Section A

1. Documents
    a. Electricity at Work Regulations 1989
    b. IEE Guidance Note 3 – Inspection & Testing
    c. HSE Guidance Note GS38

2. New Cooker Circuit
    a. Electrical Installation Certificate
    b. Schedule of Inspections
    c. Schedule of Test Results

3. Inspection & Test of industrial unit
    a. Periodic Inspection Report
    b. (Referring to question) Extent and Limitations of the Inspection
    c. The 'person ordering the work' (the client)

4. Minor Works Cert
    a. System earthing arrangements
    b. Method of protection against indirect contact
    c. Type and rating of protective device for modified circuit

5. Contact
    a. Direct
    b. Indirect
    c. Indirect

6. Units
    a. MΩ - Mega-Ohms
    b. mA (and ms) milli-Amps (and milli-seconds)
    c. Ω - Ohms

7. Sequence of tests[1]
    a. Continuity of protective conductors
    b. Insulation resistance
    c. Polarity

8. Earthing/Bonding terminology
    a. Main Earthing Conductor
    b. Circuit Protective Conductor
    c. Supplementary Bonding Conductor

9. IP Codes[2]
    a. IP4X
    b. IP2X or IPXXB

10. CPC Continuity Test
    a. Low reading ohmmeter

[1] Full sequence is given in regulation 713 – that's the order they want you to memorise. But, in real life, polarity is almost always tested in conjunction with continuity of cpc, when tested by method 1
[2] IP4X and IP2x or IPXXB are the only IP codes you are likely to be asked about

b. Either zero the meter with leads connected to each other, or record the resistance of the leads and deduct it from measurements.
c. Last point (or highest reading) is the value of $(R_1 + R_2)$ for the circuit

11. Ring Circuit Continuity
    a. Verify continuity of cpc. Confirm a ring exists without interconnections, obtain values of r_1 and r_2 with which to compare directly measured $(R_1 + R_2)$
    b. Polarity[3]

12. Resistivity[4]
    a. Double cable length – double conductor resistance to 1.6 Ω, but halve insulation resistance to 50 MΩ
    b. Halve csa – double conductor resistance to 1.6 MΩ, but insulation resistance is unaffected and remains 100 MΩ

13. Insulation Resistance of SELV Circuit
    a. Insulation Resistance Tester
    b. 250V d.c.
    c. 0.25 MΩ

14. Insulation Resistance Values
    a. 0.00 MΩ = dead short
    b. 0.08 MΩ = low insulation resistance fault
    c. >200 MΩ = healthy circuit

15. Earth Fault Loop Impedance
    a. The ¾ rule is a rule of thumb that avoids calculation and gives a worst case value for Z_s. (Calculations are rarely carried out, but involve correcting for ambient temperature and maximum conductor operating temperature.)
    b. By the ¾ rule, the maximum measured value for a circuit with a 0.9 Ω maximum value would be 0.675 Ω. So a measured 0.7 Ω will be too high.

16. More Loop Impedance…
    a. To determine that an earth fault path exists and is low enough to allow sufficient current to flow in the event of a fault to operate the protective device within the prescribed times.
    b. Increase the size of CPC if possible (The other method is to use an RCD)
    c. The highest Z_s value is recorded.

17. 30mA RCD
    a. For operation of portable equipment outside the equipotential zone
    b. To meet disconnection times if Z_s is too high
    c. For fixed equipment in bathrooms
    d. For all sockets on a TT system

18. 500mA RCD Tests
    a. Apply 50% current (250mA) – RCD should not trip on either half-cycle

[3] This is the answer our lecturer always insists on. He is taking 'automatic' to mean that the polarity is automatically confirmed when you do the figure-of-eight tests. You could, however, take 'automatically' to mean 'which other tests would you do as part of this sequence'?
[4] See explanation at the end of this document – I wrote this to explain to our lecturer how it worked!!

   b. Apply 500mA (rated current) – RCD should operate within 300ms
   c. Test ‘T’ button to verify electro-mechanical operation. (functional test)

19. Prospective Fault Current at origin
   a. Direct measurement
   b. Calculation, using Z_e value
   c. By enquiry

20. PSCC and PEFC
   a. PSCC and PEFC are the same because the neutral and earth conductors are combined up to the service head where the measurement is taken.
   b. If Z_e = 0.01, then using the formula $Z_s = \frac{U_{oc}}{I_a}$ where U_{oc} is taken as 240V for a nominal 230V supply voltage (U_o), then $PFC = \frac{240}{0.01} = 24kA$
   c. If single-phase PFC is 10kA, an approximate value for PFC between phases is found by doubling this value to 20kA.

Section B

21. Scenario
   a. Certification/documentation
      i. Electrical Installation Certificate for cooker circuit
      ii. Periodic Inspection Report for whole installation
      iii. Schedule of Inspections
      iv. Schedule of Test Results
      v. Installation Schedule
   b. Originals retained by client (‘person ordering the work’)
   c. Ideally, it should be kept next to the CCU
   d. Measured Zs, RCD trip times
   e. Documents
      i. Electricity at Work Regulations 1989 - Statutory
      ii. BS7671 Requirements for Electrical Installations – Non-Statutory
      iii. IEE Guidance Note 3 Inspection & Testing - Non-Statutory
      iv. HSE Guidance Note GS38 - Non-Statutory
      v. IEE Onsite Guide - Non-Statutory
   f. Next inspection on domestic premises = maximum, ten years
   g. The age of the installation, change of use, request of insurers, change of ownership, following damage, etc, etc…

22. .
   a. A new circuit has been installed back to the origin (cooker). This requires an Electrical Installation Certificate. On replacing the consumer unit, you are changing the protective devices and need to confirm that existing circuits are adequately protected and conform to BS7671
   b. Schedule of Inspections
      i. Routing of cables in prescribed zones
      ii. Connection of conductors
      iii. Selection of conductors for current carrying capacity
      iv. Erection methods
      v. Presence and correct location of appropriate device for isolation and switching… Etc…

   c. Practical problems
      i. Circuit tails not long enough
   d. Possible solutions
      i. Move CCU position, use crimps/terminal blocks inside CU or other appropriate housing to extend tails.

23. Test sequence (again)
   a. Cooker Circuit
      i. Tests
         1. Continuity of protective conductors
         2. Insulation Resistance
         3. Polarity (usually in conjunction with 1)
         4. Earth fault loop impedance
         5. Operation of switch/isolator
      ii. Instruments
         1. Low-reading ohmmeter – Ohms
         2. Insulation Resistance Tester – M Ω
         3. Loop Impedance Tester – Ohms
   b. Test schedule
      i. Test Instrument details
         1. make and model
         2. serial number
      ii. Supply details[5]
         1. Type of supply/Earthing arrangements
         2. External earth loop impedance - Z_s
         3. Prospective fault current

24. .
   a. Blanket Insulation Resistance Test
      i. Isolate installation from supply.
      ii. Remove all lamps
      iii. Disconnect all sensitive equipment – dimmers, neons, fluorescents etc
      iv. Close all switches
      v. Check test leads
      vi. Set IR tester to 500V d.c.
      vii. Test between Live/Neutral. Live/CPC and Neutral/CPC
      viii. Lowest reading must be greater than 2 MΩ. If a lower reading is obtained then circuits must be tested individually.
   b. Individual circuits are treated as resistances in parallel, so:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} etc... \text{ so: } \frac{1}{R} = \frac{1}{100} + \frac{1}{4} + \frac{1}{10} + \frac{1}{3} + \frac{1}{5} + \frac{1}{100} + \frac{1}{5} + \frac{1}{100} = 1.1133$$

$$R = \frac{1}{1.1133} = 0.898 M\Omega$$

   c. Although each circuit is acceptable a blanket test would put them in parallel and result in a lower value than the lowest individual value. An overall value of less than 2 MΩ requires further investigation of individual circuits.

25.
   a. The earth fault loop impedance must be low enough to comply with the requirements of the protective devices in the new CU. Also it is essential to verify that an earth fault path exists before a circuit is connected to the new CU

[5] Note that for exam purposes the **only** forms in existence are the IEE model forms in Appendix 6 of BS7671

b.
   i. Ambient temperature and conductor maximum operating temperature
   ii. Badly worded question, but I think it's asking for you to state that you can use ¾ of the stated maximum values.

c. Maximum Z_s values given in schedule:

Circuit	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Measured Z_s	0.8	1.1	1.3	6.2	5.1	2	0.6	1.3
Max Z_s	1.2	1.5	1.5	8	8	3	0.96	1.5
¾ Max Z_s	0.9	1.125	1.125	6	6	2.25	0.72	1.125
Acceptable?	Yes	Yes	No	No	Yes	Yes	Yes	No

d. For unacceptable Z_s values you can increase the size of the CPC if possible, or else use an RCD to limit shock potential.

e.
   i. Low rated MCB's may sometime trip when this test is conducted
   ii. In this case the Z_s values must be calculated and this fact noted on the test schedule

26.

a.
   i. Circuits 2, 3 and 8 supply, respectively, sockets for the use of portable equipment and the garage, which is outside the equipotential zone. These circumstances introduce a higher risk of electric shock. Note that circuit 3 also has an insufficiently low Z_s measurement, so an RCD/RCBO is necessary to meet disconnection times of 0.4 seconds. The other circuits are supplying fixed equipment, which have a required disconnection time of 5 seconds, although it is generally recommended that showers be protected by a residual current device.

   ii. RCBO's for shock protection should be tested at half nominal operating current, ($I_{\Delta n}$) full nominal current and five times this current. At half current the RCBO should not operate. At full $I_{\Delta n}$ they should operate within **300ms**[6] and at five time they should operate within 40ms.

b.

   i. PSCC is the short current circuit between phase and neutral at the installation supply origin. It involves only the phase and neutral conductors between the supply transformer and the supply cut-out. The PEFC also includes the supplier's earth facility, which in this case, is the sheathing of the supply cable and is likely to give a different value from PSCC.

   ii. The larger of these two values is recorded as the Prospective Fault Current, as it is this value that the protective devices must be capable of safely breaking.

[6] Note that for RCD protected socket outlets to BS 7288 the RCD should operate within 200ms at $I_{\Delta n}$ but general purpose RCBO's to BSEN 61008/61009 should operate within 300ms

Resistivity

Question

1. A twin cable has a phase to neutral resistance value of 100 MΩ and an individual conductor resistance value of 0.8 Ω. Determine the values if the cable…
   a. was doubled in length
   b. length was the same but the conductor cross-section area was halved

Conductor Resistance

This is a function of the resistivity of the conductor material:

$$R = \frac{\text{Resistivity}(\rho) \times \text{Length}(l)}{\text{Area}(A)}$$

In other words, resistance is directly proportional to length and inversely proportional to area, so doubling length or halving the area will both double resistance. Try it with some values:

Let's say the original length is 40m and the area is 2 mm^2. The equation then, is:

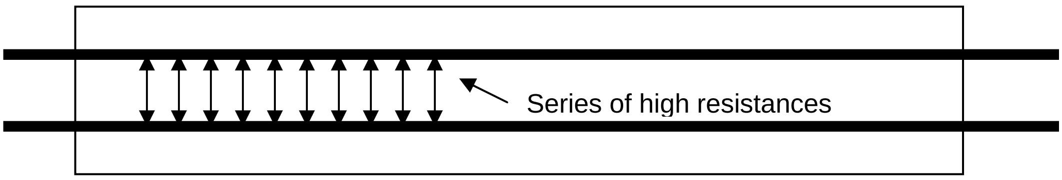
$$0.8 = \frac{\rho \times 40}{2}$$ This gives a value for ρ of, $\frac{0.8 \times 2}{40} = 0.04$ (ignoring the units)

Double length: $R = \frac{0.04 \times 80}{2} = 1.6\,\Omega$ Halve area: $R = \frac{0.04 \times 40}{1} = 1.6\,\Omega$

Beware the question that asks what happens if the *diameter* is varied, because area is proportional to the diameter squared. Doubling diameter will increase the area by four times; halving the diameter will quarter the area.

Insulation Resistance

The insulation between two conductors is considered to act as a series of many high resistances in parallel:



The greater the length, the greater the number of parallel resistors, so the lower the insulation resistance (because of the greater number of apparent parallel paths). Taking the insulation resistance of the original length as R_1, adding an identical extra length is like adding a second R_1 in parallel. So:

$$\frac{1}{R_{Total}} = \frac{1}{R_1}$$ so $R_1 = R_{Total}$ = 100M Ω. (in the first instance)

With double the length, $\frac{1}{R_{Total}} = \frac{1}{100} + \frac{1}{100} = \frac{2}{100}$ so new R_{Total} = 50M Ω

Changing the conductor c.s.a. should have no effect on the insulation resistance for the same value of voltage applied.