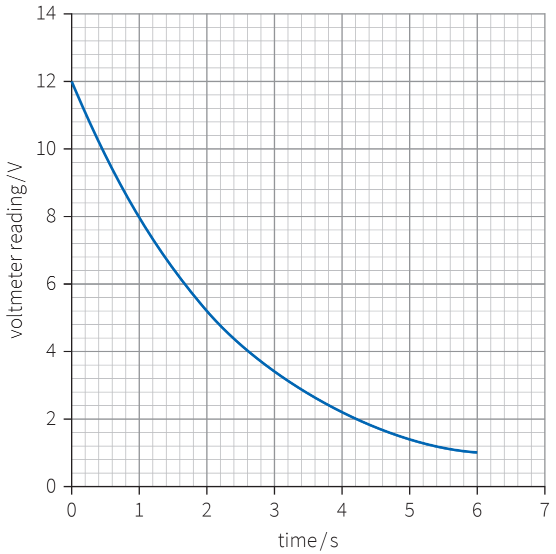
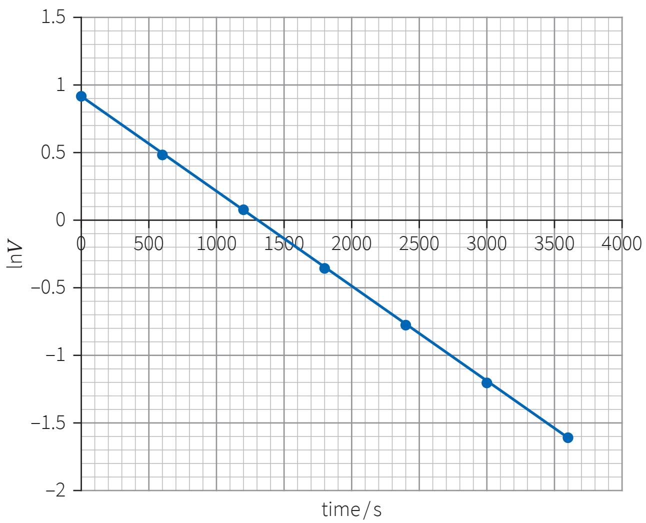
# A Level AQA Physics
## 16 Capitance – answers

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| **01.1** | $Q = CV = 1000\times10^{-6} \times 12 = 1.2\times10^{-2}$ C<br>$I = \frac{V}{R} = \frac{12\,\text{V}}{2400\,\Omega} = 5.0\times10^{-3}$ A | | 1<br>1 | 2 | 3.7.4.2 |
| **01.2** | Time for p.d. to drop to half its value<br>$= RC\ln 2 = 2400 \times 1000\times10^{-6} \times 0.693 = 1.67$ s<br> | Graph with scales/labelled axes extending to 6 seconds<br>Initial p.d. = 12 V and exponential shape by eye<br>Evidence for p.d. halving in 1.7 s | 1<br>1<br>1 | 2 | 3.7.4.4 |
| **01.3** | Original time constant $= RC = 2400 \times 1000\times10^{-6} = 2.4$ s<br>New time constant $= 1.8 \times 2.4 = 4.32$ s<br>Effective capacitance $= \frac{4.32}{2400} = 1.8\times10^{-3}$ F<br>Capacitances in parallel add so<br>$C_{total} = C + 1000\times10^{-6}\text{ F} = 1.8\times10^{-3}$ F<br>$C = 0.8\times10^{-3}\text{ F} = 800\,\mu$F | Calculation of new time constant/ method involving time constant<br>Answer | 1<br>1<br>1 | 3 | 3.7.4.4 |

# A Level AQA Physics
## 16 Capitance – answers

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| **01.4** | Assumption is that the voltmeter has infinite resistance<br>If the voltmeter has a large but finite resistance, this reduces the resistance of the circuit because there are now two resistances in parallel<br>The time constant will be smaller than it should be, so the unknown capacitance is larger than the value in **06.3** | Effect of resistance of voltmeter on resistance of circuit<br>Effect on capacitance | 1<br>1 | 1<br>3 | 3.7.4.4 |
| **02.1** | From the graph, the time for the pd to halve 0.12 ms<br>Time to halve = $RC \ln 2$<br>Time constant = $RC = \frac{\text{(time to halve)}}{0.693} = 1.73 \times 10^{-4}$ s | Use of graph to find time to halve<br>Answer | 1<br>1 | 2 | 3.7.4.4 |
| **02.2** | $C = \frac{\text{time constant}}{R}$<br>$= \frac{2.89 \times 10^{-4}}{10 \times 10^{3}}$<br>$= 2.89 \times 10^{-8}$F | Use of time constant to find $C$ | 1<br>1 | 2 | 3.7.4.4 |
| **02.3** | Curve that starts at half the pd on the $y$-axis, and has $T_{½}$ that is double the original value by eye<br>If the resistance doubles, the maximum current will halve, so the maximum pd will halve<br>If the resistance is doubled, the time constant is doubled, so the time to halve the p.d. is also doubled | Correct line on graph<br>Explanation of p.d. $\times \frac{1}{2}$<br>Explanation of time to halve $\times$ 2 | 1<br>1<br>1 | 3 | 3.7.4.4 |
| **02.4** | Use the pd and resistance to work out the current using $I = \frac{V}{R}$<br>The area under the graph is the charge stored; work out the charge represented by each square using $Q = It$; count squares and multiply | Conversion of pd to current<br>How to find charge from area | 1<br>1 | 3 | 3.7.4.4 |

# A Level AQA Physics
## 16 Capitance – answers

<table>
<tr><th>Question</th><th>Answers</th><th>Extra information</th><th>Mark</th><th>AO</th><th>Spec reference</th></tr>
<tr><td>03.1</td><td>When the switch is closed, there is a potential difference across the resistor<br>A current flows, so the charge on the capacitor decreases<br>As the charge decreases, the p.d. decreases $\left(V = \frac{Q}{C}\right)$, so the current decreases in the same way<br>The rate of change of pd depends on the charge, and hence pd, so the relationship is a negative exponential</td><td>Link between p.d. and current<br>Link to charge on capacitor<br>Explanation of exponential</td><td>1<br>1<br>1</td><td>1</td><td>3.7.4.2</td></tr>
<tr><td>03.2</td><td>
<table>
<tr><th>Time / min</th><th>p.d. / V</th><th>Time / s</th><th>ln $V$</th></tr>
<tr><td>0</td><td>2.50</td><td>0</td><td>0.92</td></tr>
<tr><td>10</td><td>1.62</td><td>600</td><td>0.482426</td></tr>
<tr><td>20</td><td>1.08</td><td>1200</td><td>0.076961</td></tr>
<tr><td>30</td><td>0.70</td><td>1800</td><td>−0.35667</td></tr>
<tr><td>40</td><td>0.46</td><td>2400</td><td>−0.77653</td></tr>
<tr><td>50</td><td>0.30</td><td>3000</td><td>−1.20397</td></tr>
<tr><td>60</td><td>0.20</td><td>3600</td><td>−1.60944</td></tr>
</table>


</td><td>Calculations of $t$ in seconds and ln$V$<br>do not penalise excessive significant figures.<br>Graph starting at (0, 0), points plotted, linear line of best fit<br>Correct labels/units</td><td>1<br>1<br>1</td><td>2</td><td>3.7.4.4</td></tr>
</table>

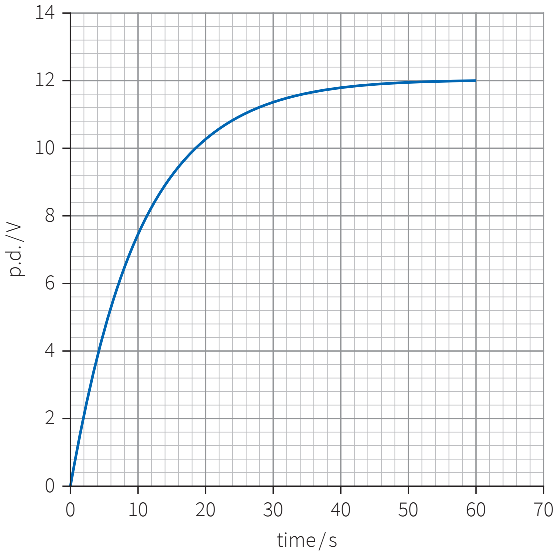
# A Level AQA Physics

## 16 Capitance – answers

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| **03.3** | $V = V_0 e^{-\frac{t}{RC}}$<br>$\ln V = \ln V_0 - \frac{t}{RC}$<br>So a graph of ln$V$ against $t$<br>gradient = $-\frac{1}{RC}$ | Taking natural logs of both sides of equation<br><br>Gradient correct | 1<br><br>1 | 2 | 3.7.4.4 |
| **03.4** | ln(1.5) = 0.405<br>Reading from graph when ln$V$ = 0.4, $t$ = 700 s<br>= 11 minutes and 40s | Correct deduction from graph | 1 | 2 | 3.7.4.4 |
| **04.1** | $E = \frac{1}{2}CV^2$<br>$= \frac{1}{2} \times 470 \times 10^{-6} \times (6.0)^2$<br>$= 8.46 \times 10^{-3}$ J $= 8.5 \times 10^{-3}$ J | Answer | 1 | 2 | 3.7.4.3 |
| **04.2** | Resistance of lamp $= \frac{6.0}{0.3} = 20\,\Omega$<br>Time to discharge to 37% = $RC = 470 \times 10^{-6} \times 20 = 9.4 \times 10^{-3}$ s<br>energy transferred $= 8.46 \times 10^{-3} \times 0.37^2 = 1.158 \times 10^{-3}$ J<br>power $= \frac{\text{energy}}{\text{time}} = \frac{1.158 \times 10^{-3}}{9.4 \times 10^{-3}} = 0.12$ W<br>You may not see this as it is less than a tenth of the bulbs normal power rating power = 6 V × 0.3 A = 1.8 W | Calculation of resistance<br>Explicit use of $RC$ as time for pd to reduce to 37%<br>energy transferred from capacitor $\propto V^2$<br>Calculation of power<br>Appropriate comment with numerical comparison | 1<br>1<br>1<br>1<br>1 | 3 | 3.7.4.3 |
| **04.3** | The energy stored would be multiplied by 4 as energy stored depends on $V^2$<br>The time is the same<br>Power would be multiplied by 4; this would definitely be observable but still dim | Reference to $E$ proportional to $V^2$<br><br>Effect on what is observed / appropriate comment | 1<br><br>1 | 3 | 3.7.4.3 |

# A Level AQA Physics

## 16 Capitance – answers

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| **04.4** | (use of $E = \frac{1}{2}CV^2$)<br>a 470 μF capacitor would need a pd of $V = \sqrt{\frac{2E}{C}}$ = 650 V<br>a 6 V p.d. would need a capacitance of $C = \frac{E}{2V^2}$ = 1.4 F<br>1.4 F is a very large capacitor, so the energy stored is achieve by increasing the p.d. | <br><br>Comment on size of capacitance | <br>1<br>1<br>1 | 3 | 3.7.4.3 |
| **05.1** | <br>Initially there is no charge on the capacitor, so zero pd; as the capacitor charges the p.d. increases as $V = \frac{Q}{C}$<br>And increases at a decreasing rate | Exponential growth by eye<br>Asymptotic to 12 V<br>Only a sketch needed, so no values needed on $x$-axis<br>Correct description of $V$ proportional to charge<br>Comment about shape | 1<br>1<br>1 | 1 | 3.7.4.4 |

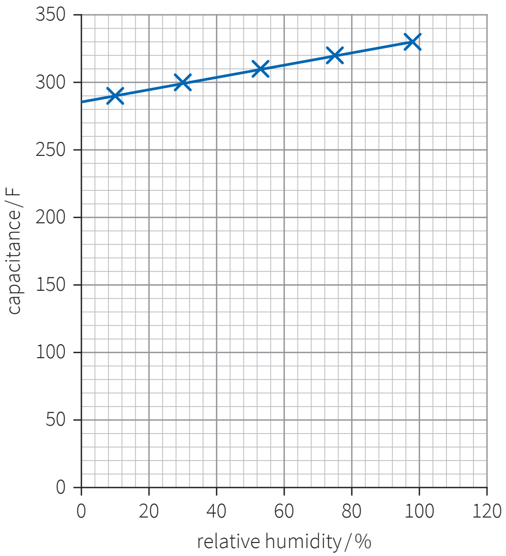
# A Level AQA Physics

## 16 Capitance – answers

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| **05.2** | Reducing the resistance; as the current normally decreases as the capacitor charges, a smaller resistance is needed to maintain the current at a constant value<br>The graph will be a straight line through (0, 0) as the pd increases at a constant rate<br>The graph will be horizontal when the capacitor is fully charged | Answer and reason needed for mark | 1<br><br>1<br><br>1 | 3 | 3.7.4.4 |
| **05.3** | Procedure described, for example:<br>• note the capacitance of the capacitor<br>• open the switch and short circuit the capacitor to ensure that it is uncharged<br>• close the switch and reduce the resistance of the variable resistor to maintain the current at a constant value<br>• when the graph on the computer is horizontal, open the switch<br>• use the graph to find the time it took to charge the capacitor from time the pd started to rise until the time the pd was constant<br>• multiply the current by the time to work out the charge<br>• replace the capacitor with one of a different capacitance, and repeat<br>• repeat for a range of capacitors<br>• repeat the experiment three times for each capacitor, and calculate the mean charge stored<br>• plot a graph of charge against capacitance | Sufficient detail<br><br>Using the graph to find the time<br><br>Calculating charge from current and time<br><br>Repetition/finding mean | <br><br>1<br><br>1<br><br>1 | 1 | 3.7.4.4 |
| **05.4** | Appropriate suggestion and solution, for example:<br>The reading on the ammeter will not be constant as it will be difficult to change the resistance to exactly match the exponential decay of current<br>Repeating the experiment many more times will give a more accurate measurement | | 1<br><br><br>1 | 1 | 3.7.4.4 |
| **06.1** | The water molecule aligns with the electric field between the plates so that the positive side of the molecule ($H^+$) is attracted to the negative plate, and the negative side ($O^-$) is attracted to the positive plate | Movement of molecule to align with field | 1 | 2 | 3.7.4.2 |

# A Level AQA Physics

## 16 Capitance – answers

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| **06.2** | The greater the humidity, the greater the capacitance | Relationship | 1 | 3 | 3.7.4.2 |
| | The water molecules effectively reduce the distance between the plates of the capacitor, and $C = \frac{A\varepsilon_0 \varepsilon_r A}{d}$, | Effect of water molecules on distance | 1 | | |
| | $C$ is inversely proportional to $d$, so as $d$ decreases, $C$ increases | Link to capacitance | 1 | | |
| **06.3** |   | Graph starting at (0, 0), points plotted, linear line of best fit | 1 | 1 | 3.7.4.2 |
| | | Correct labels/units | 1 | 1 | |
| | When the humidity is zero, the capacitance is 282 µF, and when it is 100%, the capacitance is 330 mF, | Values between 280 µF and 285 mF acceptable | 1 | | |
| | $C_{100} = \frac{\varepsilon_0(\varepsilon_r + \varepsilon_w)A}{d}$ and $C_0 = \frac{\varepsilon_0 \varepsilon_r A}{d}$<br>$\frac{C_{100}}{C_0} = \frac{\varepsilon_0(\varepsilon_r + \varepsilon_w)}{d} \times \frac{d}{\varepsilon_0 \varepsilon_r}$ | Use of ratios of capacitances | 1 | | |
| | $\frac{C_{100}}{C_0} = \frac{\varepsilon_r + \varepsilon_w}{\varepsilon_r} = \frac{330}{285} = 1.17$ | Method | 1 | 2 | |

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| | $\varepsilon_r + \varepsilon_w = 1.17\,\varepsilon_r$<br>$\varepsilon_w = 0.17\,\varepsilon_r$<br>$\varepsilon_r = \frac{80}{0.17} = 471$ | | | | |
| **06.4** | $C_0 = \frac{\varepsilon_0 \varepsilon_r A}{d}$<br>$d = \frac{\varepsilon_0 \varepsilon_r A}{C_0}$<br>$= \frac{8.85\times10^{-12} \times 470 \times (10.8\times10^{-3} \times 3.81\times10^{-3})}{282\times10^{-12}}$<br>$= 1.7(1)\times10^{-7}$ m which is about $0.2\times10^{-6}$ m | Use of equation<br>Answer/comparison | 1<br>1 | 2 | |
| **06.5** | Field strength (assuming parallel plates) $= \frac{V}{d}$<br>So $V$ = field strength $\times\, d = 74\,000 \times 1.7(1)\times10^{-7}$ m $= 1.26\times10^{-2}$ V<br>$R = \frac{\rho l}{A} = \frac{10^{12} \times 1.7\times10^{-7}}{10.8\times10^{-3} \times 3.81\times10^{3}} = 4.13\times10^{6}\,\Omega$<br>$I = \frac{V}{R} = \frac{1.26\times10^{-2}\,\text{V}}{4.13\times10^{6}\,\Omega} = 3.05\times10^{-12}$ A<br>This is an extremely small current that would be very difficult to measure | Answer = $1.48\times10^{-2}$ V if 0.2 mm used<br>Answer<br>Answer<br>Comment | 1<br>1<br>1<br>1 | 3 | 3.7.3.3<br>3.5.1.3 |
| **07.1** | $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$, $\varepsilon_r = 1$<br>$= \frac{8.85\times10^{-12} \times 150\times10^{-4}}{0.1} = 1.33\times10^{-12}$ V<br>$Q = CV = 1.33\times10^{-12} \times 4000 = 5.31\times10^{-9}$ C | Calculation of capacitance<br>Charge | 1<br>1 | 2 | 3.7.4.2 |
| **07.2** | When the ball touches the plate, electrons are transferred to it, giving the ball a net negative charge and it is attracted to the other plate/repelled from the negative plate<br>When it touches the positive plate, the electrons are transferred to the plate, so it is repelled from the plate | Transfer of electrons used<br>Correct attraction/repulsion | 1<br>1 | 3 | 3.5.1.1 |

# A Level AQA Physics
## 16 Capitance – answers

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| **07.3** | $T = 2\pi\sqrt{\frac{l}{g}}$<br>$T = 2\pi\sqrt{\frac{0.3}{9.8}} = 1.1\,\text{s}$<br>So it would take about 0.5 s to travel between the plates | Use of time period<br><br>Answer | 1<br><br>1 | 2 | 3.6.1.3 |
| **07.4** | Current $= \frac{\text{charge}}{\text{time}} = \frac{0.1 \times 5.31\times10^{-9}}{0.5} = 1.1\times10^{-10}\,\text{A}$ | Answer | 1 | 2 | 3.5.1.1 |
| **07.5** | The pd would decrease<br>$C = \frac{\varepsilon_0\varepsilon_r A}{d}$<br>And $Q = CV$ where $Q$ is constant<br>$Q = \frac{V\varepsilon_0\varepsilon_r A}{d}$<br>$Qd = V\varepsilon_0\varepsilon_r A$<br>p.d. is proportional to $d$ | | 1<br>1 | 3 | 3.7.4.2 |
| **08.1** | The dielectric would break down/the capacitor will conduct | | 1 | 1 | 3.7.4.2 |
| **08.2** | $V = V_0 e^{-\frac{t}{RC}}$<br>$C = \frac{t}{R(\ln V_0 - \ln V)}$<br>$t = 7200\,\text{s}$, $V = 1.5\,\text{V}$,<br>$V_0 = 3\,\text{V}$; $C = \frac{7200}{10\,000(\ln 3 - \ln 1.5)} = 1.0\,\text{F}$<br>$V_0 = 6\,\text{V}$; $C = \frac{7200}{10\,000(\ln 6 - \ln 1.5)} = 0.51\,\text{F}$<br>3.3 F capacitor<br>The operating pd for the 0.5 F and 1.3 F capacitor is only 3 V | Expression for $C$, explicit or implied<br><br>Values of $C$ for both initial p.d.s<br><br>Conclusion with reason | 1<br><br>1<br><br>1 | 2 | 3.7.4.4 |

# 16 Capitance – answers

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| **08.3** | $Q = It = 1400\times10^{-3} \times 3600 = 5040\,C$<br>$E = QV = 5040 \times 3 = 1.5\times10^{3}\,J$<br>$E = \frac{1}{2}CV^2 = 0.5 \times 0.5 \times 3^2 = 2.25\,J$<br>$E = \frac{1}{2}CV^2 = 0.5 \times 1.3 \times 3^2 = 5.85\,J$<br>The energy is much less than that stored in the battery by a factor of 500 | Calculation of energy<br>Calculations of energy<br>Comment | 1<br>1<br>1 | 2 | 3.5.1.1<br>3.7.4.3 |
| **08.4** | The battery has an internal resistance, $r$, so if a current flows the p.d. will be reduced by a p.d. of $Ir$, $V = \varepsilon - Ir$<br>Current in circuit $I = \frac{\varepsilon}{R + r}$<br>Terminal p.d. = $V = \varepsilon - Ir$<br>$V = \varepsilon - \frac{\varepsilon}{R + r}r$<br>So $\frac{r}{R + r} = \frac{1}{2}$<br>$R$ is equal to the internal resistance of the battery | Explanation involving internal resistance<br>Use of equation<br>Answer | 1<br>1<br>1 | 3 | 3.5.1.6 |

**Skills box answers**

| Question | Answer |
|---|---|
| **1(a)** | Graph will look similar to the one in the worked example column, with a negative gradient and an intercept on the $y$-axis at 2.33. |
| **1(b)** | Gradient of graph should be −0.02. This is equal to $\frac{-1}{RC}$, so $RC = 50\,s$. |
| **1(c)** | Capacitance = $\frac{50}{R} = \frac{50}{(330\times10^3)}\,\Omega = 1.5 \times 10^{-4}\,F$. |
| **2** | Electrolytic capacitors must be connected using the polarity marked on the capacitor. Otherwise the capacitor will overheat and be damaged. |
| **3** | The value for $RC$ using this capacitor and resistor is 2.9 s, so the voltage will decay very quickly and be difficult to measure using a multimeter and stopclock. However, a data logger could be set to take 10 measurements per second and so could be used. |