \text{Maximum}\left(\text{peak}\right)\text{current} \times 0.637$$

Peak value

You will remember when the loop in an a.c. generator has rotated for 90° it is cutting the maximum lines of magnetic flux and therefore the greatest value of induced e.m.f. is experienced at this point. This is known as the peak value and both the positive and negative half cycles have a peak value.

3. Identify and briefly explain the following:

- R
- X_L
- X_C
- Z

Answer should include:

- **The opposition to current in a resistive circuit is called resistance (R), is measured in ohms and the voltage and current are in phase with each other.**
- **The opposition to current in an inductive circuit is called inductive reactance (X_L), is measured in ohms and the current lags the voltage by 90°.**
- **The opposition to current in a capacitive circuit is called capacitive reactance (X_C), is measured in ohms and the current leads the voltage by 90°.**
- **The total opposition to current in a circuit is called impedance (Z) and is the result of resistance and reactances acting in a circuit.**

4. A resistor of 10 Ω is connected in series with an inductor of 0.02 H and a capacitor of 120 μF across a 240 V 50 Hz supply. Calculate the following:

- the impedance
- the supply current
- the power factor

Answer should include:

$X_L = 2 \pi f L = 2 \times 3.142 \times 50 \times 0.02 = 6.28\ \Omega$

$$X_c = \frac{1}{2 \pi f C}$$

$$X_c = \frac{10^6}{2 \times 3.142 \times 50 \times 120}$$

$X_c = 26.52\ \Omega$

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

$$Z = \sqrt{10^2 + 20.24^2}$$

$Z = 22.57\ \Omega$

$$I = \frac{V}{Z} = \frac{240}{22.57} = 10.63\text{A}$$

$$\text{Cos } \Phi = \frac{R}{Z} = \frac{10}{22.57} = 0.44$$

Therefore power factor = 0.44 leading as capacitive reactance was greater than inductive reactance.

5. Describe the main reason for utilising star-delta connected supplies.

Answer could include:

- **We tend to use the delta connection when we have a balanced load. This is because there is no need for a neutral connection and therefore only three wires are needed. We tend to find that this configuration is used for power transmission from power stations or to connect the windings of a three-phase motor.**
- **Although we can have a balanced load connected in star (three-wire), we tend to use the star connection when we have an unbalanced load, i.e. one where the current in each of the phases is different. In this circumstance, one end of each of the three star connected loops is connected to a central point and it is then from this point that we take our neutral connection, which in turn is normally connected to Earth. This is the three-phase four-wire system.**

6. How is power factor correction achieved in industrial installations?

An automatic power factor correction unit is used to improve power factor. These normally consist of a bank of capacitors switched in via contactors when the power factor is detected as being higher than a pre-set value.

To be able to measure power factor, the regulator uses a current transformer to measure the current in one phase.

Large industrial plants also use the effect of the synchronous motor to cancel out the effect of the induction motor, as it provides a leading power factor. Taken one step further, a synchronous condenser is a synchronous motor without a load, which when introduced into the system can compensate either a leading or lagging power factor, by absorbing or supplying reactive power to the system, which in turn enhances voltage regulation.

Page 332: Progress check

1. Describe how an artificial means of starting a single-phase motor is achieved.

Split-phase motor (induction start/induction run)

We can add another set of poles, positioned 90° around the stator from our original winding.

Now when the supply is connected, both sets of windings are energised, both windings having resistive and reactive components to them – resistance as every conductor has and also inductive reactance because the conductors form a coil. These are known as the 'start' and 'run' windings.

The start winding is wound with fewer turns of smaller wire than the main winding, so it has a higher resistance. This extra resistance creates a small phase shift that results in the current in the start winding lagging that in the run winding by approximately 30°.

2. Explain briefly the difference between synchronous speed and actual speed for an a.c. motor.

Answer could include:

- **Synchronous speed – for an a.c. motor this is the speed of rotation of the stator's magnetic field. Consequently, this is really only a theoretical speed, as the rotor will always turn at a slightly slower rate.**
- **Actual speed – this is the speed at which the shaft rotates. The nameplate on most a.c. motors will give the actual motor speed rather than the synchronous speed.**

3. What is the major advantage of using star-delta starting rather than direct-on-line?

When the motor windings are connected in star, the voltage applied to each phase winding is reduced to 58 per cent of the line voltage, thus the current in the winding is correspondingly reduced to 58 per cent of the normal starting value.

Applying these reduced values to the typical three-phase squirrel-cage induction motor, we would have: initial starting current from two to three-and-a-half times full-load current and initial starting torque of about 50 per cent of the full-load value.

The changeover from star to delta should be made when the motor has reached a steady speed on star connection, at which point the windings will now receive full line voltage and draw full-rated current.

Page 430: Progress check

1. Describe how an incandescent lamp works and why it is regarded as inefficient.

For this method of creating light, a fine filament of wire is connected across an electrical supply, which makes the filament wire heat up until it is white-hot and gives out light. The filament wire reaches a temperature of 2500–2900°C. These lamps are very inefficient and only a small proportion of the available electricity is converted into light; most of the electricity is converted into heat as infrared energy.

2. Describe the operation of a low pressure mercury vapour discharge lamp.

When a voltage is applied across the ends of a fluorescent tube the cathodes heat up, and this forms a cloud of electrons, which ionise the gas around them. The voltage to carry out this ionisation must be much higher than the voltage required to maintain the actual discharge across the lamp. Manufacturers use several methods to achieve this high voltage, usually based on a transformer or choke. This ionisation is then extended to the whole length of the tube so that the arc strikes and is then maintained in the mercury, which evaporates and takes over the discharge. The mercury arc, being at low pressure, emits little visible light but a great deal of ultraviolet, which is absorbed by the phosphor coating and transformed into visible light.

3. Explain briefly the term stroboscopic effect.

A simple example of this effect is that, when watching the wheels rotate on a horse-drawn cart on television, it appears that the wheels are stationary or even going backwards. This phenomenon is brought about by the fact that the spokes on the wheels are being rotated at about the same number of revolutions per second as the frames per second of the film being shot. This effect is known as the 'stroboscopic effect' and can also be produced by fluorescent lighting.

4. Describe briefly the inverse square law applied to lighting.

In physics, an inverse-square law is any physical law stating that some physical quantity or strength is inversely proportional to the square of the distance from the source of that physical quantity.

Simply, what this means is that an object that is twice the distance from a point source of light will receive only a quarter of the illumination. Or put another way, if you moved an object from 3 m to 6 m (twice the distance) away from a light source, you would need four times (2^2) the amount of light to maintain the same level of illumination

Page 497: Progress check

1. Explain briefly what a semiconductor diode is.

A semiconductor diode is basically created when we bring together an 'n-type' material and a 'p-type' material to form a p–n junction. The two materials form a barrier where they meet which we call the depletion layer. In this barrier, the coming together of unlike charges causes a small internal p.d. to exist.

2. How does a light emitting diode work?

The light emitting diode is a p–n junction especially manufactured from a semi-conducting material, which emits light when a current of about 10 mA flows through the junction. No light is emitted if the diode is reverse biased and if the voltage exceeds 5 volts then the diode may be damaged. If the voltage exceeds 2 volts then a series connected resistor may be required.

3. Give a common example of the use of an inverter.

Commonly, inverters are used to supply a.c. from a d.c. source such as solar panels or batteries.

Page 413: Check your knowledge

1. The SI unit for weight is known as a:
a) Mole
b) Joule
c) Newton
d) Kilogram

2. Which one of the following prefixes represents a multiplier of 1 000 000?
a) Terra
b) Kilo
c) Giga
d) Mega

3. What is the result of the following calculations 10 + 2 × 4 – 2?
a) 14
b) 16
c) 24
d) 46

4. What is the formula for calculation Force?
a) Force = Mass + Acceleration
b) Force = Mass – Acceleration
c) Force = Mass ÷ Acceleration
d) Force = Mass × Acceleration

5. What is the total resistance for a parallel combination consisting of resistors valued at 20 Ω and 30 Ω?
a) 10 Ω
b) 12 Ω
c) 25 Ω
d) 50 Ω

6. A 2 kW electric fire is used 6 hours a day in winter. What all the be the total consumption over a 13 week quarter?
a) 546 kWh
b) 54.6 kWh
c) 156 kWh
d) 15.6 kWh

7. Which of the following materials **cannot** be magnetised?
a) Iron
b) Steel
c) Cobalt
d) Aluminium

8. When selecting a relay, which of the following would **not** be considered?
a) Coil voltage
b) Contact ratings
c) Coil material
d) Contact arrangements

9. What is the force on a conductor 20 m long, lying at right angles to a magnetic field of 8 Tesla, when 10 A flows in the coil?
a) 38 T
b) 38 N
c) 1600 N
d) 1600 T

10. Which of these is a suitable transmission voltage?
a) 400 kV
b) 11 kV
c) 400 V
d) 230 V

11. What is the effective r.m.s. value of an a.c. sine wave given by?
a) $0.637 \times I_{max}$
b) $0.707 \times I_{max}$
c) $0.637 \times I_{peak}$
d) $0.707 \times I_{peak}$

12. Complete this sentence: The current in an inductive circuit…?
a) is in phase with the voltage
b) leads the voltage
c) lags the voltage
d) is resistive only

13. Which of the following is used to improve power factor?
a) Resistor
b) Inductor
c) Capacitor
d) Transformer

14. What is the impedance of a circuit with 30 Ω resistance and a 40 Ω inductive reactance?
a) 10 Ω
b) 30 Ω
c) 40 Ω
d) 50 Ω

15. What would the balanced three-phase system in a neutral current be?
a) The same as the phase current
b) The same as the line current
c) Zero
d) Low

16. How many windings does an autotransformer have?
a) None
b) One
c) Two
d) Three

17. What is the turns ratio of a safety isolating transformer?
a) 1:1
b) 2:1
c) 10:1
d) 20:1

18. Which of the following motors would be used on an a.c. supply?
a) Long shunt
b) Short shunt
c) Universal
d) Compound

19. What is the major advantage a star-delta starter has compared with a direct-on-line starter?
a) Reduced starting current
b) Increased starting current
c) Increased voltage
d) Faster motor speed

20. What is stroboscopic effect associated with?
a) Tungsten filament lamp
b) Tungsten halogen lamp
c) Incandescent lighting
d) Flourescent discharge lighting

21. What would the colour coding of a 630 kOhm resistor with a tolerance of 5%?
a) Blue, red, orange and silver
b) Blue, orange, yellow and silver
c) Blue, orange, yellow and gold
d) Blue, yellow, orange and gold

22. What device is used to measure the temperature of a motor winding?
a) Resistor
b) Thermistor
c) Transistor
d) Thyristor