PHYSICS

Crash Course for
JEE Main 2020

CAPACITANCE

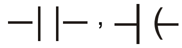
CAPACITANCE

1. (i) $q \propto V \quad \Rightarrow \quad q = CV$

q : Charge on positive plate of the capacitor

C : Capacitance of capacitor.

V : Potential difference between positive and negative plates.

(ii) Representation of capacitor : 

(iii) Energy stored in the capacitor : $U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{QV}{2}$

(iv) Energy density = $\frac{1}{2}\varepsilon_0\varepsilon_r E^2 = \frac{1}{2}\varepsilon_0 K E^2$

ε_r = Relative permittivity of the medium.

K= ε_r : Dielectric Constant

For vacuum, energy density = $\frac{1}{2}\varepsilon_0 E^2$

(v) Types of Capacitors :

(a) Parallel plate capacitor

$$C = \frac{\varepsilon_0\varepsilon_r A}{d} = K\frac{\varepsilon_0 A}{d}$$

A : Area of plates

d : distance between the plates(<< size of plate)

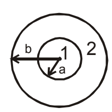
(b) Spherical Capacitor :

- Capacitance of an isolated spherical Conductor (hollow or solid)

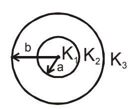
  $C = 4\pi\varepsilon_0\varepsilon_r R$

  R = Radius of the spherical conductor

- Capacitance of spherical capacitor

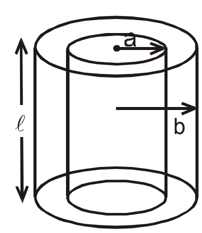


$$C = 4\pi\varepsilon_0\frac{ab}{(b-a)}$$



- $$C = \frac{4\pi\varepsilon_0 K_2 ab}{(b-a)}$$

(c) Cylindrical Capacitor : $\ell >> \{a,b\}$



Capacitance per unit length = $\frac{2\pi\varepsilon_0}{\ell n(b/a)}$ F/m

(vi) Capacitance of capacitor depends on

(a) Area of plates

(b) Distance between the plates

(c) Dielectric medium between the plates.

(vii) Electric field intensity between the plates of capacitor

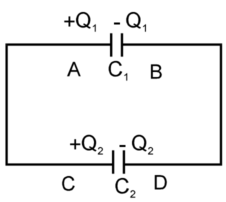
$$E = \frac{\sigma}{\varepsilon_0} = \frac{V}{d}$$

σ : Surface change density

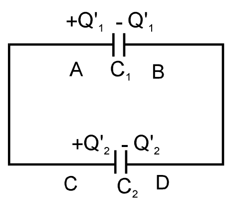
(viii) Force experienced by any plate of capacitor : $F = \dfrac{q^2}{2A\varepsilon_0}$

2. DISTRIBUTION OF CHARGES ON CONNECTING TWO CHARGED CAPACITORS:

When two capacitors are C_1 and C_2 are connected as shown in figure



Initially



Finally

(a) Common potential :

$$\Rightarrow \quad V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} = \frac{\text{Total charge}}{\text{Total capacitance}}$$

(b) $Q_1' = C_1V = \dfrac{C_1}{C_1 + C_2}(Q_1 + Q_2)$

$Q_2' = C_2 V = \dfrac{C_2}{C_1 + C_2}(Q_1 + Q_2)$

(c) Heat loss during redistribution :

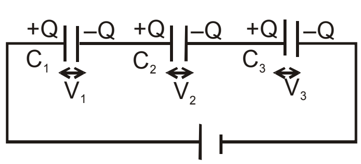
$$\Delta H = U_i - U_f = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2}(V_1 - V_2)^2$$

The loss of energy is in the form of Joule heating in the wire.

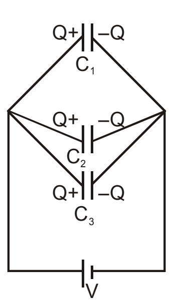
3. Combination of capacitor :

(i) Series Combination

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \qquad V_1 : V_2 : V_3 = \frac{1}{C_1} : \frac{1}{C_2} : \frac{1}{C_3}$$



(ii) Parallel Combination :

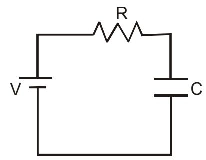


$C_{eq} = C_1 + C_2 + C_3 \qquad Q_1 : Q_2 : Q_3 = C_1 : C_2 : C_3$

4. Charging and Discharging of a capacitor :

(i) Charging of Capacitor (Capacitor initially uncharged):

$$q = q_0 (1 - e^{-t/\tau})$$

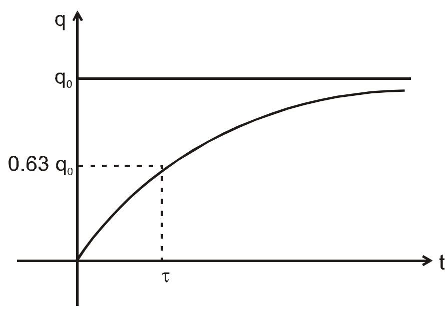


q_0 = Charge on the capacitor at steady state

q_0 = CV

τ : Time constant = $CR_{eq.}$

$$I = \frac{q_0}{\tau} e^{-t/\tau} = \frac{V}{R} e^{-t/\tau}$$

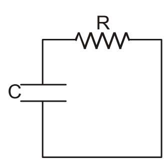


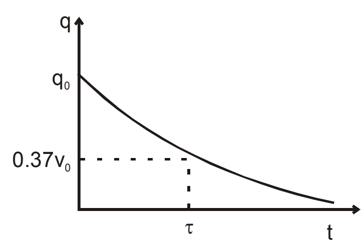
(ii) Discharging of Capacitor :

$q = q_0 e^{-t/\tau}$

q_0 = Initial charge on the capacitor

$$I = \frac{q_0}{\tau} e^{-t/\tau}$$

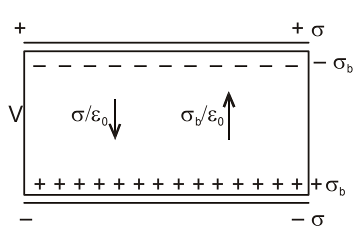




5. Capacitor with dielectric :

(i) Capacitance in the presence of dielectric :

$$C = \frac{K\varepsilon_0 A}{d} = KC_0$$



C_0 = Capacitance in the absence of dielectric.

(ii) $E_{in} = E - E_{ind} = \frac{\sigma}{\varepsilon_0} - \frac{\sigma_b}{\varepsilon_0} = \frac{\sigma}{K\varepsilon_0} = \frac{V}{d}$

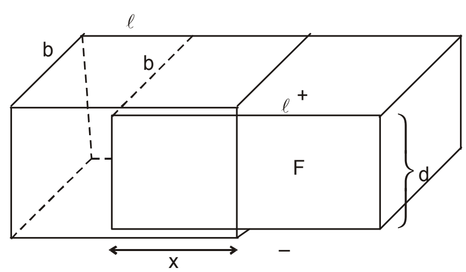
$E : \frac{\sigma}{\varepsilon_0}$ Electric field in the absence of dielectric

E_{ind} : Induced (bound) charge density.

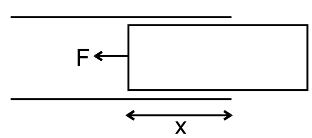
(iii) $\sigma_b = \sigma(1 - \frac{1}{K})$.

6. Force on dielectric

(i) When battery is connected $F = \frac{\varepsilon_0 b(K-1)V^2}{2d}$



(ii) When battery is not connected $F = \frac{Q^2}{2C^2}\frac{dC}{dx}$



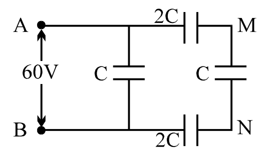
* Force on the dielectric will be zero when the dielectric is fully inside.

SECTION-1 SCQ

1. A capacitor of capacitance C is charged to a potential difference V from a cell and then disconnected from it. A charge +Q is now given to its positive plate. The potential difference across the capacitor is now

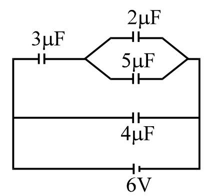
(A) V (B) $V + \frac{Q}{C}$ (C) $V + \frac{Q}{2C}$ (D) $V - \frac{Q}{C}$, if $V < CV$

2. In the circuit shown, a potential difference of 60V is applied across AB. The potential difference between the point M and N is



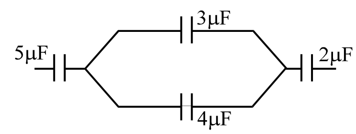
(A) 10 V (B) 15 V
(C) 20 V (D) 30 V

3. In the circuit shown in figure, the ratio of charges on 5μF and 4μF capacitor is :



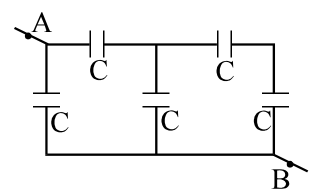
(A) 4/5 (B) 3/5
(C) 3/8 (D) 1/2

4. If charge on left plane of the 5μF capacitor in the circuit segment shown in the figure is –20μC, the charge on the right plate of 3μF capacitor is



(A) +8.57 μC (B) –8.57 μC (C) +11.42 μC (D) –11.42 μC

5. What is the equivalent capacitance of the system of capacitors between A & B



(A) $\frac{7}{6}C$ (B) 1.6 C (C) C (D) None

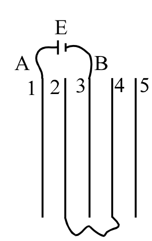
6. Two capacitor having capacitances 8 μF and 16 μF have breaking voltages 20 V and 80 V. They are combined in series. The maximum charge they can store individually in the combination is

(A) 160 μC (B) 200 μC (C) 1280 μC (D) none of these

7. A capacitor of capacitance C is initially charged to a potential difference of V volt. Now it is connected to a battery of 2V Volt with opposite polarity. The ratio of heat generated to the final energy stored in the capacitor will be

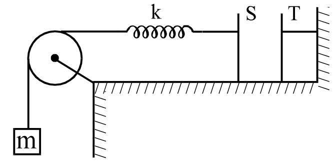
(A) 1.75 (B) 2.25 (C) 2.5 (D) 1/2

8. Five conducting parallel plates having area A and separation between them d, are placed as shown in the figure. Plate number 2 and 4 are connected wire and between point A and B, a cell of emf E is connected. The charge flown through the cell is



(A) $\frac{3}{4}\frac{\varepsilon_0 AE}{d}$ (B) $\frac{2}{3}\frac{\varepsilon_0 AE}{d}$ (C) $\frac{4\varepsilon_0 AE}{d}$ (D) $\frac{\varepsilon_0 AE}{2d}$

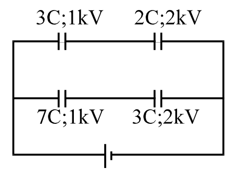
9. The plates S and T of an uncharged parallel plate capacitor are connected across a battery. The battery is then disconnected and the charged plates are now connected in a system as shown in the figure. The system shown is in equilibrium. All the strings are insulating and massless. The magnitude of charge on one of the capacitor plates is: [Area of plates = A]



(A) $\sqrt{2mgA \in_0}$ (B) $\sqrt{\dfrac{4mgA \in_0}{k}}$

(C) $\sqrt{mgA \in_0}$ (D) $\sqrt{\dfrac{2mgA \in_0}{k}}$

10. The diagram shows four capacitors with capacitances and break down voltages as mentioned. What should be the maximum value of the external emf source such that no capacitor breaks down ? [Hint : First of all find out the break down voltages of each branch. After that compare them.]



(A) 2.5 kV (B) 10 / 3kV (C) 3 kV (D) 1 kV

11. A conducting body 1 has some initial charge Q, and its capacitance is C. There are two other conducting bodies, 2 and 3, having capacitances : $C_2 = 2C$ and $C_3 \to \infty$. Bodies 2 and 3 are initially uncharged. "Body 2 is touched with body 1. Then, body 2 is removed from body 1 and touched with body 3, and then removed." This process is repeated N times. Then, the charge on body 1 at the end must be

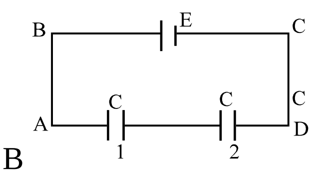
(A) $Q/3^N$ (B) $Q/3^{N-1}$ (C) Q/N^3 (D) None

12. A capacitor is connected to a battery. The force of attraction between the plates when the separation between them is halved

(A) remains the same (B) becomes eight times

(C) becomes four times (D) becomes two times

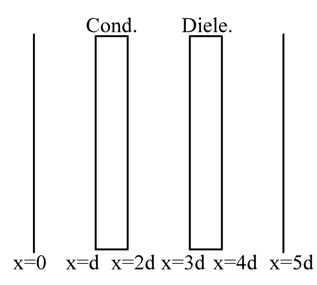
13. In the adjoining figure, capacitor (1) and (2) have a capacitance 'C' each. When the dielectric of dielectric constant K is inserted between the plates of one of the capacitor, the total charge flowing through battery is

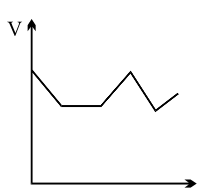


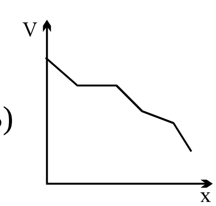
(A) $\dfrac{KCE}{K+1}$ from B to C (B) $\dfrac{KCE}{K+1}$ from C to B

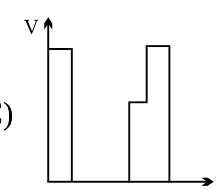
(C) $\dfrac{(K-1)CE}{2(K+1)}$ from B to C (D) $\dfrac{(K-1)CE}{2(K+1)}$ from C to B

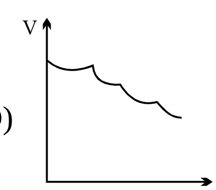
14. The distance between plates of a parallel plate capacitor is 5d. Let the positively charged plate is at x = 0 and negatively charged plate is at x = 5d. Two slabs one of conductor and other of a dielectric of equal thickness d are inserted between the plates as shown in figure. Potential versus distance graph will look like :



(A)


(B)


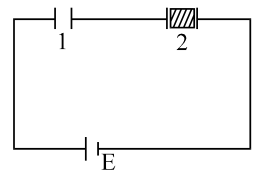
(C)


(D)


15. The distance between the plates of a charged parallel plate capacitor is 5 cm and electric field inside the plates is 200 Vcm^{-1}. An uncharged metal plate width 2 cm is fully immersed into the capacitor. The length of the metal bar is same as that of plate of capacitor. The voltage across capacitor after the immersion of the bar is

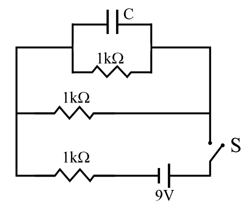
(A) zero (B) 400 V (C) 600 V (D) 100 V

16. Two identical capacitors 1 and 2 are connected in series to a battery as shown in figure. Capacitor 2 contains a dielectric slab of dielectric constant k as shown. Q_1 and Q_2 are the charges stored in the capacitors. Now the dielectric slab is removed and the corresponding charges are Q'_1 and Q'_2. Then



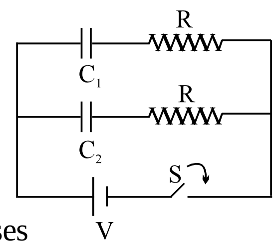
(A) $\frac{Q'_1}{Q_1} = \frac{k+1}{k}$ (B) $\frac{Q'_2}{Q_2} = \frac{k+1}{2}$ (C) $\frac{Q'_2}{Q_2} = \frac{k+1}{2k}$ (D) $\frac{Q'_1}{Q_1} = \frac{k}{2}$

17. A capacitor C = 100 μF is connected to three resistor each of resistance 1 kΩ and a battery of emf 9V. The switch S has been closed for long time so as to charge the capacitor. When switch S is opened, the capacitor discharges with time constant



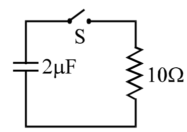
(A) 33 ms (B) 5 ms
(C) 3.3 ms (D) 50 ms

18. In the circuit shown in figure $C_1 = 2C_2$. Switch S is closed at time t = 0. Let i_1 and i_2 be the currents flowing through C_1 and C_2 at any time t, then the ratio i_1/i_2



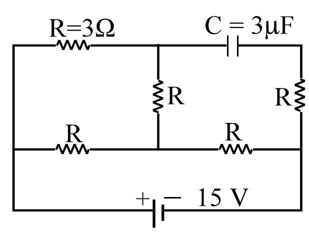
(A) is constant
(B) increases with increase in time t
(C) decreases with increase in time t (D) first increases then decreases

19. In the R – C circuit shown in the figure the total energy of 3.6×10^{-3} J is dissipated in the 10 Ω resistor when the switch S is closed. The initial charge on the capacitor is



(A) 60 μC (B) 120 μC (C) $60\sqrt{2}$ μC (D) $\frac{60}{\sqrt{2}}$ μC

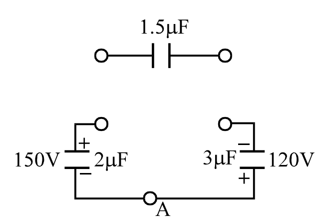
20. In the circuit shown, the cell is ideal, with emf = 15 V. Each resistance is of 3Ω. The potential difference across the capacitor is



(A) zero (B) 9 V
(C) 12 V (D) 15 V

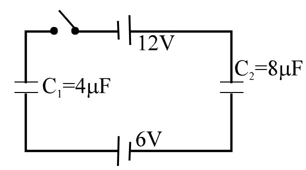
SECTION-2 MCQ

21. Two capacitors of 2 μF and 3 μF are charged to 150 volt and 120 volt respectively. The plates of capacitor are connected as shown in the figure. A discharged capacitor of capacity 1.5 μF falls to the free ends of the wire. Then



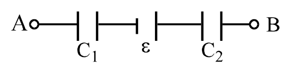
(A) charge on the 1.5 μF capacitors is 180 μC
(B) charge on the 2μF capacitor is 120 μC
(C) positive charge flows through A from right to left
(D) positive charge flows through A from left to right

22. In the circuit shown initially C_1, C_2 are uncharged. After closing the switch



(A) The charge on C_2 is greater that on C_1
(B) The charge on C_1 and C_2 are the same
(C) The potential drops across C_1 and C_2 are the same
(D) The potential drops across C_2 is greater than that across C_1

23. A circuit shown in the figure consists of a battery of emf 10 V and two capacitance C_1 and C_2 of capacitances 1.0 μF and 2.0 μF respectively. The potential difference $V_A - V_B$ is 5V

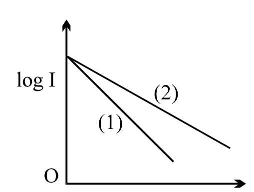


(A) charge on capacitor C_1 is equal to charge on capacitor C_2
(B) Voltage across capacitor C_1 is 5V.
(C) Voltage across capacitor C_2 is 10 V
(D) Energy stored in capacitor C_1 is two times the energy stored in capacitor C_2.

24. The capacitance of a parallel plate capacitor is C when the region between the plate has air. This region is now filled with a dielectric slab of dielectric constant k. The capacitor is connected to a cell of emf E, and the slab is taken out slowly.
(A) charge $CE(k - 1)$ flows through the cell
(B) energy $E^2C(k - 1)$ is absorbed by the cell
(C) the energy stored in the capacitor is reduced by $E^2C(k - 1)$
(D) the external agent has to do $\frac{1}{2}E^2C(k-1)$ amount of work to take the slab out

25. A parallel-plate capacitor is connected to a cell. Its positive plate A and its negative plate B have charges +Q and –Q respectively. A third plate C, identical to A and B, with charge +Q, is now introduced midway between A and B, parallel to them. Which of the following are correct?
(A) The charge on the inner face of B is now $-\frac{3Q}{2}$
(B) There is no change in the potential difference between A and B.
(C) The potential difference between A and C is one-third of the potential difference between B and C.
(D) The charge on the inner face of A is now Q/2.

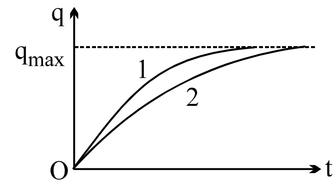
26. A capacitor of capacity C is charged to a steady potential difference V and connected in series with an open key and a pure resistor 'R'. At time t = 0, the key is closed. If I = current at time t, a plot of log I against 't' is as shown in (1) in the graph. Later one of the parameters i.e. V, R or C is changed keeping the other two constant, and the graph (2) is recorded. Then



(A) C is reduced
(B) C is increased
(C) R is reduced
(D) R is increased

Question No.27 to 28 (2 questions)

The charge across the capacitor in two different RC circuits 1 and 2 are plotted as shown in figure.



27. Choose the correct statement(s) related to the two circuits.

(A) Both the capacitors are charged to the same charge.

(B) The emf's of cells in both the circuit are equal.

(C) The emf's of the cells may be different.

(D) The emf E_1 is more than E_2

28. Identify the correct statement(s) related to the R_1, R_2, C_1 and C_2 of the two RC circuits.

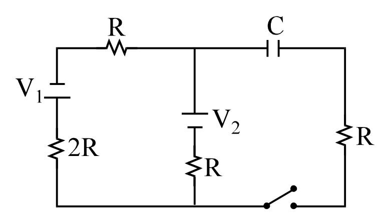
(A) $R_1 > R_2$ if $E_1 = E_2$ (B) $C_1 < C_2$ if $E_1 = E_2$

(C) $R_1C_1 > R_2C_2$ (D) $\frac{R_1}{R_2} < \frac{C_2}{C_1}$

29. The capacitance (C) for an isolated conducting sphere of radius (a) is given by $4\pi\varepsilon_0 a$. If the sphere is enclosed with an earthed concentric sphere. The ratio of the radii of the spheres being $\frac{n}{(n-1)}$ then the capacitance of such a sphere will be increased by a factor

(A) n (B) $\frac{n}{(n-1)}$ (C) $\frac{(n-1)}{n}$ (D) a . n

30. In the transient circuit shown the time constant of the circuit is :



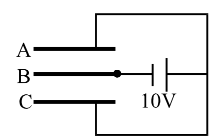
(A) $\frac{5}{3}$RC (B) $\frac{5}{2}$RC

(C) $\frac{7}{4}$RC (D) $\frac{7}{3}$RC

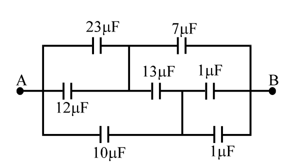
SECTION-3 INTEGER TYPE

31. The minimum number of capacitors each of 3 μF required to make a circuit with an equivalent capacitance 2.25 μF is

32. Three plates A, B and C each of area 0.1 m^2 are separated by 0.885 mm from each other as shown in the figure. A 10 V battery is used to charge the system. The energy stored in the system is

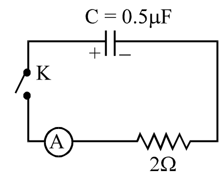


33. Find the equivalent capacitance across A & B

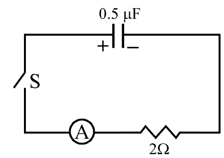


34. Three capacitors 2 μF, 3 μF and 5 μF can withstand to 3V, 2V and 1V respectively. Their series combination can withstand a maximum voltage equal to

35. A charged capacitor is allowed to discharge through a resistor by closing the key at the instant t = 0. At the instant t = (ln 4) μs, the reading of the ammeter falls half the initial value. The resistance of the ammeter is equal to



36. A charged capacitor is allowed to discharge through a resistance 2Ω by closing the switch S at the instant t = 0. At time t = *l*n 2 μs, the reading of the ammeter falls half of its initial value. The resistance of the ammeter equal to



ANSWER KEY

SCQ

1.	C	**2.**	D	**3.**	C	**4.**	A	**5.**	B
6.	A	**7.**	B	**8.**	B	**9.**	A	**10.**	A
11.	A	**12.**	C	**13.**	D	**14.**	B	**15.**	C
16.	C	**17.**	D	**18.**	B	**19.**	B	**20.**	C

MCQ

21.	A, B, C	**22.**	B	**23.**	A, D	**24.**	A, B, D		
25.	A, B, C, D	**26.**	B	**27.**	A, C	**28.**	D	**29.**	A
30.	C								

INTEGER

31.	4	**32.**	10^{-1} μJ	**33.**	$\frac{15}{2}$ μF	**34.**	(31/6) Volts	**35.**	2Ω
36.	2Ω								