WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 2

PHYSICS



EXAM QUESTION PACK

2.4 CAPACITANCE

SCORE	PERCENTAGE
/65	%

STEMUP

These questions belong to WJEC Eduqas, not to us.

The examination questions, mark schemes and examiner comments in this pack were written and published by WJEC Eduqas. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with WJEC Eduqas and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. WJEC Eduqas has not endorsed, approved or been involved in the production of it. WJEC Eduqas and the qualification titles used here belong to their respective owners and appear for identification only.

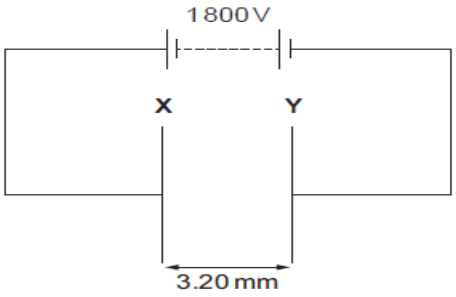
Where to find the originals

WJEC Eduqas publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at eduqas.co.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

#1

A scientist investigating electric fields places two parallel plates **X** and **Y** a distance 3.20 mm apart and connects them to a high voltage supply as shown. There is a vacuum between the plates.



(a) **Sketch the electric field pattern** between the plates indicating clearly the direction of the field. [1]

(b) Electrons are accelerated from plate **Y** to plate **X**. Calculate:

(i) the force on an electron; [2]

(ii) the gain in kinetic energy of an electron as it travels from **Y** to **X**; [2]

(iii) the time it takes for an electron to travel from **Y** to **X**. Assume the electron starts from rest at plate **Y**. [3]

(c) The separation between the plates is now halved but the pd is unchanged. The scientist believes that the gain in kinetic energy of an electron travelling (from rest) from **Y** to **X** will be unchanged. Verify this claim. [2]

Question taken from Eduqas examination paper 842102, June 2017

#3

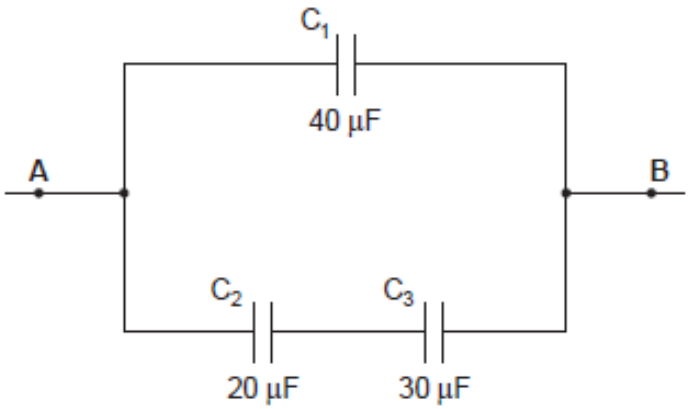
3. *(a)* Two parallel plate capacitors, X and Y, have equal plate areas. The capacitance of X is greater than the capacitance of Y. Suggest two possible reasons for the difference. [2]

.....

.....

.....

(b) The diagram shows an arrangement of 3 capacitors.



(i) Calculate the total capacitance of this combination of capacitors. [3]

.....

.....

.....

.....

.....

(ii) Explain why:

pd across C_2 = 1.5 × pd across C_3. [2]

.....

.....

.....

.....

(iii) Hence, calculate the pd across C_3 given that 100 V is applied between A and B. [1]

.....

.....

.....

(iv) Explain which of the three capacitors stores the greatest charge, and calculate the size of this charge. [2]

.....

.....

.....

(c) A 1.6 mF capacitor is charged from a 300 V d.c supply. Engineers wish to use the energy stored in this capacitor to heat a small coil embedded in a thermally insulated block of aluminium of mass 0.10 kg. It is required that the heating process be at least 80% efficient. Experiments show that when the capacitor is discharged through the coil, the temperature of the block increases by 0.60 K.

Determine whether this method of heating meets the efficiency specified.
[Specific heat capacity of aluminium, $c = 910\,J\,kg^{-1}\,K^{-1}$]. [5]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Question taken from Eduqas examination paper 842102, June 2019

6. *(a)* Define the *capacitance* of a capacitor. [1]

.....

.....

(b) Two capacitors, initially uncharged, are arranged in series as shown. When a battery is connected across A and B, the charge on plate P is found to be +75 nC.



(i) Write down the charges on each of the plates Q, R and S. Give a reason for your answer to the charge on plate S. [3]

Charge on Q: .....

Charge on R: .....

Charge on S: .....

Reason:

.....

.....

.....

(ii) Calculate the pd across A and B. [2]

.....

.....

.....

.....

(iii) A Physics student makes the following comment:

For capacitors in series, a capacitor of higher capacitance stores more energy than a capacitor of smaller capacitance.

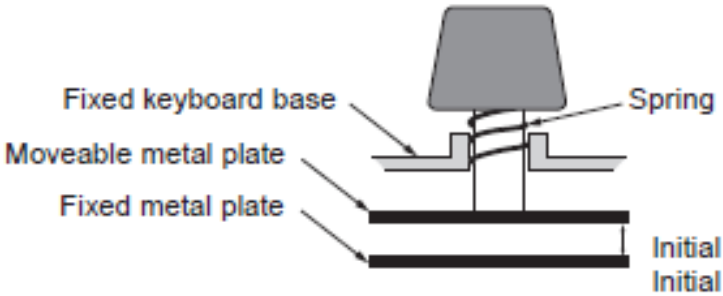
By considering this combination of capacitors, investigate whether or not the student is correct. [2]

.....

.....

.....

(c) Some computer keyboards work on the principle of varying capacitance. When a key is pressed, a spring is compressed and the separation of two parallel metal plates is decreased. The computer responds if the increase in capacitance of the plates is 0.20 pF or more.
The diagram shows how a single key is constructed.



Initial separation of plates = 5.2×10^{-3} m
Initial capacitance = 0.27 pF
Plate area = 1.6×10^{-4} m^2

The designers of a keyboard require that the increase in capacitance of 0.20 pF occurs when a force of 0.20 N is exerted on a key. Different springs are available, of spring constant 90 N m^{-1}, 120 N m^{-1} and 150 N m^{-1}. Determine which (if any) of these springs would be suitable in meeting the designer's requirements. The capacitor is filled with air. [4]

.....

.....

.....

.....

.....

.....

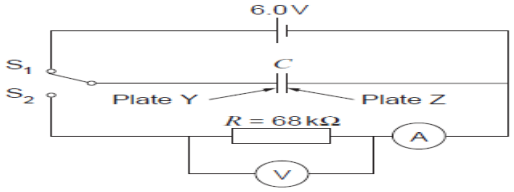
.....

.....

Question taken from Eduqas examination paper 842102, June 2018

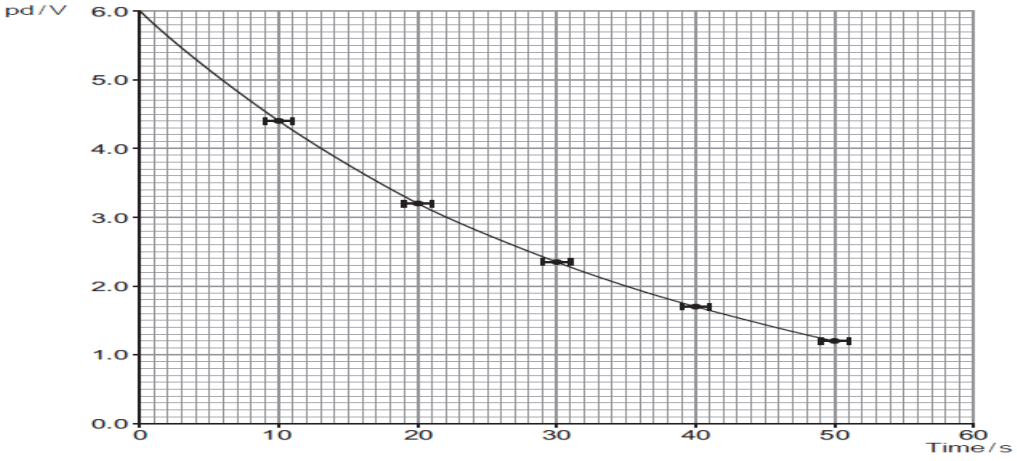
#5

Katie uses the following circuit to investigate the discharging of a capacitor of unknown value C.



(a) The plates of the capacitor are labelled Y and Z. When the switch is moved to S_1, explain how each plate becomes charged in terms of the movement of charges in the circuit. [2]

(b) The switch is now moved to S_2 and the capacitor is allowed to discharge through the resistor. Katie takes readings of pd every 10 s for a period of 50 s and plots her results on the following grid.



(i) The initial current in the circuit was 88 μA. Show that this is consistent with the value $R = 68\ \text{k}\Omega$. [1]

(ii) Katie took **single** readings of pd. She used a voltmeter with a resolution of 0.01 V. Explain why it was not appropriate to include error bars when plotting pd. [2]

(iii) She uses a stopwatch of resolution 1 second. State how this is represented on the graph. [1]

(iv) Show that the time constant of the circuit is approximately 30 s. [2]

(v) The resistor manufacturer states that the resistors are accurate to ± 3% of their given values. Use this information to calculate C along with its **absolute** uncertainty. [Take the absolute uncertainty in the time constant as being the same as the absolute uncertainty in the readings of time.] [4]

(vi) Determine a value for pd at a time $t = 55$ s and state whether this is consistent with the trend shown by the graph. [3]

Question taken from Eduqas examination paper 842102, June 2017

Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Horizontal line[s] with direction indicated from X to Y	1			1		
	(b)	(i)	Substitution into $F = \frac{Ve}{d}$ shown: $\frac{1800 \times 1.6 \times 10^{-19}}{3.2 \times 10^{-3}}$ (1) $F = 9.0 \times 10^{-14}$ [N] (1)	1	1		2	2	
		(ii)	[Gain in E_k = Work done by field] Gain in $E_k = 9.0 \times 10^{-14} \times 3.2 \times 10^{-3}$ (1) (**ecf** on F) Gain in $E_k = 2.88 \times 10^{-16}$ J **unit mark** (1) **Alternative:** $W = 1.6 \times 10^{-19} \times 1800$ (1) $W = 2.88 \times 10^{-16}$ J **unit mark** (1) [Accept 1 800 eV **unit mark**]	1	1		2	2	
		(iii)	$x = ut + \frac{1}{2}at^2$ and $u = 0$ (all possible by implication) (1) $a = \frac{F}{m}$ **and** substitution step: **ecf** on F e.g. $t^2 = \frac{2 \times 3.2 \times 10^{-3} \times 9.11 \times 10^{-31}}{9.0 \times 10^{-14}}$ (1) $t = 2.54 \times 10^{-10}$ [s] (1) **Alternative:** $\frac{1}{2}mv^2 = 2.88 \times 10^{-16}$ to calculate v (1) Application of $x = \frac{(u+v)t}{2}$ (1) **ecf** on v $t = 2.54 \times 10^{-10}$ [s] (1)	1	1 1		3	3	
	(c)		F doubled (explained from $\frac{Ve}{\frac{1}{2}d}$) (1) $W = 2F \times \frac{d}{2}$ so no change (1) **Accept:** $W = QV$ and Q stated to be constant (1) so W remains unchanged (1)			2	2		
			Question total	**4**	**4**	**2**	**10**	**7**	**0**

#2

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)		Statement that length of error bar = largest reading (of U) – smallest reading (of U) [1] Accept reference from mean point to max or min if clearly stated. Data from one plot to show this e.g. for 6.8 μF capacitor, length of error bar calculated as = 14×10^{-4} - 13.2×10^{-4} [1] [award 1st mark by implication if 2nd mark awarded]		2		2	1	2
		(ii)		Length of horizontal error bar for one data point taken and divided by 2. e.g. for 6.8 μF, (0.65 to 0.70 seen) [1] % tolerance calculated: 10% (Accept 6% to 12%) e.g. $0.68 \times \frac{100}{6.8}$ [1]		2		2	1	2
	(b)	(i)		$U = \frac{1}{2}CV^2$ used and V shown (by implication possibly) to $= (2 \times \text{gradient})^{1/2}$ [1] $V_{max} = 22.4$ [V] [1] $V_{min} = 18.0$ [V] [1]		3		3	3	3
		(ii)		Mean $V = \frac{(22.4+18.0)}{2} = 20.2$ [V] (any sig fig.) [1] Uncertainty $= \frac{(22.4-18.0)}{2} = 2.2$ [V] (any sig fig) [1] or candidate answers to (i) used correctly (**ecf**) 2 or 3 sig figs seen for mean V and 1or 2 sig figs for uncertainty [1]		3		3	3	3
	(c)			Substitution into $V = V_0 e^{-\frac{t}{CR}}$ [1] Algebra to show either $V = 8$ V or $V_0 = 20$ V or $t = 35$ s or CR value [1] Relevant statement: e.g. value confirmed [1]			3	3	2	3
				Question total	**0**	**10**	**3**	**13**	**10**	**13**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*		Plates of X are closer together (than plates of Y) or vice-versa [1] X contains dielectric (or space between plates of X contains material of higher permittivity) or vice-versa [1] **Accept:** Overlap of plates in X > overlap of plates in Y	2			2		
	(b)	(i)	Series combination: Substitution - $\frac{1}{C_{series}} = \frac{1}{20\,[\mu F]} + \frac{1}{30\,[\mu F]}$ or $C_{series} = \frac{20 \times 30}{20 + 30}\,[\mu F]$ [1] C_{series} = 12 μ[F] [1] Total capacitance = 52 μ[F] [1]	1 1	1		3	2	
		(ii)	Idea that Q is same on both capacitors, either stated or e.g. $C \propto \frac{1}{V}$ [1] 20 [× 10^{-6}] × pd across C_2 = 30 [× 10^{-6}] × pd across C_3 [1] [Both marks can be awarded if this seen]	1	1		2	1	
		(iii)	40 [V]		1		1	1	
		(iv)	C_1 stores the greatest charge with explanation: Largest capacitance **and** greatest pd across it [1] Q = 40 × 10^{-6} × 100 = 0.004 [C] [1]	1	1		2	1	
	(c)		Substitution: E = ½ × 1.6 × 10^{-3} × $(300)^2$ [1] E = 72 [J] [1] Energy gained by Al block = $mc\Delta\theta$ or substitution seen i.e. E = 0.1 × 910 × 0.6 [1] E = 54.6 [J] [1] Efficiency (%) = $\frac{54.6ecf \times 100}{72ecf}$ = 75.8 % ∴ Not justified / criteria not met [1]			5	5	3	
			Question 3 total	**6**	**4**	**5**	**15**	**8**	**0**

#4

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		capacitance = $\frac{\text{charge (on either plate)}}{\text{pd (between the plates)}}$ Accept charge per unit pd / voltage [between plates] (1) Accept $C = \frac{Q}{V}$ if Q and V defined	1			1		
	(b)	(i)	Q = - 75 nC, R = + 75 nC, S = - 75 nC All numerical values stated as 75 [nC] (1) Correct signs and unit, i.e. nC (1) One of: (1) • Capacitors in series carry equal charges when joined to common pd • Conservation of charge applies for series circuit [hence if +75 μC moves from A to plate P, the same moves from Q → R etc] • Opposite charge to P (accept R), since connected to negative potential [Accept: battery transfers electrons from P to Q]	3			3		
		(ii)	Total capacitance = 7.5 nF (1) $V = \frac{75 \times 10^{-9}}{7.5 \times 10^{-9}}$ **(ecf on total C)** V = 10 V (1) **Alternative:** Application and substitution into $\frac{Q}{C_1} + \frac{Q}{C_2}$ i.e. $\frac{75 \times 10^{-9}}{30 \times 10^{-9}} + \frac{75 \times 10^{-9}}{10 \times 10^{-9}}$ (1) V = 10 V (1)		2		2	2	
		(iii)	**Either:** Q same on both capacitors (1) $\frac{1}{2}\frac{Q^2}{C}$ is bigger on smaller capacitor (1) (Award 2 marks for correct numerical analysis) **Or:** $V \propto \frac{1}{C}$ so V bigger across smaller capacitor (1) ½ CV^2 bigger across smaller capacitor (V^2 factor) (1) (Award 2 marks for correct numerical analysis) **Or** Q same on both capacitors and $V \propto \frac{1}{C}$ so V bigger across smaller capacitor (1) ½ QV is bigger on smaller capacitor (1) (Award 2 marks for correct numerical analysis			2	2		
	(c)		New C = 0.47 pF (1) New $d = 3.0 \times 10^{-3}$ m (1) $\Delta d = 5.2 \times 10^{-3} - 3.0 \times 10^{-3} = 2.2 \times 10^{-3}$ m (1) (**ecf** from new d) Application of $F = k\Delta d$ ecf k = 91 N m^{-1} so spring of k = 90 N m^{-1} suitable [conclusion consistent with value of F](1) **Alternative 'Trial and Error' :** Application of $x = \frac{F}{k}$ for each spring constant, showing that for: k = 120 N m^{-1}, $x = 1.67 \times 10^{-3}$ m k = 150 N m^{-1}, $x = 1.33 \times 10^{-3}$ m k = 90 N m^{-1}, x = 2.22 x 10^{-3} m (All required for1) New C = 0.47 pF (1) Application of $C = \frac{\varepsilon_0 A}{d}$ for each value of x above to show that, for $x = 2.22 \times 10^{-3}$ m, $C = 0.475 \times 10^{-12}$ F, so k = 90 N m^{-1} suitable. (1)			4	4	3	
			Question 6 total	**4**	**2**	**6**	**12**	**5**	**0**

#5

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Electrons (or negative charges) are deposited on Z [and this plate becomes negatively charged] (1) Electrons (or negative charges) are removed from Y [and this plate becomes positively charged] (1)		2		2		2
	(b)	(i)	Initial pd across capacitor = pd of cell (by implication) **and** correct application to show R or I		1		1		1
		(ii)	Reference to **resolution of voltmeter** (1) which is **too small to be plotted** (1) (on given scale)			2	2		2
		(iii)	Error bars [are ±1 s]		1		1		1
		(iv)	Appropriate (corresponding) values from graph e.g. $V_0 = 6$ V, $V = 4$ V, $t = 13$ s (1) Correct algebra [$V = V_0 e^{-\frac{t}{CR}}$] to show $t = 32$ [s] (1) **Alternative:** Time constant = 0.37 V_0 stated or implied or $V = 2.2$[2] V (1) Time constant = 32 [s] (1) **Alternative:** $T_{½} = 0.69RC$ (1) $RC = 31$ [s] (1) **Alternative:** Initial gradient = $-\frac{V_0}{RC} = -\frac{6}{33}$ (tangent at $t = 0$ intercepts time axis at $t = 33$ s) (1) $RC = \frac{6 \times 33}{6} = 33$ [s] (1)		2		2	2	2
		(v)	Application of time constant = CR (1) $C = \frac{32}{68\,000} = 471$ μF (**ecf** in t or candidate value used) (1) % uncertainty calculated as 3% + 3.2% = 6.2% (1) Absolute uncertainty = ± 30 μF So: 470 ± 30 μF (or 0.47 ± 0.03 mF) (1) consistency of sig figs	1	1 1 1		4	4	4
		(vi)	Correct substitution into $V = V_0 e^{-\frac{t}{CR}}$ (1) V shown = 1.1 [V] (1) Reference to continued graph line going through this point (1)			3	3	2	3
			Question total	**1**	**9**	**5**	**15**	**8**	**15**