# Mark schemes

**1** A **[1]**

**2** D **[1]**

**3** B **[1]**

**4** D **[1]**

**5** D **[1]**

**6** B **[1]**

**7** B **[1]**

**8** B **[2]**

**9** C **[1]**

**10** D **[1]**

**11** C **[1]**

**12** A **[1]**

**13** D **[1]**

**14** B **[1]**

**15** (a) $Q = CV$ **(1)**

(= $4.7 \times 10^{-6} \times 6.0$) = $28 \times 10^{-6}$ C or 28 μC **(1)**

**2**

(b) $E = ½CV^2$ **(1)**

= $½ \times 4.7 \times 10^{-6} \times 2.0^2$ **(1)**

= $9.4 \times 10^{-6}$ J **(1)**

[or $E = ½QV$ **(1)**

= $½ \times 9.4 \times 10^{-6} \times 2.0$ **(1)**

= $9.4 \times 10^{-6}$ J **(1)**]

**3**

(c) time constant is time taken for $V$ to fall to $\frac{V_0}{e}$ **(1)**

$\therefore V$ must fall to 2.2 V **(1)**

time constant = 32 ms **(1)**

[or draw tangent at $t$ = 0 **(1)**

intercept of tangent on $t$ axis is time constant **(1)**

accept value 30 - 35 ms **(1)**]

[or $V = V_0 \exp(-t / RC)$ or $Q = Q_0 \exp(-t / RC)$ **(1)**

correct substitution **(1)**

time constant = 32 ms **(1)**]

**3**

(d) time constant = $RC$ **(1)**

$$R = \frac{32 \times 10^{-3}}{4.7 \times 10^{-3}} = 6800\ \Omega\ \textbf{(1)}$$

(allow C.E. for value of time constant from (c))

2

**[10]**

**16** (a) 1 coulomb of charge is stored for a p.d. of 1 V between the plates
(or equivalent statement) Condone I coulomb per volt

B1

1

(b) (i) Correct substitution in $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$ (ignore powers of 10)

C1

Plate area = $4.65 \times 10^{-3}$ m$^2$ or $C = \frac{\varepsilon_0 \varepsilon_r \pi r^2}{d}$ with correct data

A1

Radius = (their area /3.14)1/2; 0.038(4 or 5) m if correct

B1

3

(ii) $E = ½ CV^2$ or correct numerical substitution or
$E = ½ QV$ & $Q = VC$

C1

$4.1(4) \times 10^{-10}$ J

A1

2

(c) Time constant = *RC* or Time to halve = *0.69 RC*
or $V = V_0 e^{-t/RC}$

C1

Time to fall to 1/e (0. 19 ms) or time to halve (0. 13 ms)
or $V_0 = 6$ V and correct coordinates of point on line
(0.6 ms max)

C1

8.1 - 8.6 MΩ

A1

3

**[9]**

**17** (a) (i) $2200 \times 10^{-6}$ farads (C $V^{-1}$ ) or 2200 $\mu$C $V^{-1}$
**or** idea of capacitance measuring charge (or coulomb) per volt
**or** C = $Q / V$ with terms defined

**C1**

the capacitor 'stores' 2200 $\mu$C of charge for a potential difference of 1 volt

**A1**

**(2)**

(ii) 15 V is
the maximum safe voltage between the terminals of the capacitor.
or the maximum voltage that should be used across the capacitor
or the voltage at which the capacitor breaks down / insulator conducts

**B1**

**(1)**

(b) (i) correct curvature starting at 6 V at time = 0
points plotted correctly at 3 and 6 minutes with reasonable curve (2.2 V and 0.8 V)

**B1**

**or** at 3 V at 2.1 minutes and 1.5 V at 4.2 minutes if 'half life' calculated and used

allow ±0.5 small square

**B1**

**(2)**

(ii) time alarm rings read correctly from the graph at 2 V
(about 200 s but use candidate's graph condone any shape graph)

**B1**

**(1)**

(iii) time constant = $RC$ or ($R = \frac{180}{2.2 \times 10^{-3}}$) **or** time to halve = 0.69$CR$

**C1**

82 kΩ

**A1**

**(2)**

(iv) cooking time ∝ $CR$ ∝ $R$
**or** quotes $V = V_0 \, e^{-t/CR}$ **or** $2 = 6\, e^{-300/CR}$

**C1**

resistance = 120 kΩ (124 kΩ)

**A1**

**(2)**

(v) connect it in parallel (with the other capacitor)
**or**
replace capacitor with one of higher value (not just use a larger capacitor)

**B1**

**(3)**

**[11]**

**18** (a) (i) 0.02 C of charge produce a p.d. of 1 V between the two terminals

**or** 0.02 C of charge per unit p.d.

**B1**

**(2)**

(ii) straight line through the origin

**M1**

correct gradient (possible check point 0.2 C at 10 V)

and graph line up to 20 V

**A1**

**(2)**

(iii) area between graph line and charge axis

(allow area under graph)

**not** area of the graph

**not** area under graph / 2

**M1**

from 0 to the required voltage or up to the required voltage

**A1**

**or** energy = ½$QV$ or ½$CV^2$

**M1**

read corresponding $Q$ from the graph

**A1**

(only allow second mark if graph is straight line through the origin)

**or** $C$ determined from gradient of graph and $V$ given

**(2)**

(iv) sketch showing two capacitors in parallel connected to a supply

**B1**

**(1)**

(b) (i) energy stored = 0.5 $CV^2$

**C1**

4.0 J (condone 1 sf answer)

**A1**

**(2)**

(ii) (useful) energy output = $mgh$

**or**

efficiency = useful energy out / energy input(in same time)

**or**

efficiency = useful power out / power input

**C1**

energy output = 0.15 × 9.8 × 0.8 = 1.18 J

**C1**

efficiency = 0.294 or 29.4% e.c.f. from (b)(i)

**A1**

(allow 29% – 30%)

**(3)**

**[11]**

**19** (a) (i) straight line through origin **(1)**

(ii) $\frac{1}{\text{capacitance}}$ **(1)**

(iii) energy (stored by capacitor) **(1)** (or work done (in charging capacitor))

**3**

(b) (i) $RC = 5.6 \times 10^3 \times 6.8 \times 10^{-3}$ **(1)** (= 38.1 s)

$V(= V_0\, e^{-t/RC}) = 12\, e^{-26/38.1}$ **(1)**

$= 6.1$ V **(1)** (6.06 V)

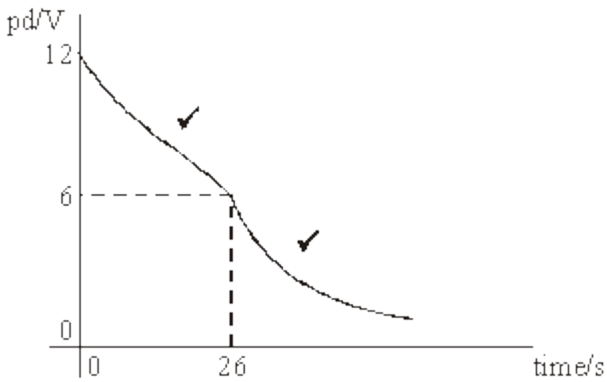
[or equivalent using $Q = Q_0 e^{-t/RC}$ and $Q = CV$]

(ii) $(RC)' = 2.8 \times 10^{3} \times 6.8 \times 10^{-3}$ **(1)** (= 19.0 s)

$V\,(= 6.06\, e^{-14/19}) = 2.9(0)$ V **(1)**

(use of $V = 6.1$ V gives $V = 2.9(2)$ V)

(iii)




**7**

**[10]**

**20**

(a) (i) initial discharge current $\left(= \frac{V}{R} = \frac{6.0}{1.0 \times 10^5}\right) = 6.0 \times 10^{-5}$ (A) **(1)**

1

(ii) time constant is time for $V$ to fall to (1/e) [or 0.368] of initial value **(1)**

pd falls to (6.0/e) = 2.21 V when $t$ = time constant **(1)**

reading from graph gives time constant = 22 (± 1) **(1)**

unit: s **(1)** (ΩF not acceptable)

[**alternatively** accept solutions based on use of $V = V_0 e^{-t/RC}$

eg $1.5 = 6.0\ e^{-30/RC}$ **(1)** gives $RC = \frac{30}{\ln(6.0/1.5)}$ **(1)** = 22 **(1)** s **(1)**]

4

(iii) capacitance of capacitor $C = \left(\frac{\text{time constant}}{R} = \frac{22}{1.0 \times 10^5}\right)$
$= 2.2 \times 10^{-4}$ (F) = 220 ($\mu$F) **(1)**

1

(iv) energy $\propto V^2$ (or energy = ½ $CV^2$) **(1)**

$\therefore \frac{E_2}{E_1} = 0.10$ gives $= \frac{V_2}{V_1} (0.10)^{1/2}$ **(1)** (= 0.316)

$\therefore V_2 = 0.316 \times 6.0 = 1.90$ (V) **(1)**

reading from graph gives $V_2 = 1.90$ V when $t = 25$ s **(1)**

[**alternatively** accept reverse argument:

ie when $t = 25$ s, $V_2 = 1.9$ V from graph **(1)**

final energy stored = ½ × 2.2 × $10^{-4}$ × $1.9^2$

= 3.97 × $10^{-4}$ (J) and initial energy stored = 3.96 × $10^{-3}$ (J) **(1)**

which is 10 × greater, so 90% of initial energy has been lost **(1)**]

[**alternatively**, using exponential decay equation:

use of $V = V_0 e^{-t/R}$ with $t = 25$ s and $RC = 22$ s gives $V = 1.93$ V **(1)**

energy $\propto V^2$ (or energy = ½ $CV^2$) gives $\frac{E_2}{E_1} = \left(\frac{1.93}{6.0}\right)^2 = 0.103$ **(1)**

$\therefore$ fraction of stored energy that is lost = $\frac{E_2 - E_1}{E_1} = 1 - \frac{E_2}{E_1} = 0.90$ **(1)**]

**3**

(b) (i) initial energy stored is 4 × greater **(1)**

because energy $\propto V^2$ (and $V$ is doubled) **(1)**

**2**

(ii) time to lose 90% of energy is unchanged because time constant is unchanged (or depends only on R and C) **(1)**

**1**

**[12]**

**21** (a) (i) tangent drawn at $t = 0$

M1

coordinates correct and manipulated correctly
0.015 to 0.020 (A) 15 mA – 20 mA
**or** $V = 4000$ V as in (ii) then $I = 18$ mA

A1

**2**

(ii) $V = 220 \times$ their (i) condoning powers of 10

C1

about 4000 V (3300 – 4400 V)

A1

**or** use of $V = Q/C$; $V = 100$ mC/25 $\mu$F

C1

4000 V

A1

**2**

(iii) more charge leads to increased potential difference across the capacitor

M1

pd = $V_R + V_C$
**or** if $V_C$ increases then $V_R$ decreases

M1

(if $V_R$ falls) so $I$ falls

A1

**3**

(b) (i) use of energy = ½ $Q^2/C$ or use of $C = Q/V$ and ½ $QV$

C1

0.083(7) or 0.084 C condone 0.083 C

A1

**2**

(ii) power = 14 kW

B1

**1**

(c) time constant = 5.5 s

M1

sensible attempt to find the charge after 8.3 s – by calculation or reading from graph

M1

about 78 mC and needs to be 85 mC/has not reached 85 mC so designer's suggestion is not valid

A1

3

**[13]**

**22** (a) (i) energy stored by capacitor (= ½ $CV^2$)

= ½ × 70 × 1.2$^2$ ✓ (= 50.4) = 50 (J) ✓

to **2 sf** only ✓

3

(ii) energy stored by cell (= $I\ V\ t$) = 55 × 10$^{-3}$ × 1.2 × 10 × 3600 ✓

(= 2380 J)

$$\frac{\text{energy stored by cell}}{\text{energy stored by capacitor}} = \frac{2380}{50} = 48$$ (ie about 50) ✓

2

(b) capacitor would be impossibly large (to fit in phone) ✓

capacitor would need recharging very frequently [**or** capacitor could only power the phone for a short time] ✓

capacitor voltage [**or** current supplied or charge] would fall continuously while in use ✓

max 2

**[7]**

**23** (a) ratio of charge to potential C1

4.2 μC per volt etc A1

2

(b) (i) method: time for voltage to half/tangent at origin/use of decay equation/1/e value B1

appropriate reading from graph ($T_{½}$ = 440 or 450 μs) B1

substitution into correct equation B1

*R* correct for method (151/152/155 Ω) B1

4

(ii) **B** smaller than **A** **M0**

**B** discharges faster/**A** discharges slower B1

reference to decay equation/calculation for **B** B1

2

(c) $E = ½ CV^2$ or $½ QV$ seen C1

both 4.0 (V) and 0.9 (V)/16.8 (μC) and 3.8 (μC) seen C1

31.9 (μJ) A1

3

**[11]**

**24** (a) time to halve = 0.008 s or two coordinates correct

C1

$C = T_{1/2}/(0.69 \times 150)$ or eg $0.4 = 1.4\ e^{-0.015/150C}$

A1

77 μF (consistent with numerical answer)

A1

**3**

(b) **max 3 from**

as capacitor discharges:

pd decreases

B1

current through resistor decreases (since $I \propto V$)

B1

rate at which charge leaves the capacitor decreases (since $I = \Delta Q/\Delta t$)

B1

rate of change of charge is proportional to rate of change of pd (since $V \propto Q$)

B1

condone quicker discharge when pd is larger

B1

**3**

(c) energy stored $\propto V^2$ or use of ½ $CV^2$
**or** initial energy = 78.4 (or 75.5) μJ
**or** final energy using V = 0.38–0.4 0 V
(answer in range 5.6 – 6.4 μJ)

C1

fraction remaining = $(0.4/1.4)^2$ or 0.072 – 0.081
**or** energy lost = 72 μJ

C1

91.8 to 92.8% lost

A1

**3**

(d) (i) charge = 77 μC to 82 μC

B1

**1**

(ii) charge required = $77 \times 10^{-6} \times 5 \times 3.15 \times 10^{7}$ (= 12128 C)
or 1A–h =3600 C

C1

3.36(3.4) Ah

A1

**2**

**[12]**

**25** (a) charge (stored) ✓ per unit potential difference ✓

[**or** $C = Q/V$ where $Q$ = charge (stored by one plate) ✓ $V$ = pd (across plates) ✓]

**2**

(b) (i) $C\left(=\frac{Q}{V}\right) = \frac{13.2 \times 10^{-6}}{6.0}$ ✓ $= 2.2 \times 10^{-6}$ (F) ✓ (or 2.2 μF)

**2**

(ii) when $t$ = time constant $Q = 0.63 \times 13.2 = 8.3$ (μC) ✓

[**or** = 0.63 × 13(.0) (from graph) = 8.2 (μC)]

reading from graph gives time constant = 15 (± 1) (ms) ✓

**2**

(iii) resistance of resistor $= \left(= \frac{\text{time constant}}{C}\right) = \frac{15 \times 10^{-3}}{2.2 \times 10^{-6}}$ = 6820 (Ω) ✓

**1**

(iv) gradient = current ✓

**1**

(c) (i) maximum current $= \left(= \frac{V}{R}\right) = \frac{6.0}{6820}$ = 0.88 (mA) ✓

[**or** value from initial gradient of graph: allow 0.70 – 1.00 mA for this approach]

**1**

(ii) curve starts at marked $I_{max}$ on $I$ axis and has decreasing negative gradient ✓

line is asymptotic to $t$ axis and approaches ≈ 0 by $t$ = 60 ms ✓

**2**

**[11]**

**26** (a) ($Q = Q_0 e^{-t/RC}$ gives )$1.0 = 4.0e^{-300/RC}$ ✓

from which $\frac{300}{RC} = \ln 4$ ✓ and time constant $RC$ = 220 (216) (ms) ✓

***[Alternative answer:***
time constant is time for charge to decrease to $Q_0$ /e [**or** 0.37 $Q_0$ ] ✓
4.0/e = 1.47 ✓

reading from graph gives time constant = 216 ± 10 (ms) ✓

*In alternative scheme, 4.0/e = 1.47 subsumes 1st mark. Also, accept $T_{½}$ = 0.693 RC (or = ln 2 RC) for 1st mark.*

**3**

(b) current is larger (for given $V$)(because resistance is lower)
[**or** correct application of $I = V / R$] ✓
current is rate of flow of charge
[**or** correct application of $I = \Delta Q / \Delta t$]

larger rate of flow of charge (implies greater rate of discharge)
[**or** causes larger rate of transfer of electrons from one plate back to the other] ✓

***[Alternative answer:***
time constant (or $RC$) is decreased (when $R$ is decreased) ✓
explanation using $Q = Q_0 e^{-t/RC}$ **or** time constant explained ✓]

*Use either first or alternative scheme; do not mix and match.*

*Time constant = RC is insufficient for time constant explained.*

**max 2**

**[5]**

**27** (a) (i) $Q(= It)$ $4.5 \times 10^{-6} \times 60$ **or** $= 2.70 \times 10^{-4}$ (C) ✓

$C\left(=\frac{Q}{V}\right) = \frac{2.70 \times 10^{-4}}{4.4}$ ✓ $= 6.1(4) \times 10^{-5} = 61$ (μF) ✓

**3**

(ii) since $V_C$ was 4.4V after 60s, when $t$ = 30s $V_C$ = 2.2 (V) ✓
[ **or** by use of $Q = It$ and $V_C = Q / C$ ]
∴ pd across R is (6.0 – 2.2) = 3.8 (V) ✓

$R\left(=\frac{V}{I}\right) = \frac{3.8}{4.5 \times 10^{-6}} = 8.4(4) \times 10^{5}$ (Ω) ✓ (=844 kΩ)

*In alternative method,*
*$Q = 4.5 \times 10^{-6} \times 30 = 1.35 \times 10^{-4}$ (C)*
*$V_C = 1.35 \times 10^{-4} / 6.14 \times 10^{-5} = 2.2$ (V)*
*(allow ECF from wrong values in (i)).*

**3**

(b) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**
The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

**High Level (Good to excellent): 5 or 6 marks**
The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

*The candidate gives a coherent and logical description of the flow of electrons taking place during the charging and discharging processes, indicating the correct directions of flow and the correct time variations. There is clear understanding of how the pds change with time during charging and during discharging. The candidate also gives a coherent account of energy transfers that take place during charging and during discharging, naming the types of energy involved. They recognise that the time constant is the same for both charging and discharging.*

*A **High Level** answer must contain correct physical statements about at least **two** of the following for **both** the charging and the discharging positions of the switch:-*

- *the direction of electron flow in the circuit*
- *how the flow of electrons (or current) changes with time*
- *how $V_R$ and / or $V_C$ change with time*
- *energy changes in the circuit*

**Intermediate Level (Modest to adequate): 3 or 4 marks**
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

*The candidate has a fair understanding of how the flow of electrons varies with time, but may not be entirely clear about the directions of flow. Description of the variation of pds with time is likely to be only partially correct and may not be complete. The candidate may show reasonable understanding of the energy transfers.*

*An **Intermediate Level** answer must contain correct physical statements about at least **two** of the above for **either** the charging or the discharging positions of the switch.*

**Low Level (Poor to limited): 1 or 2 marks**
The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

*The candidate is likely to confuse electron flow with current and is therefore unlikely to make effective progress in describing electron flow. Understanding of the variation of pds with time is likely to be quite poor. The candidate may show some understanding of the energy transfers that take place.*

*A **Low Level** answer must contain a correct physical statement about at least **one** of the above for **either** the charging or the discharging positions of the switch.*

**Incorrect, inappropriate or no response: 0 marks**

No answer, or answer refers to unrelated, incorrect or inappropriate physics.

**The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.**

***Charging***

- electrons flow from plate **P** to terminal **A** and from terminal **B** to plate **Q** (ie. from plate **P** to plate **Q** via **A** and **B**)
- electrons flow in the opposite direction to current
- plate **P** becomes + and plate **Q** becomes –
- the rate of flow of electrons is greatest at the start, and decreases to zero when the capacitor is fully charged
- $V_R$ decreases from E to zero whilst $V_C$ increases from zero to $E$
- at any time $V_R + V_C = E$
- time variations are exponential decrease for $V_R$ and exponential increase for $V_C$
- chemical energy of the battery is changed into electric potential energy stored in the capacitor, and into thermal energy by the resistor (which passes to the surroundings)
- half of the energy supplied by the battery is converted into thermal energy and half is stored in the capacitor

***Discharging***

- electrons flow back from plate **Q** via the shorting wire to plate **P**
- at the end of the process the plates are uncharged
- the rate of flow of electrons is greatest at the start, and decreases to zero when the capacitor is fully discharged
- $V_C$ decreases from $-E$ to zero and $V_R$ decreases from $E$ to zero
- at any time $V_C = - V_R$
- both $V_C$ and $V_R$ decrease exponentially with time
- electrical energy stored by the capacitor is all converted to thermal energy by the resistor as the electrons flow through it and this energy passes to the surroundings
- time constant of the circuit is the same for discharging as for charging

*Any answer which does not satisfy the requirement for a Low Level answer should be awarded 0 marks.*

**max 6**

**[12]**

**28** (a) (i) $7.5 \times 10^{-6}$ (C) or $7.5\ \mu$(C)

B1

**1**

(ii) Suitable scale and charge from (i) correctly plotted at 2.5 V

*Large square = 1 or 2 $\mu C$* ***or***
*With false origin then large square = 0.5 $\mu C$*

B1

Only a Straight line drawn through or toward origin

C1

Line must be straight, toward origin **and** only drawn between 2.5 V and 1.2 V (± 1 / 2 square on plotted points)

A1

**3**

(b) Attempted use of E= ½ $CV^2$ Or attempted use of E=½ $QV$

C1

9.38 ($\mu$J) − 2.16 ($\mu$J) seen
**or** E = ½ × 3 × $10^{-6}$ × $2.5^2$ – ½ × 3 × $10^{-6}$ × $1.2^2$ *seen*
**or** E = ½ × 3 × $10^{-6}$ × ($2.5^2$ – $1.2^2$) *seen*
**or** E =½ × 7.5 × $10^{-6}$ × 2.5 – ½ × 3.6 × $10^{-6}$ × 1.2 *seen*

C1

7.2 × $10^{-6}$ (J) c.a.o

A1

**3**

(c) (i) *Use of* $V = V_0 e^{-\frac{t}{RC}}$

*or equivalent with*

$Q = Q_0 e^{-\frac{t}{RC}}$

C1

$$R = -\left(\frac{1.4\times10^{-3}}{ln\left(\frac{1.2}{2.5}\right)\times3\times10^{-6}}\right) \text{ or } R = -\left(\frac{t}{ln\left(\frac{V_o}{V}\right)\times C}\right) \text{ or } R = \left(\frac{t}{ln\left(\frac{V_o}{V}\right)\times C}\right)$$

C1

636 or 640 (Ω)

A1

**3**

(ii) Current decreases (I = V / R) / describes rate of flow of electrons decreasing / rate of flow of charge decreases

M1

Charge lost more slowly so pd falls more slowly because $V \propto Q$ or Q=CV where C is constant

A1

**MAX 2**

**[12]**

**29** (a) (i) determine area under the graph
[**or** determine area between line and time axis] ✓

**1**

(ii) *as seen*
line starts at very low current (within bottom half of first square) ✓
**either** line continuing as (almost) horizontal straight line to end ✓✓
**or** very slight exponential decay curve ✓
which does not meet time axis ✓

**OR** suitable verbal comment that shows appreciation of difficulty of representing this line on the scales involved ✓✓✓

*Use this scheme for answers which treat the information in the question literally.*

**3**

*as intended*
line starts at half of original initial current ✓
slower discharging exponential (ie. smaller initial gradient) than the original curve ✓
correct line that intersects the original curve (**or** meets it at the end) ✓

*Use this scheme for answers which assume that both resistance values should be in Ω or kΩ.*

*½ initial current to be marked within ±2mm of expected value.*

**3**

(b) (i) energy stored (= ½ $CV^2$) = ½ × 0.12 × $9.0^2$ ✓ ( = 4.86 (J) )
4.86 = 3.5 $\Delta h$ ✓
gives $\Delta h$ = (1.39) = 1.4 (m) ✓
to 2SF only ✓

*SF mark is independent.*

*Students who make a PE in the 1st mark may still be awarded the remaining marks: treat as ECF.*

**4**

(ii) energy is lost through heating of wires **or** heating the motor (as capacitor discharges) ✓

*Allow heating of circuit **or** $I^2 R$ heating.*

energy is lost in overcoming frictional forces in the motor (or in other rotating parts) ✓

*Location of energy loss (wires, or motor, etc) should be indicated in each correct answer.*

[**or** any other well-expressed sensible reason that is valid e.g. capacitor will not drive motor when voltage becomes low ✓ ]

*Don't allow losses due to sound, air resistance or resistance (rather than heating of) wires.*

**max 2**

**[10]**

**30** (a) Capacitor must not lose charge through the meter ✓ **1**

(b) Position on scale can be marked / easier to read quickly etc ✓ **1**

(c) Initial current = $\frac{6}{100000}$ = 60.0 μA ✓

100 μA or 200 μA ✓ (250 probably gives too low a reading)

Give max 1 mark if 65 μA (from 2.6) used and 100 μA meter chosen

**2**

(d) 0.05 V ✓ **1**

(e) Total charge = $6.0 \times 680 \times 10^{-6}$ (C) (= 4.08 mC) ✓

Time = $4.08 \times 10^{-3} / 60.0 \times 10^{-6}$ = 68 s ✓

Hence 6 readings ✓

**3**

(f) Recognition that total charge = 65 $t$ μC and final pd = 0.098 $t$

so $C$ = 65μ / 0.098✓

660 μF ✓

*Allow 663 μF*

**2**

(g) (yes) because it could lie within 646 – 714 to be in tolerance ✓

OR

it is 97.5 % of quoted value which is within 5% ✓

**1**

(h) Suitable circuit drawn ✓

Charge C then discharge through R and record $V$ or $I$ at 5 or 10 s intervals ✓

Plot ln $V$ or ln $I$ versus time ✓

gradient is 1 / $RC$ ✓

OR

Suitable circuit drawn ✓

Charge C then discharge through R and record $V$ or $I$ at 5 or 10 s intervals✓

Use $V$ or $I$ versus time data to deduce half-time to discharge ✓

1 / $RC$ = ln 2 / $t_{½}$ quoted ✓

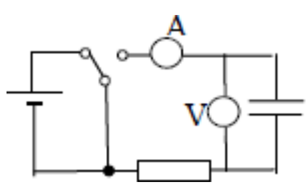
OR

Suitable circuit drawn ✓

Charge C then discharge through R and record $V$ or $I$ at 5 or 10 s intervals ✓

Plot $V$ or $I$ against $t$ and find time $T$ for $V$ or $I$ to fall to 0.37 of initial value ✓

$T = CR$ ✓




*Either A or V required*

*For 2nd mark, credit use of datalogger for recording V or I.*

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**[15]**