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WORKSHEETS
ATTEMPT | CHECK | CORRECT | IMPROVE

Capacitors 1

Charge combinations and stored energy

35–40 minutes independent work + 15–20 minutes review

OCR A H556 and AQA 7408 | A-level physics

Specification and route

OCR A H556: 6.1.1(a)–(e), 6.1.2(a)–(c).

AQA 7408: 3.7.4.1 and 3.7.4.3. Combination work in Questions 4–7 is a supported extension for AQA; the relationships are supplied.

A-level only. Parallel-plate geometry and dielectric action are outside this sheet.

23 core parts | 43 marks

A seabed sampling robot must close its sample cartridge and save one final record if its main supply fails. Engineers are choosing a capacitor bank for these two jobs. Use ideal capacitors with constant capacitance and negligible leakage unless told otherwise.

Show your working, include units and justify decisions using the information given.

1 Understand the charge

1(a) A component is labelled 2200 μF. State what its capacitance means in terms of charge and potential difference. **[1 mark]**

1(b) Explain how the robot's supply charges a capacitor, and why an ideal charged capacitor can have zero net charge. **[2 marks]**

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2 Test a single component

For Questions 2–3 use an ideal 2200 μF capacitor. It is initially uncharged.

2(a) Calculate the charge magnitude on either plate when the p.d. is 18.0 V. Give your answer in mC. **[1 mark]**

2(b) The capacitor later holds 18.0 mC on either plate. Calculate its p.d. **[1 mark]**

2(c) In a separate test a constant current of 4.40 mA charges an initially uncharged component for 9.00 s. Its final p.d. is 18.0 V. Use these measurements to determine its capacitance. **[2 marks]**

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3 Connect charge and energy

For a constant-capacitance component, a graph of p.d. V vertically against plate-charge magnitude Q horizontally is a straight line through the origin.

3(a) Sketch this V–Q graph up to 39.6 mC and 18.0 V. Use its area to show that $W = \frac{1}{2}QV$, then calculate the stored energy at 18.0 V. **[3 marks]**

3(b) Use $Q = CV$ to obtain both $W = \frac{1}{2}CV^2$ and $W = Q^2/(2C)$ from $W = \frac{1}{2}QV$. **[2 marks]**

3(c) An engineer uses $W = QV$ because “all the charge ends up at 18 V”. Explain why this doubles the energy for charging from zero. **[2 marks]**

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4 Compare capacitor banks

Each bank in Figure 1 is initially uncharged, then connected between X and Y across an ideal 18.0 V supply. All quoted capacitances and ratings are component values. The two components in B are matched.

OCR required / supported AQA extension. For two capacitors: series $1/C = 1/C_1 + 1/C_2$; parallel $C = C_1 + C_2$. In series the initially neutral isolated junction gives equal charge magnitudes; in parallel each branch has the same p.d.

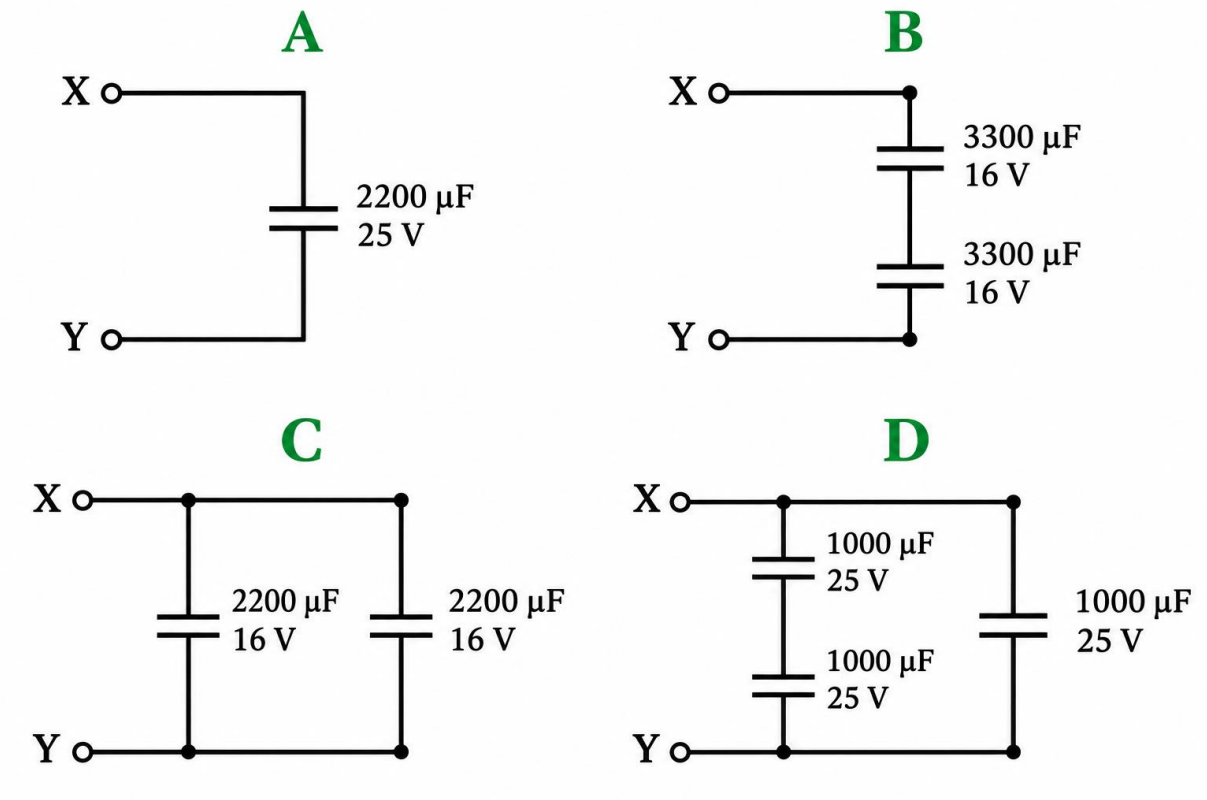


Figure 1 Four independent banks. The second label on each component is its maximum permitted p.d.

4(a) Calculate the equivalent capacitance of bank B. **[1 mark]**

4(b) Calculate the charge magnitude on each capacitor in B at a total p.d. of 18.0 V. **[2 marks]**

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Series and parallel reasoning

Refer to Figure 1 on the preceding page. The supply p.d. remains 18.0 V.

4(c) Calculate the p.d. across each capacitor in B and decide whether its 16 V rating is exceeded. **[2 marks]**

4(d) In a separate 18.0 V series test, 1000 μF and 2000 μF capacitors are used. Without calculating the charge, explain which has the larger p.d. and give the two p.d.s. **[2 marks]**

5(a) Calculate the equivalent capacitance of bank C. **[1 mark]**

5(b) Calculate the charge on each capacitor in C and the total charge supplied to the bank at 18.0 V. **[2 marks]**

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5 Check the energy and the ratings

Use Figure 1. Bank C is assessed as an ideal arrangement before its component ratings are checked; it must not be used above a rating.

5(c) Calculate the energy in each component of C at 18.0 V and show that their sum equals the energy calculated using the equivalent capacitance. **[2 marks]**

5(d) Bank C stores more energy than B at the same total p.d. Explain why C is nevertheless unsuitable at 18.0 V. **[1 mark]**

6(a) Find the equivalent capacitance of bank D by reducing its series pair first. **[2 marks]**

6(b) The robot's electronics stop using the bank when its p.d. reaches 9.0 V. Calculate the energy released by bank A between 18.0 V and 9.0 V. **[2 marks]**

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6 Decide what the robot can use

From 18.0 V down to 9.0 V, 70% of the energy released by the bank reaches the robot's useful jobs. The cartridge closure needs 0.100 J and the final record needs 0.0400 J. Both jobs must be completed.

For the same voltage interval, the energy released is 0.200475 J for B, 0.5346 J for C and 0.18225 J for D. Use your answer for A from 6(b).

6(c) Calculate the useful energy delivered by A and decide whether it meets the combined demand. **[2 marks]**

6(d) Determine the minimum bank capacitance needed to deliver 0.140 J usefully over this voltage interval at 70% efficiency. **[2 marks]**

7(a) Compare A–D at their nominal values. State which satisfy both the useful-energy demand and their component voltage ratings. Support your decisions numerically. **[3 marks]**

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7 Test the margin and the measurement

For this tolerance test only, each bank's actual capacitance is 10% below its nominal equivalent value. Matched series components remain matched, so nominal voltage-sharing ratios are unchanged.

7(b) Decide whether A and B still meet the useful-energy demand at the lower capacitance. Recommend one bank. **[2 marks]**

7(c) Describe how a controlled constant-current charging test, using an ammeter, voltmeter and timer, could check the equivalent capacitance of the chosen bank. Include one useful measurement precaution. **[3 marks]**

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