# Exam

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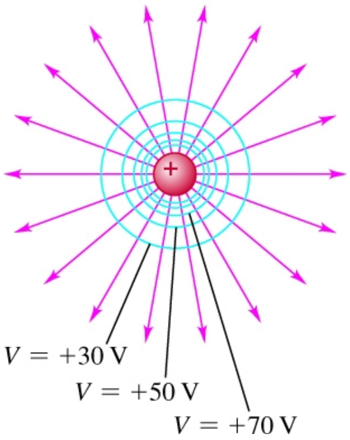
**2022**

# Electrostatic ( Chapter 23)

Consider the figure below. (**Total Marks 2**)




Would the shape of the equipotential surfaces change if the sign of the charge is reversed?

(I)Yes. (II) No. **Answer: (II) Marks 1.**

Will the potential at the indicated equipotential surfaces change?

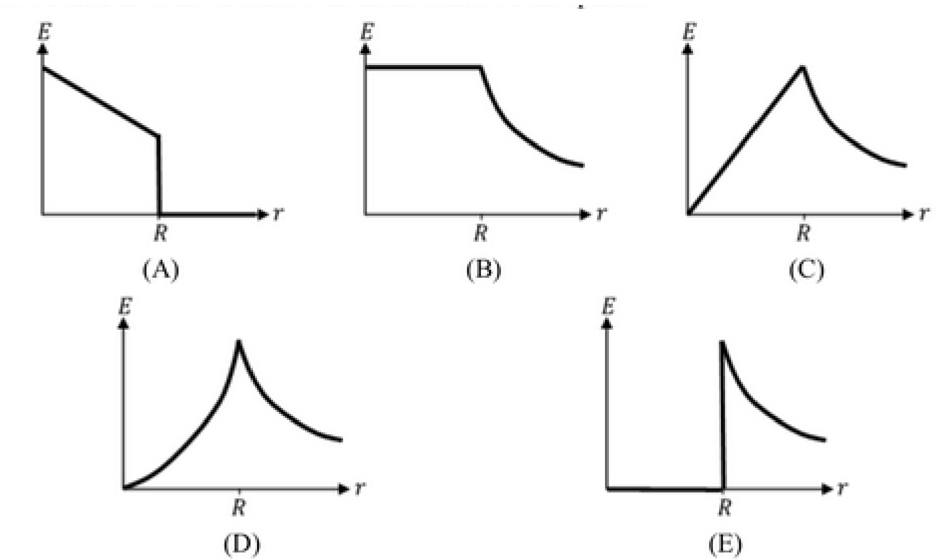
(I) Yes. (II) No. **Answer: (I) Marks 1.**

**Comment:** The equipotential surfaces of a point charge are always spherical in 3D view, and, circular in 2D view, whatever is the sign of the point charge. However, the value of the potential at the equipotential surfaces will change according to the formula:

$$V(r) = \frac{q}{4\pi\epsilon_0} \cdot \frac{1}{r}$$

# Electrostatic (Chapter 22)

The following graphs show the electric field at a variable distance r. (**Total Marks 4**)




Which one corresponds to the electric field generated by a spherical charged conductor of radius R?

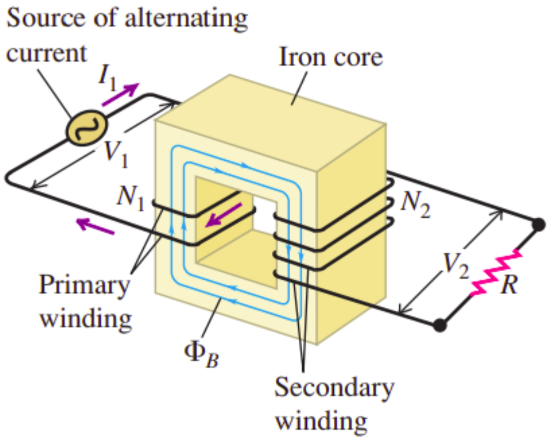
(I) E (II) C (III) A (IV) B. (V) D. **Answer: (I). Marks 2.**

Which one corresponds to the electric field generated by a uniformely charged insulating sphere of radius R?

(I) E (II) C (III) A (IV) B. (V) D. **Answer: (II). Marks 2.**

# Alternating Currents (Chapter 31)

Linnea is moving out from Norway for a six months study experience in the USA. She would like to use the 960W coffeemaker that she bought in Norway. She needs a transformer to convert the 120V ac to the 230 V that the coffeemaker requires to function. (**Total Marks 4**)




What is the ratio between the number of turns in the secondary winding (i.e. $N_2$) and the number of turns in the primary winding (i.e. $N_1$) of the transformer she needs?

**Answer: (I) Marks 2.**

(I) $N_2/N_1 = 1.92$ (II) $N_2/N_1 = 5.28$ (III) $N_2/N_1 = 0.52$ (IV) $N_2/N_1 = 0.02$ (V) $N_2/N_1 = 19.2$

What current will the coffemaker draw from the 120 V supply?

(I) 10.0 A (II) 4.0A (III) 3.0A (IV) 8.0A

**Answer: (IV) Marks 2.**

# Solution

Linnea's transformer needs to convert $V_1$ = 120V given by the USA power supply to the $V_2$ =240V required by the Norwegian coffeemaker to work.

(a) The required turns ratio of the transformer is:

$$\frac{N_2}{N_1}=\frac{V_2}{V_1}=\frac{230\,V}{120\,V}=1.92\,V$$

(b) The current that the coffeemaker will draw from the 120 V supply is:

$$I=\frac{P_{av}}{V}=\frac{960\,W}{120\,V}=8.0\,A$$

# Capacitors (Chapter 24)

Imagine that the two conductors of a parallel-plate capacitor have different areas. Such capacitor is fully charged by connecting the plates to a battery. Will the charge in the two planes be the same or of different magnitudes?

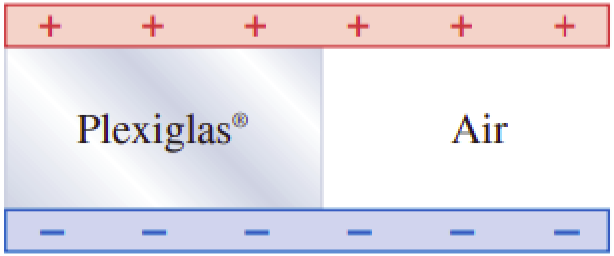
(I) The capacitor must be neutral. The two plates have the same amount of charges.

(II) In a parallel plate capacitor, the amount of charge is proportional to the plate area. Hence, there is more charge on the large plate than on the small plate.

**Answer: (I) Marks 4.**

# Dieletrics (Chapter 24)

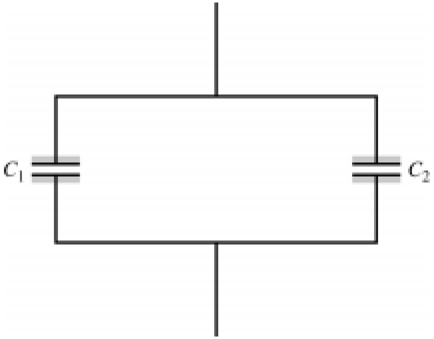
Consider the capacitor in the picture below. The parallel-plate capacitor is made of two squared plates of area 1.44 x $10^{-2}$ $m^2$ on each side and 4.50 mm apart. Half of the space in between the two plates is filled with air, and, the other half is filled with Plexiglas of dielectric constant 3.40. What is the capacitance of this system? (*Hint: Consider if this capacitor can be seen as a combination of two different capacitors connected in parallel, each with plates of area 7.20 x* $10^{-3}$ $m^2$).




(I) 6.23 μF. (II) 6.23 pF. (III) 62.3 μF. (IV) 62.3 pF. **Answer: (IV) Marks 4.**

# Solution

The «Hint» mentions that the capacitor can be seen as a combination of two different capacitors connected in parallel. We call $C_1$ the capacitor of which the space in between the plates is filled with air, and, $C_2$ the capacitor of which the space is filled with Plexiglas. Plexiglas has a dielectric constant k=3.40.




$$C_1 = \epsilon_0 \frac{A}{d}$$

$$C_2 = \epsilon_0 \frac{A_1}{d} k = k C_1$$

$$\epsilon_0 = 8.854 \cdot 10^{-12} \frac{C^2}{N \cdot m^2}$$

$$A = 7.20 \times 10^{-3} m^2$$

$$d = 4.50 \cdot 10^{-3} m$$

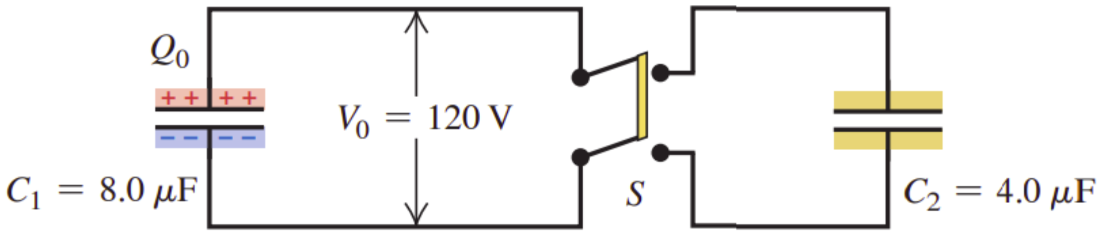
The equivalent capacitance $C_{eq}$ of two capacitors in parallel is:

$$C_{eq} = C_1 + C_2 = \epsilon_0 \frac{A}{d} (1 + k)$$

$$C_{eq} = C_1 + C_2 = \left( 8.854 \cdot 10^{-12} \frac{C^2}{N \cdot m^2} \right) \left( \frac{7.20 \times 10^{-3} m^2}{4.50 \cdot 10^{-3} m} \right) \cdot (4.40) = 0.0623 \cdot 10^{-9} F = 62.3\ pF$$

# Dieletrics (Chapter 24)

Consider the circuit below. The capacitance $C_1$ and $C_2$ of the two capacitors are indicated in the figure, as well as the potential difference $V_0$. (**Total Marks 8**)




What is the energy stored in the capacitor $C_1$ while the switch S is opened and the capacitor is fully charged?

(I) 0.058 J (II) None of the alternatives are correct. (III) 3.0 J. (IV) 0.5 J (V) 0.20 J

**Answer: (I) Marks 4.**

What is the total energy stored by the capacitors when the switch S is closed and both of the capacitors are charged?

(I) 0.13 J (II) None of the alternatives are correct. (III) 3.2 J. (IV) 0.32 J (V) 0.038 J

**Answer: (V) Marks 4.**

# Solution

(a) Energy stored in $C_1$?

$U_{initial} = \frac{1}{2} Q_0 \cdot V_0$ → $Q_0$ on $C_1$? $\quad Q_0 = C_1 \cdot V_0 = (8.0\,\mu F)(3.40)(120\,V) = 960\,\mu C$

$$U_{initial} = \frac{1}{2} Q_0 \cdot V_0 = \frac{1}{2}(960\,\mu C)(120\,V) = 0.058\,J$$

(b) We close S and we let the capacitors charge. What is the energy stored in both of the capacitors?

When we close S, the charge $Q_0$ is split between the plates of the capacitors.

$Q_0 = Q_1 + Q_2$; $\quad Q_1 = C_1 \cdot V$; $\quad Q_2 = C_2 \cdot V$; $\quad$ What are $Q_1$, $Q_2$ and $V$?

$Q_1 = C_1 \cdot V = 8.0\,\mu F \cdot 80\,V = 640\,\mu C$; $\quad Q_2 = 960\,\mu C - 640\,\mu C = 320\,\mu C$;

$$V = \frac{Q_0}{C_1 + C_2} = \frac{960\,\mu C}{8.0\,\mu F + 4.0\,\mu F} = 80\,V;$$

$U_{final} = \frac{1}{2} Q_0 \cdot V$ → $U_{final} = \frac{1}{2} Q_0 \cdot V = \frac{1}{2} Q_1 \cdot V + \frac{1}{2} Q_2 \cdot V = \frac{1}{2}(960 \times 10^{-6}\,C)(80\,V) = 0.038\,J$

# Currents (Chapter 25)

Estimate the drift velocity $v_d$ for electrons in a cylindrical copper wire with a diameter d equal to 0.30 cm. The wire carries a current of 2.00 A. You can assume one free electron per copper atom. Furthermore, consider that the mass density of copper is 8.92 $g/cm^3$, and its molecular weight is 63.5g/mol.

Remember the following constants:

Avogadro's number $N_A = 6.022 \cdot 10^{23}$ $mol^{-1}$

Electron charge $e = 1.602 \cdot 10^{-19}$ C.

(I) $V_d = 2.08 \times 10^{-3}$ cm/s

(II) $V_d = 12.08 \times 10^{-9}$ cm/s

(III) $V_d = 8 \times 10^{3}$ cm/s

**Answer: (I) Marks 4.**

# Solution

$$d = 0.3\,cm \qquad I = 2.00\,A \qquad \rho = 8.92\,\frac{g}{cm^3} \qquad m_w = 63.5\,\frac{g}{mol}$$

$$v_d = \frac{J}{n|q|}$$

$$n = \frac{\rho}{m_w} N_A = \frac{8.92\,g/cm^3}{63.5\,g/mol} \cdot \frac{6.022\times 10^{23}}{mol} \approx 8.5\times 10^{22}\,cm^{-3}$$

→ There is one electron per atom. The number of free electrons per $cm^3$ is n.

What is the current density J ?

$$A = \pi\frac{d^2}{4} \qquad A = \pi\frac{(0.3\,cm)^2}{4} = 0.07065\times cm^2 = 7.06\times 10^{-2}\,cm^2$$

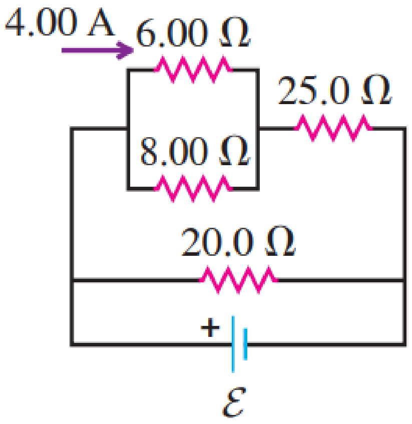
→ $$J = \frac{I}{A} = \frac{2.00}{7.06\times 10^{-2}\,cm^2} = 28.33\,\frac{A}{cm^2}$$

What is the drift speed $v_d$ ?

$$v_d = \frac{J}{n|q|} = \frac{28.33\,\frac{A}{cm^2}}{8.5\times 10^{22}\,cm^{-3}\cdot 1.602\times 10^{-19}\,C} = 2.08\times 10^{-3}\,\frac{cm}{s}$$

# DC (Chapter 26)

Consider the circuit below. The current through the 6.00 Ω resistor is 4.00 A, with the direction indicated in the figure. (**Total Marks 4**)




What is the current through the 25.0 Ω resistor?

(I) 7.0 A (II) 10.0 A (III) 3.0 A (IV) 20.0 A **Answer: (I) Mark 2.**

What is the current through the 20.0 Ω resistor?

(II) 7.0 A (I) 15.0 A (III) 20.0 A (IV) 9.95 A **Answer: (IV) Mark 2.**

# Solution

a) What is the current through the 25.0 Ω resistor?

The voltages at the 6Ω and at the 8Ω resistors are equal, while the current depends on the resistor that it meets and it splits according to the formula:

$$I_{25.0\,\Omega}=I_{6.00\,\Omega}+I_{8.00\,\Omega}$$

$$V_{6\,\Omega}=(6.00\,\Omega)(4.00\text{ A})=24.0\text{ V}=V_{8\Omega}$$

$$I_{8.00\,\Omega}=\frac{V_{8\Omega}}{R}=\frac{24.0\text{ V}}{8.00\,\Omega}=3.00\text{ A} \longrightarrow I_{25.0\,\Omega}=3.00\text{ A}+4.00\text{ A}=7.00\text{ A}$$

b) What is the current through the 20.0 Ω resistor?

The voltage at the 20.0 Ω resistor is the same as the one at the upper branch. Hence:

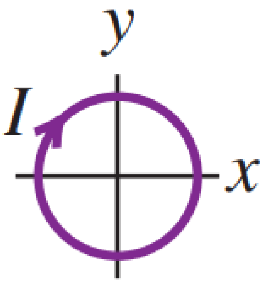
$$V_{25.0\,\Omega}=(25.0\,\Omega)(7.00\text{ A})=175.0\text{ V}$$

$$V_{20.0\,\Omega}=V_{6.00\,\Omega}+V_{25.0\,\Omega}=24.0\text{ V}+175.0\text{ V}=199.0\text{ V}$$

$$I_{20.0\,\Omega}=\frac{V_{20.0\,\Omega}}{R}=\frac{199.0\text{ V}}{20.0\,\Omega}=9.95\text{ A}$$

# Magnetic field and forces (Chapter 27)

Consider the circular coil in the figure. The coil is immersed in a uniform magnetic field that points in the +z-direction, i.e. out of the page. (**Total Marks 5**)




What is the direction of the dipole moment of this coils? The dipole moment is directed in the ...

(I) -z direction, i.e., into the page.

(II) -y direction.

(III) +z direction, i.e, out of the page.

(IV) +x direction.

**Answer: (I) Mark 1.**

Is the coil in a rotational equilibrium condition?

(I) None of the alternatives are correct.

(II) No. It is rotating around the x-axes because the torque of the force is different than zero.

(III) Yes, it is in an unstable equilibrium condition.

(IV) No. It rotates because the magnetic flux chaging.

(V) Yes. The torque of the force is always zero in a uniform magnetic field.

(VI) Yes, it is in a stable equilibrium condition.

**Answer: (III) Marks 2.**

Is the coil attracted or repulsed by the external magnetic field?

(I) It is attracted by the source of the magnetic field.

(II) The net force on a current loop in a uniform magnetic field is zero.

(III) None of the alternatives are correct.

(IV) It is repulsed by the source of the magnetic field.

**Answer: (II) Marks 2.**

# Solution

(a) Applying the right-hand rule for the magnetic moment, we can find out that the dipole moment is directed in the -z direction, i.e. into the page.

(b) The direction of the uniform magnetic field and of the dipole moment are opposed to each other. This means the dipole moment is in an unstable equilibrium position.

(c) The net force on a current loop in a uniform magnetic field is zero.

# Source of Magnetic Fields (Chapter 28)

A topic of interest in physics research is the existence of an isolated magnetic pole or magnetic monopole. What is the Maxwell's equation that excludes the existence of the monopole? (**Total Marks 4**)

(I) Gauss's law for electric fields. (II) Gauss's law for magnetic fields. (III) Ampere's law. (IV) Faraday's law.

**Answer: (II) Marks 2.**

If such an entity were found, how could it be recognized?

(I) None of the alternatives is correct.

(II) The displacement current would be the same as the standard current.

(III) The faraday's law would be equal to the Gauss's law.

(IV) The magnetic flux through a closed surface would be proportional to the net number of magnetic monopoles included in the surface.

**Answer: (IV) Marks 2.**

# Paramagnetic and diamagnetic materials (Chapter 28).

What features of the material determines whether an element is ferromagnetic, diamagnetic, or paramagnetic?

(I) The presence of the total magnetic moment. Paramagnetic materials have a non null total magnetic moment while diamagnetic materials have zero total magnetic moment.

(II) None of the alternatives are correct.

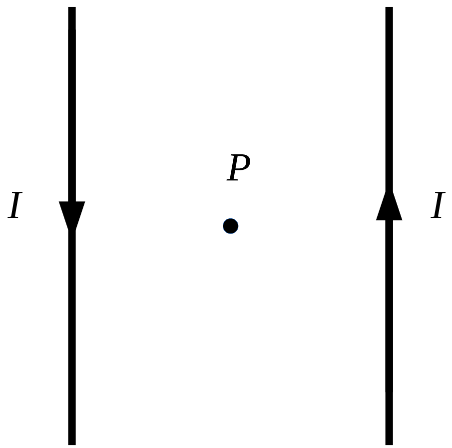
(III) The presence of the total magnetic moment. Paramagnetic materials have a null total magnetic moment while diamagnetic materials have a non zero total magnetic moment.

(IV) The presence of unbalanced electric charges. Paramagnetic materials have a non null total electric charge while diamagnetic materials have zero total electric charge.

**Answer: (I) Marks 4**

# Magnetic field (Chapter 28)

Two wires lie in the plane of the page, and each carries a current of the same magnitude. However, those two currents have opposite directions as shown in the below picture.




The magnetic field in the point P is:

(I) zero.

(II) Toward one of the two wire.

(III) into the page.

(IV) Parallel to one of the wire currents.

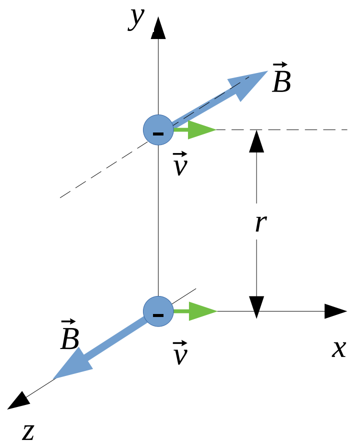
(V) out of the page.

**Answer: (V) Marks 4.**

**Solution:** Using the right-hand rule, you will find that the magnetic field generated from each current in P are directed out of the page.

# Source of magnetic field (Chapter 28)

Two electrons are travelling parallel to each other with the same speed and in the same direction. Each electron generates a magnetic field onto the other charge with the direction shown in the picture.(**Total Marks 4**)




How is the magnetic force between them?

(I) Attractive. (II) Repulsive. (III) Zero. (IV) Conservative. **Answer: (I). Marks 2**

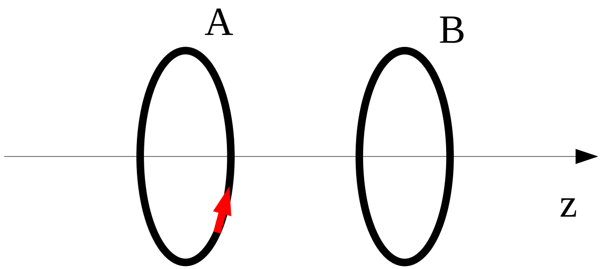
How is the electric force between them?

(I) Attractive. (II) Repulsive. (III) Zero. (IV) None of the alternatives is true.

**Answer: (II). Marks 2**

# Induction (Chapter 30)

The planes of the circular loops in the picture are parallel. As viewed from the left, the current in loop A is counterclockwise.(**Total Marks 4**)




If the magnitude of the current in loop A is increasing, what is the direction of the current induced in loop B?

I) clockwise.

II) There is no current in the loop B.

III) counterclockwise.

**Answer: (I) Marks 2.**

Do the loops attract or repel each other?

I) There is not force between them.

II) They attract each other.

III) They repel each other.

IV) The torque of the force is different than zero.

**Answer: (III) Marks 2.**

# Solution

(a) According to the Len’z law, the direction of the current in loop B must be clockwise.

(a) The two loops repel each other. There are many ways to obtain this result, one is thinking that the currents generate two magnetic moments with the south poles close to each other.

# Maxwell's Equations (Chapter 29)

Match the following statements with the electromagnetism Maxwell's Equations.

(a) Only changing magnetic fields produce closed electric fields line.

(b) Electric field lines can start from positive and end in negative charges.

(c) The motion of electric charges and variation of electric fields produce closed magnetic field lines.

(d) Magnetic monopoles do not exist.

$$(1)\oint \vec{B}\cdot\vec{dA}=0$$

$$(2)\oint \vec{E}\cdot\vec{dA}=\frac{Q_{enclosed}}{\epsilon_0}$$

$$(3)\oint \vec{E}\cdot\vec{dl}=-\frac{d\Phi_B}{dt}$$

$$(4)\oint \vec{B}\cdot\vec{dl}=\mu_0\left(i_C+\epsilon_0\frac{d\Phi_E}{dt}\right)$$

**Answer: Marks 4. Every correct pairing counts 1 Mark.**

| | (2) | (3) | (4) | (1) |
|---|---|---|---|---|
| (c) | | | ✓ | |
| (a) | | ✓ | | |
| (b) | ✓ | | | |
| (d) | | | | ✓ |

# (Chapter 21-22-28)

## Magnetic and Electric fields

**The following sentences refer to properties related to magnetic and electric fields. Mark the ones you think are true.**
**Select one or more alternatives:**

- [x] Electric fields are generated by stationary and moving charges, while magnetic fields are generated only by moving charges. ✔
- [x] Magnetic fields are always non conservative, electric fields can be both conservative and non conservative. ✔
- [ ] Magnetic and electric fields are always conservative.
- [x] The strength of the magnetic and electric field is indicated by the closeness of the field lines. ✔
- [ ] Magnetic forces between magnet bars are always attractive, electric forces between point charges can be attractive or repulsive.
- [ ] Magnetic and electric fields generate forces inversely proportional to the square of the distance between the sources.
- [x] Magnetic forces between magnet bars and electric forces between point charges can be attractive or repulsive. ✔

Correct. 4 of 4 marks. Try again

**Marking: Every correct answer counts 1 Mark.**

# Electrostatic (Chapter 22)

**The following paragraph has been extracted from the "Feynman Lectures of Physics" Volume II. Choose the word you think is correct among the alternatives offered in each menu.**

We calculate the field from a [uniform] ✓ (non uniform, uniform) plain sheet of charge. Suppose that the sheet is infinite and that the [charge per unit area] ✓ (charge per unit length, charge per unit area, charge, charge per unit volume) is $\sigma$ .

Consideration of symmetry leads us to believe that the field direction is everywhere [normal] ✓ (parallel, normal) to the plane, and, if we have no field from any other charges in the world, the field must be [the same] ✓ (half , null, the same, different) on each side.

This time we choose as Gaussian [surface] ✓ (surface, volume, line ) a rectangular box that cuts the sheet. The two faces parallel to the sheet have equal area A. The electric field is [normal] ✓ (normal, parallel) to these two faces, and [parallel] ✓ (parallel, normal) to the other four. The total [electric flux] ✓ (magnetic field, electric field, charge, electric flux) is E times the area of the first face, plus E times the area of the opposite face, with no contribution from the other four faces. The total [charge] ✓ (flux, volume, area, charge) enclosed in the box is $\sigma A$. Equating the [electric flux] ✓ (electric field , magnetic field, electric flux , magnetic flux) to the charge inside, we have:

$$EA + EA = \frac{\sigma A}{\epsilon_0}$$

from which:

$$E = \frac{\sigma}{2\epsilon_0} \qquad (5.3)$$

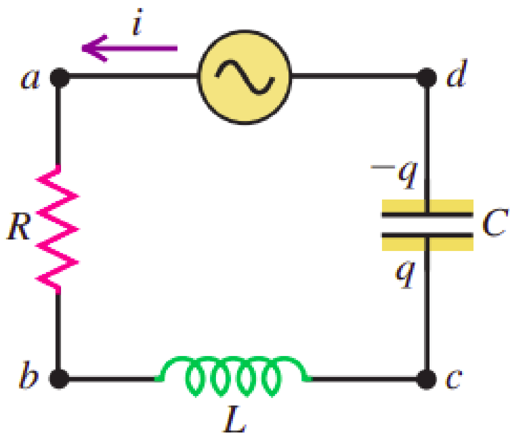
a simple but important result.

Correct. 5 of 5 marks. Try again

**Marking: Every correct answer counts 0.5 Marks**.

# Impedance (Chapter 31)

In the LRC circuit of the picture below, suppose R = 300Ω, L=40 mH, C= 0.50μF, V = 50V and $\omega$=1.0 x $10^4$ rad/s. Remember that V represents the voltage amplitude. (**Total Marks 6**)




What is the power factor of the circuit?

(I) 0.83 (II) 0.60 (III) 0.90 (IV) 5 (V) 10 (VI) 0.20

**Answer: (I) Marks 3.**

What is the average power delivered to the entire circuit?

(I) 2.9 W (II) 50 W (III) 600 W (IV) 3.5 W (V) 7.0 W (VI) 15 W

**Answer: (I) Marks 3.**

# Solution

a) Power factor

$$X_L = \omega L = (10000\ rad/s)(40\ mH) = 400\,\Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{(10000\,rad/s)(0.50\,\mu F)} = 200\,\Omega$$

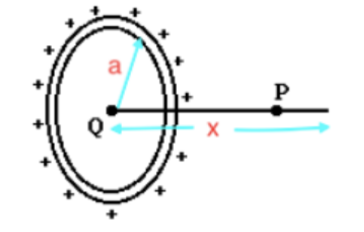
$$\phi = \arctan\frac{X_L - X_C}{R} = \arctan\frac{200\,\Omega}{300\,\Omega} \approx 34°$$ → $$\cos\phi = 0.83$$

b) Average power delivered to the entire circuit

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{50\,V}{\sqrt{(300\,\Omega)^2 + (200\,\Omega)^2}} = 0.14\,A$$

$$p_{av} = \frac{1}{2} VI\cos\phi = \frac{1}{2}(50\,V)(0.14\,A)(0.83) = 2.9\,W$$

# Electrostatic (Chapter 22 and 23)




A point charge is placed at the middle of a conducting ring with radius *a* that has a total charge of *C* coulombs. If the electric field is measured to be zero at a point P on the axis, a distance *x* from the plane of the ring, what is the value of the charge, Q?

*C*= 210nC

*x*= 0.3 m

*a*= 0.49 m

**Select one alternative:**

- -47 nC
- -30 nC ✔
- -71nC
- -20 nC
- - 37 nC
- -25 nC

Correct. 2 of 2 marks. Try again

# Solution

Considering that the electric field generated by a point charge is:

$$\vec{E}_C(P)=\frac{1}{4\pi\epsilon_0}\frac{C\,x}{(x^2+a^2)^{3/2}}\hat{i}$$

And, the electric field generated by a conducting ring in the point P is:

$$\vec{E}_Q(P)=\frac{1}{4\pi\epsilon_0}\frac{Q}{x^2}\hat{i}$$

The value of Q such that the total electric field in the point P would sum up to zero must be found from the relation:

$$\vec{E}_Q(P)+\vec{E}_C(P)=0 \longrightarrow E_Q(P)=-E_C(P)$$

$$\frac{1}{4\pi\epsilon_0}\frac{Q}{x^2}=-\frac{1}{4\pi\epsilon_0}\frac{C\,x}{(x^2+a^2)^{3/2}} \longrightarrow \frac{Q}{C}=-\frac{x^3}{(x^2+a^2)^{3/2}}$$

$$\frac{x^3}{(x^2+a^2)^{3/2}}\approx 0.1424 \longrightarrow Q\approx -0.1424\,x\,210\,nC=29.904\approx -30\,nC$$