Loughborough University

ELECTRICAL SYSTEMS: BUILDINGS AND RENEWABLE ENERGY
(21CVP300)

Semester 1 2021-22 (1b) Exam paper

This is a (1b) online examination, meaning you have a total of **2 hours plus additional 30 minutes** to complete and submit this paper. The additional 30 minutes are for downloading the paper and uploading your answers when you have finished. If you have extra time or rest breaks as part of a Reasonable Adjustment, you will have further additional time as indicated on your exam timetable.

It is your responsibility to submit your work by the deadline for this examination. You must make sure you leave yourself enough time to do so.

It is also your responsibility to check that you have submitted the correct file.

Exam Help
If you are experiencing difficulties in accessing or uploading files during the exam period you should contact the exam helpdesk. For urgent queries please call **01509 222900**. For other queries email examhelp@lboro.ac.uk

You may handwrite and/or word process your answers, as you see fit.

You may use any calculator (not just those on the University's approved list).

Answer **THREE** questions.

All questions carry equal marks.

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1 a) A solar PV array is located in Loughborough at a latitude of 51.5°N. The PV array is tilted at 40° from the horizontal and pointed southwest. At 11:00 (solar time) on April 3rd, the direct solar irradiance is 700 W/m^2 and the diffuse solar irradiance is 150 W/m^2.

For 11:00 (solar time) on April 3rd, calculate:

i) the declination angle; [2 marks]

ii) the hour angle; [2 marks]

iii) the angle of incidence; [3 marks]

Question 1 continues/…

iv) the total solar irradiance falling on the PV array; [4 marks]

v) the length of the day in hours. [6 marks]

b) A solar PV array has an area of 20 m^2, a module efficiency of 12.5% at standard test conditions and a temperature coefficient of power of -0.45%/°C. Calculate:

i) the power output of the module under standard test conditions; [2 marks]

ii) the power output of the module under standard test condition but with a cell temperature of 70°C; [2 marks]

iii) the cell temperature if, for solar irradiance of 1000 W/m^2 and air mass 1.5, the power output is 2200W. [4 marks]

c) Calculate the cell temperature and PV module efficiency of the PV array described in Table Q1(c) in a location with ambient temperature of 10°C, solar radiation of 400 W/m^2 and wind speed of 3.2 m/s. Make the standard assumptions about any unknown variables as necessary and carry out at least 3 iterations.

Table Q1(c): PV array characteristics

Maximum power at STC	1500 W
Temperature co-efficient of power	-0.45 %/°C
Module area	15 m^2
NOCT	46°C

[8 marks]

2 a) A wind turbine has a rotor diameter of 220m, a hub height of 150m, a rated power output of 12MW and a combined drive train/generator efficiency of 90%.

For a wind speed of 10 m/s, calculate:

i) the wind power; [4 marks]

ii) the theoretical maximum power that the wind turbine could extract from the wind; [4 marks]

iii) a reasonable estimate for the maximum power of a real turbine; [4 marks]

iv) a reasonable estimate of the electrical power output of a real turbine. [4 marks]

Question 2 continues/…

b) You are a consultant working for a heat pump installation firm. A client approaches you who is interested in installing a heat pump in their home, which is a large 5 bedroom detached dwelling. The client wishes to make use of a recent government subsidy scheme, which will provide £5,000 towards the costs of heat pump installation.

In your own words, write a technical note for this client which:

i) provides a concise explanation of heat pump technology suitable for a technical non-specialist reader; [4 marks]

ii) explains the installation process of a heat pump and associated equipment for a domestic building; [4 marks]

iii) discusses the advantages and disadvantages of using heat pumps for domestic heating; [4 marks]

iv) discusses the overall finances of using heat pumps for heating and the potential financial impact for the client. [5 marks]

3 a) A balanced star-connected three-phase load with a resistance of 10Ω per phase is supplied from a 400V 50Hz main supply at a unity power factor.

Calculate.

i) The phase voltage. [4 marks]

ii) The line current. [4 marks]

iii) The total power consumed. [4 marks]

b) A 230V to 12V bell transformer is constructed with 400 turns on the primary winding.

When the transformer supplies a 12W alarm, calculate:

i) The number of turns on the secondary winding. [2 mark]

ii) The secondary current. [2 mark]

iii) The primary current. [2 mark]

c) Calculate the current demand of a 7.36 kW electric shower connected to the 230 V mains supply. [6 marks]

Question 3 continues/…

d) A 10A lighting circuit is wired in 1.5mm^2 PVC cable. The circuit length is 35m and the cable resistance is 24.20 mΩ/m. The earthing arrangement is TN-S. The multiplying factor under fault conditions is 1.20.

Calculate the total earth fault loop impedance.

[9 marks]

4 a) A capacitor of reactance 12 Ω is connected in series with a 9 Ω resistor across a 150 V supply. Calculate:

i) The impedance. [3 mark]

ii) The current. [3 mark]

iii) The power factor [3 mark]

iv) The power [3 mark]

b) A 230 V ring main circuit of socket outlets is wired in 2.5 mm^2 single PVC copper cables in a plastic conduit with a separate 1.5 mm^2 CPC. An earth fault loop impedance test identifies (Zs) as 1.15 Ω. Verify that the 1.5 mm^2 CPC meets the requirements of IET Wiring Regulations when the protective device is a 30 A semi-enclosed fuse.

k = 115 (from table in the IET Wiring Regulations)

[8 marks]

c) Calculate the minimum size of trunking required to accommodate the following single-core PVC cables:

20 x 1.5 mm^2 solid conductors.
20 x 2.5 mm^2 solid conductors.
21 x 4.0 mm^2 stranded conductors.
16 x 6.0 mm^2 stranded conductors.

[6 marks]

d) A lamp of luminous intensity 1000 cd is suspended 2 m above a laboratory bench. Calculate the illuminance directly below the lamp. [3 marks]

e) Using a scale rule, draw a room that is 14m x 7.5m. The room is a kitchen with a flat ceiling. In the room, denote where you would site automatic fire detection devices. [4 marks]

S K Firth
A L Fletcher