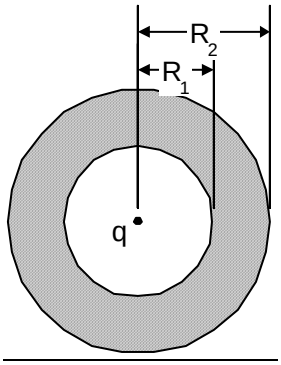
# 第二节 电磁学

Questions 1-2




A conducting sphere of radius $R_2$ has a concentric spherical cavity of radius $R_1$, as shown above. The sphere has no charge. However, there is a charge q in the center of the cavity.

1. What is the surface charge density on the inner surface of the sphere?

(A) $-\frac{q}{4\pi R_1^2}$

(B) $-\frac{q}{8\pi R_1^2}$

(C) $-\frac{q}{4\pi R_2^2}$

(D) $-\frac{q}{8\pi R_2}$

(E) $\frac{R_2^2 q}{4\pi R_1^3}$

解：电荷 q 发出的电力线均终止在球壳内表面上（或终止于 q 的电力线全来自于球壳内表面），所以球壳内表面电量为–q。由于球对称性，电量均匀分布，面电荷密度

$$\sigma = -\frac{q}{4\pi R_1^{\ 2}}。$$

选(A)。

2. What is the potential of the sphere? (Assume that the potential is zero at an infinite distance away.)

(A) $\frac{q}{R_1}$

(B) $\frac{q}{R_2}$

(C) $\frac{qR_1}{R_2}$

(D) $\frac{qR_2}{R_1}$

(E) $q(\frac{1}{R_1}+\frac{1}{R_2})$

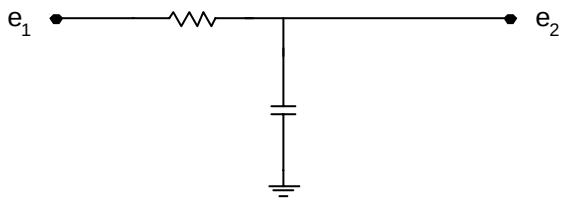
解：由导体球壳电量守恒，外表面电量为 q。所以球壳外电场强度为

$$E = \frac{q}{4\pi\varepsilon_0 r^2},$$

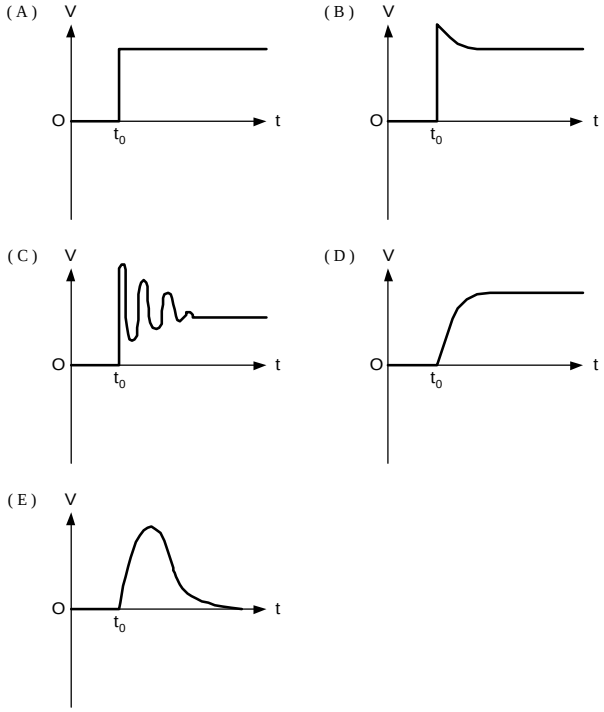
电势为

$$U = \int_{R_2}^{\infty} \frac{q}{4\pi\varepsilon_0 r^2} dr = \frac{q}{R_2},$$

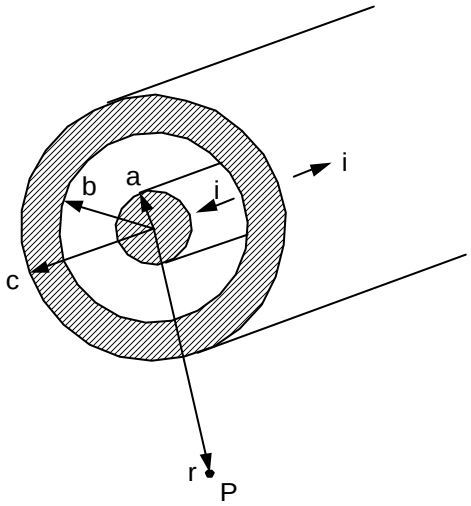
注意答案为 Gauss 单位制。选（B）。




3. In the circuit illustrated above, the point marked $e_1$ is raised instaneously at time $t_0$ from zero to a fixed positive potential. If $e_2$ is connected to a high-impedance D.C. oscilloscope input, the gragh of its voltage V as a function of time t will most resemble which of the following?




解：$t_0$ 瞬间电容上电量无法突变，所以示波器信号电压为 0，可排除(A)、(B)、(C)三种情况；当 $t\to\infty$ 时，电路处于稳定状态，电容相当于短路，电阻上无压降，示波器信号电压为 $V_0$。选（E)。




4. a coaxial cable having radii a, b, andc carries equal and opposite currents of magnitude i on the inner and outer conductors.What is the magnitude of the magnetic induction at point P outside of the cable at a distance r from the axis?

(A) Zero

(B) $\dfrac{\mu_0 ir}{2\pi a^2}$

(C) $\dfrac{\mu_0 i}{2\pi r}$

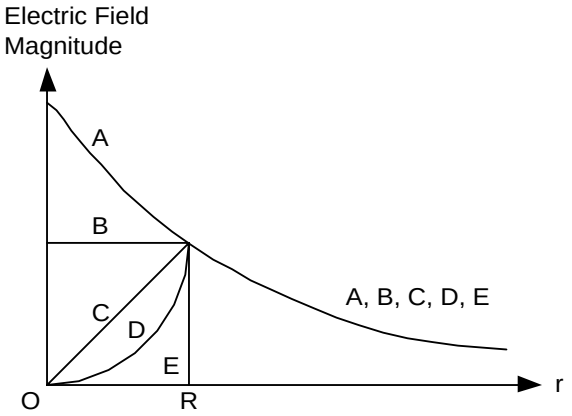
(D) $\dfrac{\mu_0 i}{2\pi r}\dfrac{c^2-r^2}{c^2-b^2}$

(E) $\dfrac{\mu_0 i}{2\pi r}\dfrac{r^2-b^2}{c^2-b^2}$

解：系统具有轴对称性，r 相同的地方磁感应强度相等。由 Ampere 环路定理，

$$B=\frac{1}{2\pi r}\oint \mathbf{B}\cdot\mathbf{dr}=\frac{\mu_0}{2\pi r}\iint \mathbf{j}\cdot\mathbf{ds}=\frac{\mu_0}{2\pi r}I\text{。}$$

因为电流总量为 0，所以磁感应强度为 0。选(A)。




5. A isolated sphere of radius R contains a uniform volume distribution of positive charge. Which of the curves on the graph above correctly illustrates the dependence of the magnitude of the electric field of the sphere as function of the distance r from its center?

(A) A

(B) B

(C) C

(D) D

(E) E

解：由 Gauss 定理，在球内部

$$E4\pi r^2=\frac{1}{\varepsilon_0}\rho\frac{4}{3}\pi r^3\text{，}$$

故 $E\propto r$。选（C)。

6. Which of the following equations is a consequence of the equation $\nabla \times \mathbf{H} = \dot{\mathbf{D}} + \mathbf{J}$?

(A) $\nabla \cdot (\dot{\mathbf{D}} + \mathbf{J}) = 0$

(B) $\nabla \times (\dot{\mathbf{D}} + \mathbf{J}) = 0$

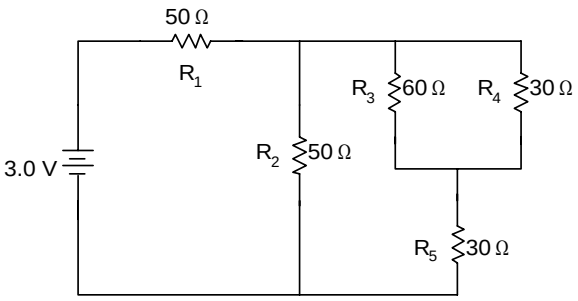
(C) $\nabla (\dot{\mathbf{D}} \cdot \mathbf{J}) = 0$

(D) $\dot{\mathbf{D}} + \mathbf{J} = 0$

(E) $\dot{\mathbf{D}} \cdot \mathbf{J} = 0$

解：旋度场无散，选（A）。

Questions 7-8




In the circuit shown above, the resistances are given in ohms and the battery is assumed ideal with emf equal to 3.0 volts.

7. The resistor that dissipates the most power is

(A) $R_1$

(B) $R_2$

(C) $R_3$

(D) $R_4$

(E) $R_5$

解：比较简单的方法是设 $R_3$ 上电流为 $I_0$，利用串并联的关系易得：($R_4$，$2I_0$)；($R_5$，$3I_0$)；($R_2$，$3I_0$)；($R_1$，$6I_0$)。显然 $R_1$ 上功率 $P = I^2 R$ 最大，选(A)。

8. The voltage across resistor $R_4$ is

(A) 0.4 V

(B) 0.6 V

(C) 1.2 V

(D) 1.5 V

(E) 3.0 V

解：由上一问的分析，且总电阻为 75 Ω ，则

$$I_0 = \frac{I}{6} = \frac{1}{6}\frac{U}{R} = \frac{1}{6}\frac{3.0}{75} = \frac{1}{150}\,\mathrm{A}\,,$$

$R_4$ 上的电压为

$$2I_0 R_4 = 2 \times \frac{1}{150} \times 30 = 0.4\,\mathrm{V}\,。$$

选（A）。

9. A conducting cavity is driven as an electromagnetic resonator. If perfect conductivity is assumed, the transverse and normal field components must obey which of the following conditions at the inner cavity walls?

(A) $E_n = 0, B_n = 0$

(B) $E_n = 0, B_t = 0$

(C) $E_t = 0, B_t = 0$

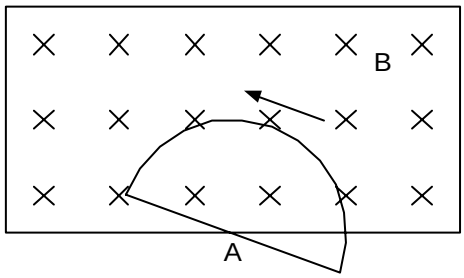
(D) $E_t = 0, B_n = 0$

(E) None of the above

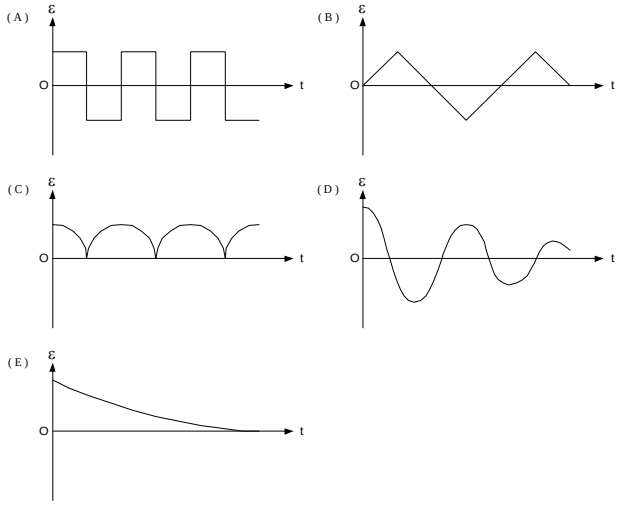
解：由电磁场的边界条件，

$$E_{1t} = E_{2t}\,, \qquad B_{1n} = B_{2n}\ 。$$

因为理想导体内部电磁场为 0，$E_{2t} = 0$，$B_{2n} = 0$，所以 $E_{1t} = 0$，$B_{1n} = 0$。选(D)。




10. A uniform and constant magnetic field B is directed perpendicularly into the plane of the page everywhere within a rectangular region as shown above. A wire circuit in the shape of a semicircle is rotated counterclockwise in the plane of the page about an axis A. The axis A is perpendicular to the page at the edge of the field and directed through the center of the straight-line portion of the circuit. Which of the following graphs best approximates the emf ε induced in the circuit as a function of time t?




解：由 Faraday 电磁感应定律

$$\mathrm{E}=-\frac{d\Phi}{dt},$$

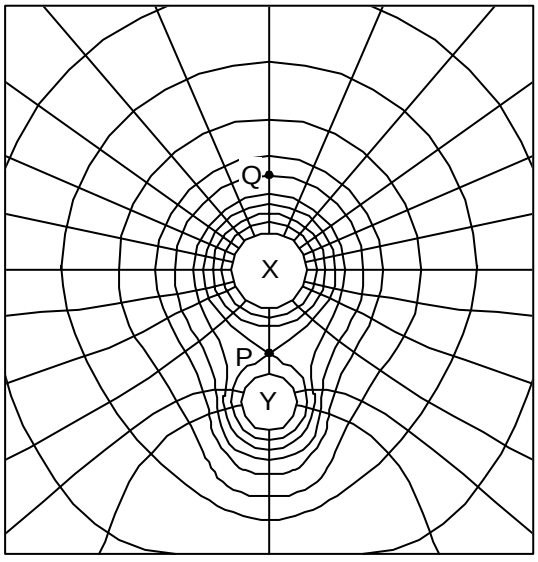
其中Φ为磁通量，对于本题中的均匀磁场，

$$\Phi = BS,$$

所以感生电势为

$$\mathrm{E}=-\frac{d\Phi}{dt}=-\frac{BdS}{st}=\pm\frac{1}{2}BR^2\omega。$$

感生电势的绝对值与时间无关，感生电势为交替的两个互为相反数的值，图形应为方波。选（A)。




11. The diagram above represents the electric field and the equipotential line for two charged conductors, X and Y. The charge on X is positive. Which of the following statements is NOT correct?

(A) The charges on X and Y are of the same sign.

(B) The charge on X is greater than that on Y.

(C) The electric field lines and the equipotential lines always intersect each other at an angle of 90 degrees.

(D) A test charge placed at point P would be in equilibrium under the action of the electrical forces.

(E) The electrical potential at point P is less than it is at point Q, which is symmetrically located on the other side of X.

解：X、Y 之间没有被电力线连接，说明二者电荷同号，（A）正确。由于 Y 周围的等势线比较密集，或者说相同的等势线距离 X 的平均距离比 Y 长，由电势的公式，

$$U=\frac{1}{4\pi\varepsilon_0}\frac{q}{r},$$

X 电量大，（B）正确。（C）显然正确。P 是两组等势面交汇的地方，该点电场强度必须和两组等势面都垂直，因此只能是零，（D）正确。对于选项（E)，Q 处在比 P 远离电荷的等势线上，但由于不知道电荷的正负，无法判断接近电荷的地方电势高还是低，所以（E）不正确。选（E)。

12. The potential difference across the terminals of a battery is 10 volts if no current is drawn from it. When a 4-ohm resistor is connected across the terminals, a current of 2 amperes is drawn from the battery. This resistor is then removed and replaced with a variable resistor that can have any value of resistance from 0 to ∞. If the internal resistance of the battery is constant, the maximum power P the battery can deliver to the variable resistor is

(A) 16 Watts

(B) 25 Watts

(C) 50 Watts

(D) 100 Watts

(E) arbitrarily large as the resistance goes to zero

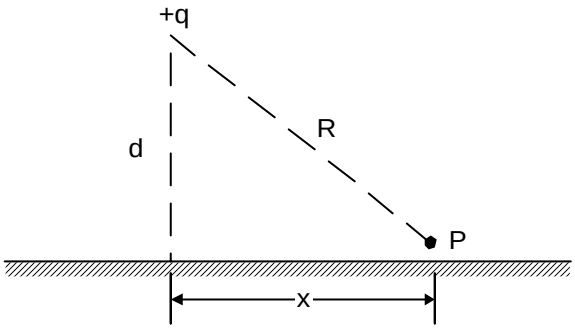
解：电池的内阻为

$$r=\frac{U}{I}-R_{外}=\frac{10}{2}-4=1\ \Omega。$$

当外接电阻与电池内阻相同即 R = r 时，电池输出功率最大，为

$$W = I^2 R_{外} = \left(\frac{U}{r+r}\right)^2 r = 25 \text{ watts}。$$

选（B）。




13. A point charge +q is located a distance d above a grounded conducting plane. The magnitude, in MKS units, of the electric field at point P just above the surface is

(A) $\frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$

(B) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{R^2}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{2qd}{R^3}$

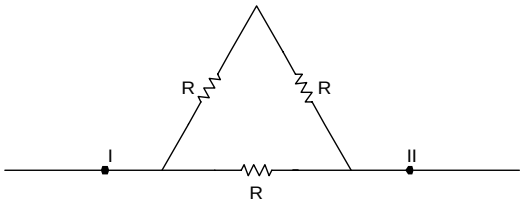
(D) $\frac{1}{4\pi\varepsilon_0}\frac{2qx}{R^3}$

(E) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{xd^2}$

解：导电平面接地，电势为零。用镜像法，在–d 处放置一像电荷–q。则

$$E_P = 2\times\frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}\frac{d}{R} = \frac{1}{4\pi\varepsilon_0}\frac{2qd}{R^3}。$$

答案选（C）。




14. If V is the potential difference between points I and II in the diagram above and all three resistors have the same resistance R, what is the total current between I and II.

(A) $\frac{V}{3R}$

(B) 3VR

(C) $\frac{2V}{3R}$

(D) $\frac{3VR}{2}$

(E) $\frac{3V}{2R}$

解：混联电路，等效电阻

$$R_E = \frac{2R\cdot R}{2R+R} = \frac{2}{3}R,$$

电流为

$$I = \frac{U}{R_E} = \frac{3V}{2R}。$$

选（E）。

Questions 15-16

An ion with charge +q travels in the +x direction relative to a right-handed coordinate system. A magnetic field of intensity B webers per square meter is applied in the +y direction.

15. For the ion to be undeflected if its velocity is v = 0.01c, there must also be an electric field E of magnitude in volts per meter and direction equal to

(A) B, in the –y direction

(B) vB, in the –y direction

(C) B, in the +z direction

(D) vB, in the +z direction

(E) vB, in the –z direction

解：由 Lorentz 力公式

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v}\times\mathbf{B}),$$

而

$$\mathbf{v}\times\mathbf{B}=vB\hat{\mathbf{z}}\text{。}$$

所以为使$\mathbf{F}=0$，电场强度$\mathbf{E}=-vB\,\hat{\mathbf{z}}$。答案选（E）。

16. For the ion to be undeflected if its velocity is v = 0.99c, the magnitude in volts per meter of the required electric field E is equal to

(A) B

(B) vB

(C) $\dfrac{B}{\sqrt{1-\dfrac{v^2}{c^2}}}$

(D) $\dfrac{vB}{\sqrt{1-\dfrac{v^2}{c^2}}}$

(E) $\dfrac{vB}{\left(1-\dfrac{v^2}{c^2}\right)}$

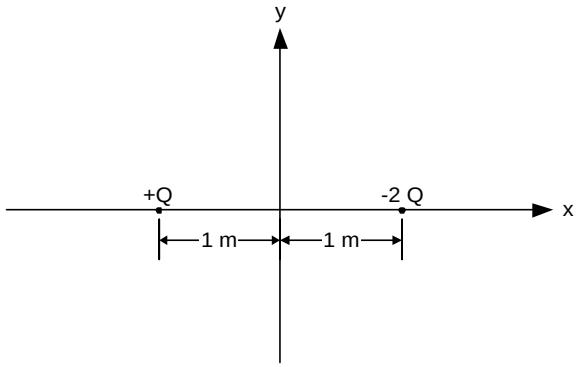
解：其实答案与上一问完全相同，因为 Lorentz 力公式总是适用的。许多人由于对相对论的惧怕而不敢选。我们换一个参照系看问题。选带电粒子的静止参考系。此时带电粒子只受电场力。设两参考系之间相对速度为 **v**，沿 x 轴正方向，由变换公式（只写出了电场的变换）

$$\overline{E}_x=E_x$$
$$\overline{E}_y=\gamma(E_y-vB_z)\text{，}$$
$$\overline{E}_z=\gamma(E_z+vB_y)$$

未加电场前，**B** =（0, B, 0）。显然如果电场为 **E** =（0, 0, –vB），则

$$\overline{E}_x=\overline{E}_y=\overline{E}_z=0\text{，}$$

带电粒子不受力。选（B）。




17. A charge of +Q coulombs is placed on the x-axis at x = –1 meter and a charge of –2Q coulombs is placed at x = +1 meter as shown above. A test charge of +q coulombs will experience zero net force if placed on the x-axis at x equals

(A) $-\left(3+\sqrt{8}\right)m$

(B) $-\dfrac{1}{3}m$

(C) 0 m

(D) $\dfrac{1}{3}m$

(E) $\left(3+\sqrt{8}\right)m$

解：首先推断一下 x 的大概范围。在两电荷之间二者电场方向相同，不可能有零点。在二者之外电场相反，由于左边电荷电量小，试验电荷应放在+Q 的左侧，x < –1。由受力平衡

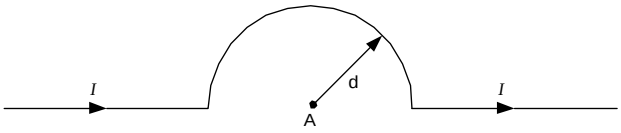
$$\frac{Q}{(x+1)^2}=\frac{2Q}{(x-1)^2}\text{，}$$

$$\left|\frac{x-1}{x+1}\right|=\sqrt{2}\text{。}$$

因为 x < –1，所以$\dfrac{x-1}{x+1}>0$，进而有

$$\frac{x-1}{x+1}=\sqrt{2}\text{，}$$
$$\text{x}=-\left(3+\sqrt{8}\right)\text{。}$$

选（A）。




18. A circular wire loop having radius d and carrying current I has at its center a magnetic field of magnitude $B_0$. If another wire carrying current I is curved to form a semicircle of radius d as shown above, the magnitude of the magnetic field at point A is

(A) $4\ B_0$
(B) $2\ B_0$
(C) $B_0$
(D) $\frac{B_0}{2}$
(E) $\frac{B_0}{4}$

解：由 Biot-Savart 定律

$$\mathbf{B} = \int \frac{Id\mathbf{l} \times \hat{\mathbf{r}}}{r^2}$$

知，直线部分 I 与 **r** 同向，对原点处的磁场贡献为零。圆环上各点贡献均等。因此后来的磁感应强度为整个圆环产生的一半。选（D）。

19. If the currents in two parallel wires are in the same direction, the force between them

(A) is zero
(B) is repulsive and in the plane containing the wires
(C) is attractive and in the plane containing the wires
(D) is perpendicular to the plane containing the wires
(E) depends on the sign of the current-carrying charges

解：由右手定则可判断一根导线在另一根导线处产生的磁感应强度的方向。由 Ampere 力公式

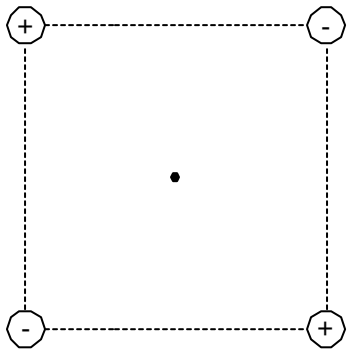
$$d\vec{F} = Id\vec{l} \times \vec{B}$$

知二者之间为吸引力，方向在纸面内。这一结论与导线中电流方向无关。选（C）。

20. The most general motion of a charged particle in a uniform magnetic field is

(A) a parabola
(B) a hyperbola
(C) a helix
(D) an ellipse
(E) a cycloid

解：垂直磁场方向做匀速圆周运动，沿磁场方向做匀速直线运动。整体为螺旋线型运动。答案选(C)。认识一下选项中的单词，(A)为抛物线，（B）为双曲线，(D)为椭圆，（E）为悬轮线。

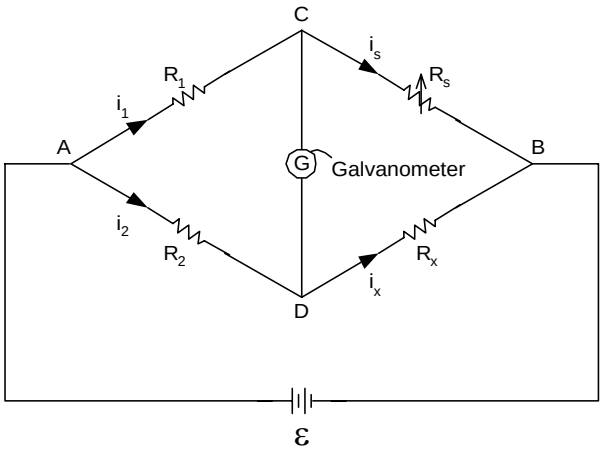



21. Four equal-magnitude point charges, two positive and two negative, are arranged at the corners of a square as shown above. Let V and E be the potential and the electric field magnitude, respectively, at the center of the square, and let $V_0$ and $E_0$ be the same quantities at the same point if the upper left positive charge only were present. Which of the following expresses the values of V and E?

(A) $V = V_0,\ E = E_0$
(B) $V = 4\ V_0,\ E = 0$
(C) $V = 0,\ E = 4\ E_0$
(D) $V = 4\ V_0,\ E = 4\ E_0$
(E) $V = 0,\ E = 0$

解：四个电荷在中心处产生的电势大小相等，两正两负，总量为 0。对角线上两同号电荷在中心处产生的电场强度大小相等方向相反，合矢量为 0。所以中心处场强为 0。选（E）。

Questions 22-23 relate to the following Wheatstone bridge circuit used for determining the unknown resistance $R_x$.




22. When the bridge is balanced by adjusting $R_s$, which of the following statements is FALSE?

(A) The current through the galvanometer is zero.

(B) $i_2 = i_x$.

(C) $i_sR_s = i_xR_x$.

(D) The potential at A is the same as that at B.

(E) The potential at C is the same as that at D.

解：Wheatstone 电桥是我国高中物理课程的知识。其关键点是电桥平衡时 C、D 两点电势相等，检流计示数为 0。从而 $i_1 = i_s$ ，$i_2 = i_x$ 。选（B）。

23. If $R_1$ = 10 Ω, $R_2$ = 2000 Ω, and $R_s$ = 50 Ω, what is $R_x$ if the bridge is balance?

(A) 0.025 Ω

(B) 0.25 Ω

(C) 4 Ω

(D) 400 Ω

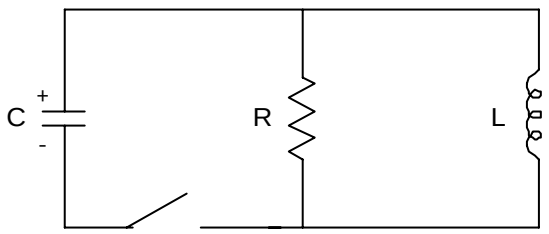
(E) 10,000 Ω

解：如图所示的 Wheatstone 电桥的平衡条件是

$$R_1 \cdot R_x = R_2 \cdot R_s ,$$

$$R_x = \frac{R_2}{R_1} R_s = \frac{2000}{10} 50 = 10000 。$$

选(E)。




24. The capacitor C in the circuit shown above is initially charged. Neglect the resistance, capacitance, and inductance of the connecting wires. Immediately after the switch S is closed, which of the following is correct?

(A) The voltage across the resistor is zero.

(B) The voltage across the inductor is zero.

(C) The current through the inductor is zero.

(D) The current through the switch is zero.

(E) The current through the inductor is a maximum.

解：电感 L 上感生电压为

$$\mathrm{E} = L\frac{dI}{dt} ,$$

阻碍电流突变。所以 S 闭合瞬间通过电感的电流为 0。由于电感 L 两端有电压，而电阻 R 与电感电压相同，所以电阻有电流通过，且为

$$I = \frac{U}{R} = \frac{L\dfrac{dI}{dt}}{R} = \frac{\dfrac{Q}{C}}{R} = \frac{QC}{R} ,$$

其中由于电容上电荷无法突变，保持为 Q，所以电压为 Q/C。选(C)。

25. A metallized balloon of radius R carries a constant charge Q. The total energy in the electrostatic field is proportional to

(A) $R^2$

(B) R

(C) $R^0$ (i.e., constant)

(D) 1/R

(E) $1/R^2$

解：电场的能量密度为 $\frac{\varepsilon_0}{2}E^2$，球壳产生的电场为

$$E = \begin{cases} 0 & \mathrm{r} < \mathrm{R} \\ \dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{r} & \mathrm{r} > \mathrm{R} \end{cases}$$

所以电场的总能量为

$$U = \frac{\varepsilon_0}{2}\iiint E^2 d\tau = \frac{\varepsilon_0}{2}\int_R^\infty \left(\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\right) 4\pi r^2 dr = \frac{Q^2}{8\pi\varepsilon_0 R}$$

。

选（D）。考试现场如果不会，可以想一下极限情况。如果 R→∞ ，因为球壳内部电场为 0，则此时

没有电场能，答案只能选（D）或（E），这样去猜答案比较容易猜对。

26. A region of space contains a uniform electric field in the +z-direction and a uniform magnetic field in the –z-direction. Which of the following statements is true?

(A) A particle could have a positive charge and initial velocity such that it would pass unaccelerated through this region.
(B) The Poynting vector of this distribution of fields is zero.
(C) This arrangement of fields can produce the Hall effect.
(D) The vector potential of the magnetic field is also parallel to the x-axis.
(E) Since the divergence and curl of both fields are zero, the fields must be antiparallel everywhere in space.

解：(A)、(C)不对，均要求电场和磁场相互垂直。答案（D）也不对，因为矢势有多种取法，例如本题情况可取（yB, 0, 0）、（ 0, –xB, 0）等等。由 Poynting 矢量的定义式 $\mathbf{S}=\mathbf{E}\times\mathbf{H}$，而本题中 **E** 与 **H** 反平行，叉乘为 0，（B）正确。（E）不对，电场可以在一个局部区域内均匀，但在一个更大的区域内不均匀，比如一个无穷大均匀带电平面两侧的电场，方向就是相反的。

27. A hollow metal sphere X of radius 10 centimeters is supported on an insulating stand A second hollow metal sphere Y of radius 2 centimeters is supported on an insulating rod. A hole is made in sphere X just large enough so that sphere Y can be introduced into the interior of X without toughing it. With the two spheres separated, X is given a positive charge of 2000 picocoulombs and Y is given a negative charge of 500 picocoulombs. Y is now introduced into the interior of X so that the two spheres do not touch. After Y is in the interior of X the two spheres are brought into contact and held there. Which of the following statements is true?

(A) There is an electric field inside sphere Y.
(B) The potential of sphere X is equal to that of sphere Y.
(C) The charge redistributes itself so that the charge on sphere X is 5 times the charge on sphere Y.
(D) All of the charge is transferred from sphere X to sphere Y.
(E) No charge is transferred between the two spheres.

解：导体 X、Y 相接触，电势相等。电荷只处在 X 壳上，而壳内无电场。所以答案选（B）。

28. Which of the following pairs of macroscopic electromagnetic field components is continuous across a boundary between two media of different dielectric constants and different magnetic permeablities?

(A) $B_\perp$ and $B_{//}$
(B) $B_\perp$ and $E_{//}$
(C) $D_\perp$ and $B_{//}$
(D) $E_\perp$ and $H_{//}$
(E) $H_\perp$ and $D_{//}$

解：再重复一遍电磁场的边界连接方程

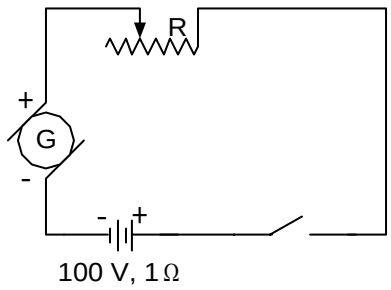
$$\mathbf{n}\cdot(\mathbf{D}_2-\mathbf{D}_1)=\Sigma$$

$$\mathbf{n}\times(\mathbf{E}_2-\mathbf{E}_1)=0$$

$$\mathbf{n}\cdot(\mathbf{B}_2-\mathbf{B}_1)=0$$

$$\mathbf{n}\times(\mathbf{H}_2-\mathbf{H}_1)=\mathbf{K}$$

其中Σ为自由面电荷密度，**K**为传导电流的面密度。由第二、三式，$B_\perp$和 $E_{//}$保持不变。选（B）。




29. The battery in the diagram above is to be charged by the generator G. The generator has a terminal voltage of 120 volts and when the charging current is 10 amperes. The battery has a emf of 100 volts and an internal resistance of 1 ohm. In order to charge the

battery at 10 amperes charging current, the resistance R should be set at

(A) 0.1 Ω

(B) 0.5 Ω

(C) 1.0 Ω

(D) 5.0 Ω

(E) 10.0 Ω

解：注意电池与发电机 G 反接，所以

$$R=\frac{120-100}{10}-1=1.0(\Omega)。$$

选（C）。

30. A charged particle is released from rest in a region where there is a constant electric field and a constant magnetic field. If the two fields are parallel to each other, the path of the particle is a

(A) circle

(B) parabola

(C) helix

(D) cycloid

(E) straight line

解：带电体由静止释放，初始受力沿电场方向，使得 $\mathbf{v}//\mathbf{E}$，从而也平行于磁场 **B**。由 Lorentz 力公式，$\mathbf{F}=q(\mathbf{v}\times\mathbf{B})$，粒子不受磁场力作用，只受电场作用，直线运动。选（E）。

31. A negative test charge is moving near a long straight wire in which there is a current. A force will act on the test charge in a direction parallel to the direction of the current if the motion of the charge is in a direction

(A) toward the wire

(B) away from the wire

(C) the same as that of the current

(D) opposite to that of the current

(E) perpendicular to both the direction of the current and the direction toward the wire

解：磁场方向环绕电流，服从右手定则。由 Lorentz 公式，$\mathbf{F}=q(\mathbf{v}\times\mathbf{B})$。本题关键是注意到电量为负，$\mathbf{F}=-|q|(\mathbf{v}\times\mathbf{B})$。选（A）。

32. A cube has a constant electric potential V on its surface. If there are no charges inside the cube, the potential at the center of the cube is

(A) zero

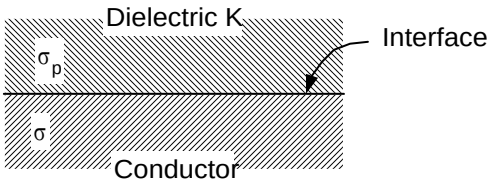
(B) V/8

(C) V/6

(D) V/2

(E) V

解：立方体内无电荷，没有电力线，电势相等。选(E)。




33. A dielectric of dielectric constant K is placed in contact with a conductor having surface charge density σ, as shown above. What is the polarization (bound) charge density $\sigma_p$ on the surface of the dielectric at the interface between the two materials?

(A) $\sigma\dfrac{K}{1-K}$

(B) $\sigma\dfrac{K}{1+K}$

(C) $\sigma K$

(D) $\sigma\dfrac{1+K}{K}$

(E) $\sigma\dfrac{1-K}{K}$

解：由边界条件

$$\mathbf{n}\cdot(\mathbf{D}_2-\mathbf{D}_1)=\sigma,$$

由于导体内部电场为零，

$$\mathbf{D}_1=0,$$

所以介质内部

$$D_{2n}=\sigma。$$

而

$$\mathbf{D}_2=\varepsilon_0\mathbf{E}_2+\mathbf{P}=K\varepsilon_0\mathbf{E}_2$$

$$P_{2n}=\mathbf{n}\cdot\mathbf{P}_{2n}=\mathbf{n}\cdot(\mathbf{D}_2-\varepsilon_0\mathbf{E}_2)=\sigma-\frac{\sigma}{K}=\frac{K-1}{K}\sigma$$

，

所以束缚电荷密度

$$\sigma_P = -P_{2n} = \frac{1-K}{K}\sigma \text{。}$$

选（E)。

34. A point charge –q coulombs is placed at a distance d from a large grounded conducting plane. The surface charge density on the plane a distance D from the point charge is

(A) $\frac{q}{4\pi D}$

(B) $\frac{qD^2}{2\pi}$

(C) $\frac{qd}{2\pi D^3}$

(D) $\frac{qd}{2\pi D^4}$

(E) $\frac{qd}{4\pi\varepsilon_0 D^2}$

解：因为导体板电势为 0，用镜像法。在–d 放置一镜电荷+q，易得在 D 处

$$E = 2\times\frac{q}{4\pi\varepsilon_0 D^2}\times\frac{d}{D} = \frac{qd}{2\pi\varepsilon_0 D^3} \text{。}$$

由边界条件

$$\vec{n}\cdot(E_2 - E_1) = \frac{\sigma}{\varepsilon_0} \text{，}$$

并考虑到导体内部电场为 0，有

$$\sigma = \frac{qd}{2\pi D^3} \text{。}$$

选（C)。

35. A current i in a circular loop of radius b produces a magnetic field. At a fixed point far from the loop, the strength of the magnetic field is proportional to which of the following combinations of i and b?

(A) ib

(B) $ib^2$

(C) $i^2b$

(D) $\frac{i}{b}$

(E) $\frac{i}{b^2}$

解：取一特殊点，计算环轴线上距中心距离为 L 处的磁感应强度 **B**：

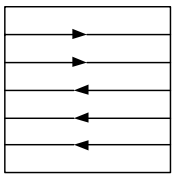
$$\mathbf{B} = \frac{\mu_0}{4\pi}\oint\frac{Id\mathbf{l}\times\hat{\mathbf{r}}}{r^2} = \frac{\mu_0}{4\pi}\frac{i2\pi b}{L^2+b^2}\frac{b}{\sqrt{L^2+b^2}}$$

$$= \frac{\mu_0 i}{2}\frac{b^2}{\left(L^2+b^2\right)^{\frac{3}{2}}}$$

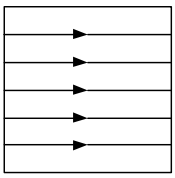
当 L>>b 时，$B \propto ib^2$。选（B)。

36. One of Maxwell's equations is $\nabla\cdot\mathbf{B} = 0$. Which of the following sketches shows magnetic field lines that clearly violate this equation within the region bounded by the dashed lines?

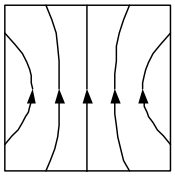
(A)



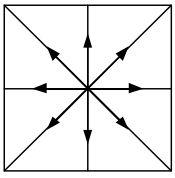
(B)



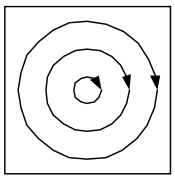
(C)



(D)



(E)



解：(A)、(B)、(C)、(E) 为常见的磁力线。(D) 给人的第一印象是点电荷的电力线，由

$$\nabla\cdot\mathbf{E} = \frac{\rho}{\varepsilon_0} \text{，}$$

散度不为零，所以它代表磁力线时将导致 $\nabla\cdot\mathbf{B} \neq 0$。选（D)。

37. Which of the following electric fields could exist in a finite region of space that contains no charges?

(In these expressions, A is a constant, and **i**, **j**, and **k** are unit vectors pointing in the x, y, and z directions, respectively.)

(A) A(2xy**i**–xz**k**)

(B) A(–xy**j**+xz**k**)

(C) A(xz**i**+xz**j**)

(D) Axyz(**i**+**j**)

(E) Axyz**i**

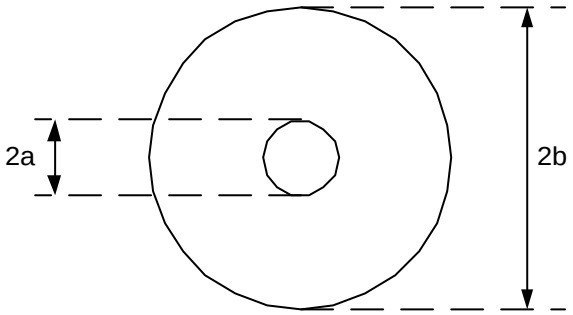
解：由 Maxwell 方程组，

$$\nabla \cdot \vec{E} = \rho / \varepsilon_0 ,$$

本题中只有选项（B）

$$\nabla \cdot \left( - xy\vec{j} + xz\vec{k} \right) = -x + x = 0 ,$$

空间处处无电荷。选（B）。




38. A small circular wire loop of radius a is located at the center of a much larger circular wire loop of radius b sa shown above. The larger loop carries an alternating current $I=I_0\cos\omega t$, where $I_0$ and ω are constants. The magnetic field degenerated by the current in the large loop induces in the small loop an emf that is approximately equal to which of the following? (Either use mks units and let $\mu_0$ be the permeability of free space, or use Gaussian units and let $\mu_0$ be $4\pi/c^2$.)

(A) $\left( \frac{\pi\mu_0 I_0}{2} \right) \frac{a^2}{b} \omega \cos \omega t$

(B) $\left( \frac{\pi\mu_0 I_0}{2} \right) \frac{a^2}{b} \omega \sin \omega t$

(C) $\left( \frac{\pi\mu_0 I_0}{2} \right) \frac{a}{b^2} \omega \sin \omega t$

(D) $\left( \frac{\pi\mu_0 I_0}{2} \right) \frac{a}{b^2} \omega \cos \omega t$

(E) $\left( \frac{\pi\mu_0 I_0}{2} \right) \frac{a}{b} \omega \sin \omega t$

解：由 Biot-Savart 定律

$$\vec{B} = \frac{\mu_0}{4\pi} \oint \frac{Id\bar{l} \times \hat{\hat{r}}}{r^2} ,$$

外环上各点在中心产生的磁感应方向相同，均垂直于圆环平面，易得

$$B = \frac{\mu_0}{4\pi} \frac{2\pi b}{b^2} I = \frac{\mu_0}{2} \frac{I}{b} 。$$

因为 a << b，故内环磁感应强度近似为 B，磁通量为

$$\Phi = \pi a^2 B = \frac{\pi\mu_0}{2} \frac{a^2}{b} I = \frac{\pi\mu_0}{2} \frac{a^2}{b} I_0 \cos \omega t ,$$

所以感生电场

$$\mathrm{E} = \left| \frac{d\Phi}{dt} \right| = \left( \frac{\pi\mu_0 I_0}{2} \right) \frac{a^2}{b} \omega \sin \omega t 。$$

选（B）。

39. The exponent in Coulomb's inverse square law has been found to differ from two by less than one part in a billion by measuring which of the following?

(A) The charge on an oil drop in the Millikan experiment

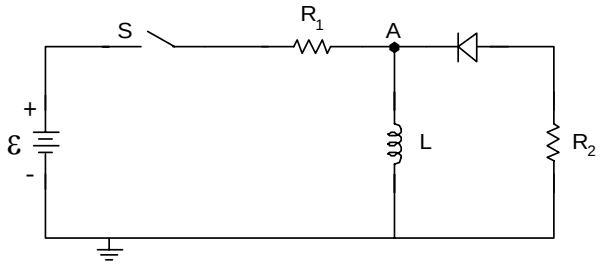
(B) the deflection of an electron beam in an electric field

(C) The neutrality of charge of an atom

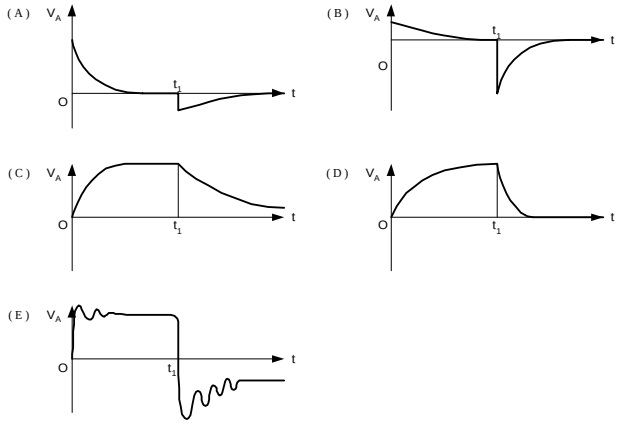
(D) The electric force between two charged objects

(E) The electric field inside a charged conducting shell

解：如果 Coulomb 平方反比定律严格成立，则可以用 Gauss 定理证明在均匀带电球壳内部电场处处为零。选（E）。




40. In the circuit shown above, $R_2=3R_1$ and the battery of emf E has negligible internal resistance. The resistance of the diode when it allows current to pass through it is also negligible internal resistance. At time t=0, the switch S is closed and the currents and voltages are allowed to reach their asymptotic values. Then at time $t_1$, the switch is opened. Which of the following curves most nearly represents the potential at point A as a function of time t?



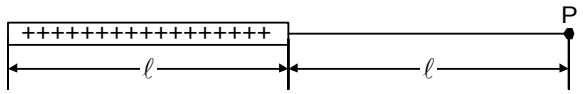

解：技巧如下：在 $t_1$ 前瞬间，系统处于稳定状态，电感不起作用（$\frac{dI}{dt}=0$），所以 A 点电压为 0，答案只能为（A）或（B）；断开 S 前瞬间，

$$I=\frac{\varepsilon}{R_1}。$$

故断开 S 后瞬间 A 点电压为

$$U_A=-IR_2=-3\varepsilon。$$

选（B）。




41. The long thin cylindrical glass rod shown above has length l and is insulated from its surroundings. The rod has an excess charge Q uniformly distributed along its length. Assume the electric potential to be zero at infinite distances from the electric potential at a point P along the axis of the rod and a distance l from one end is $\frac{kQ}{l}$ multiplied by

(A) $\frac{4}{9}$

(B) $\frac{1}{2}$

(C) $\frac{2}{3}$

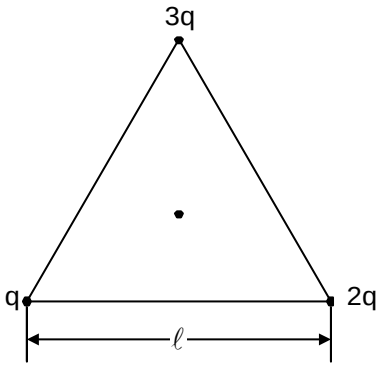
(D) ln 2

(E) 1

解：电势沿杆积分得

$$U=\int_0^l K\frac{\frac{Q}{l}dx}{l+x}=K\frac{Q}{l}\ln 2。$$

选（D）。




42. Positive charge of magnitude q, 2q, and 3p are located at the corners of an equilateral triangle as shown above. The sides of the triangle have a length l. What is the minimum amount of work requires to bring a positive charge Q from infinity to the center of the triangle?

(A) $\frac{2\sqrt{3}qQ}{l}$

(B) $\frac{4\sqrt{3}qQ}{l}$

(C) $\frac{6\sqrt{3}qQ}{l}$

(D) $\dfrac{8\sqrt{3}qQ}{l}$

(E) $\dfrac{12\sqrt{3}qQ}{l}$

解：无穷远处电势为零，则

$$U=\frac{q+2q+3q}{r}=\frac{6q}{\sqrt{3}l/3}=\frac{6\sqrt{3}q}{l},$$

所以需要

$$W=QU=\frac{6\sqrt{3}Qq}{l}。$$

选（C）。

43. If an electric field is given in a certain region by $E_x = 0$, $E_y = 0$, $E_z = kz$, where k is a nonzero constant, which of the following is true?

(A) There is a time-varying magnetic field
(B) There is charge density in the region
(C) The electric field cannot be constant in time
(D) The electric field is impossible under any circumstances
(E) None of the above

解：由 Maxwell 方程组

$$\nabla\cdot\mathbf{E}=\rho/\varepsilon_0$$

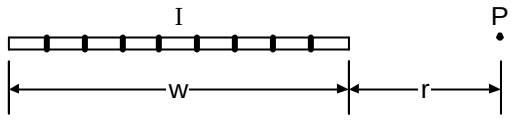
所以电荷密度为

$$\rho=\varepsilon_0\nabla\cdot\mathbf{E}=\varepsilon_0\left(\frac{\partial E_x}{\partial x}+\frac{\partial E_y}{\partial y}+\frac{\partial E_z}{\partial z}\right)=\varepsilon_0 k,$$

选（B）。由于

$$\nabla\times\mathbf{E}=-\frac{\partial\mathbf{B}}{\partial t},$$

而本题中$\nabla\times\mathbf{E}=0$，所以并不一定存在变化的磁场，（A）不对。




44. The diagram above represent the cross section, a very long thin strip of conductor of width.The strip carries a total current I uniformly distributed and directed into the plane of the page. What is the magnitude of the magnetic field due to I at point P in the plane of the strip a distance r from the closer edge?

(A) $\dfrac{\mu_0 I}{2\pi r}$

(B) $\dfrac{\mu_0 I}{2\pi(r+w)}$

(C) $\dfrac{\mu_0 I}{2\pi(r+w/2)}$

(D) $\dfrac{\mu_0 I}{2\pi w}\ln\left(\dfrac{r+w}{r}\right)$

(E) $\dfrac{\mu_0 I}{2\pi r}\ln\left(\dfrac{r-w}{r}\right)$

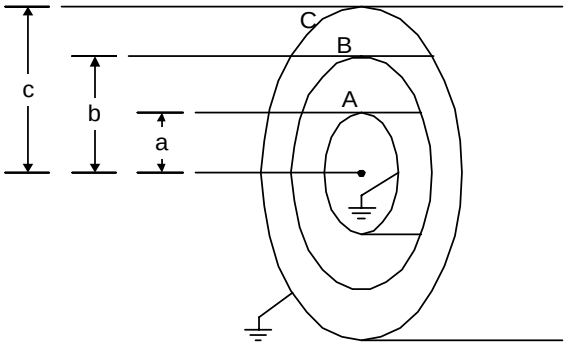
解：由 Ampere 环路定理易得，载流为 I 的无穷长导线在距离 r 处产生的磁感应强度为

$$B=\frac{\mu_0 I}{2\pi r},$$

所以对于本题

$$B=\int_0^w\frac{\mu_0}{2\pi(r+x)}\frac{I}{w}dx=\frac{\mu_0 I}{2\pi w}\ln(r+x)\Big|_0^w$$
$$=\frac{\mu_0 I}{2\pi w}\ln\left(\frac{r+w}{r}\right)。$$

选（E）。




45. Three long concentric conducting cylinders A, B, and C have radii a, b, and c, respectively, as shown above. The thickness of each cylinder is much

smaller than a. The innermost and outermost cylinders are grounded. A charge Q is placed on cylinder B. If end effects are negligible, the ratio of the charge on the inner surface of B to the charge on the outer surface of B, $Q_{inner}/Q_{outer}$, is

(A) 0

(B) 1

(C) $\dfrac{\ln(b/a)}{\ln(c/b)}$

(D) $\dfrac{\ln(c/b)}{\ln(b/a)}$

(E) $\dfrac{\ln(c/a)}{\ln(b/c)}$

解：圆柱体 A 和 B、C 和 B 分别组成同轴柱形电容。因为 A、C 电势相等同为 0，所以系统可看为这两个电容的并联。由电容并联的性质，

$$\frac{Q_A}{Q_C}=\frac{C_{AB}}{C_{CB}}。$$

为计算同轴柱形电容的值，设长度为 L，每个电极电荷的线密度的绝对值为 λ，则由 Gauss 定理，电极间的电场强度为

$$E=\frac{\lambda}{2\pi\varepsilon_0 r},$$

所以电势差为

$$U_{AB}=\int_A^B \mathbf{E}\cdot\mathbf{dl}=\int_{R_A}^{R_B}\frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}dr=\frac{\lambda}{2\pi\varepsilon_0}\ln\frac{R_B}{R_A}。$$

而电极上总电量为 q = λ L，所以

$$C=\frac{q}{U_{AB}}=\frac{2\pi\varepsilon_0 L}{\ln\dfrac{R_B}{R_A}}。$$

$$\frac{Q_A}{Q_C}=\frac{C_{AB}}{C_{CB}}=\frac{\ln\dfrac{R_C}{R_B}}{\ln\dfrac{R_B}{R_A}}=\frac{\ln(c/b)}{\ln(b/a)}。$$

选（D）。

46. Two infinite conducting planes are located at x = 0 and y = 0, respectively. These planes intersect each other at right angles along the z-axis. The planes are grounded. A point charge q is located at x = c, y = c. What is the magnitude of the force on the charge?

(A) $\dfrac{3}{8}\dfrac{q^2}{a^2}$

(B) $(\dfrac{1}{4}+\dfrac{\sqrt{2}}{8})\dfrac{q^2}{a^2}$

(C) $(\dfrac{1}{4}-\dfrac{\sqrt{2}}{8})\dfrac{q^2}{a^2}$

(D) $(\dfrac{\sqrt{2}}{4}+\dfrac{1}{8})\dfrac{q^2}{a^2}$

(E) $(\dfrac{\sqrt{2}}{4}-\dfrac{1}{8})\dfrac{q^2}{a^2}$

解：用镜像法。因为两导体板接地电势为 0，所以要放置三个像电荷，分别是在（–a，a）、（a，–a）放置 电量为–q 的 电荷，在（–a，–a）放置电量为 q 的电荷。则电荷受到导体板的作用力可等效为这三个像电荷对它的作用力，

$$\begin{aligned}\mathbf{F}&=\mathbf{F_1}+\mathbf{F_2}+\mathbf{F_3}\\&=\frac{q^2}{a^2}\left(-\frac{1}{4}\mathbf{i}-\frac{1}{4}\mathbf{j}+\frac{\sqrt{2}}{16}\mathbf{i}+\frac{\sqrt{2}}{16}\mathbf{j}\right)。\\&=-\frac{q^2}{4a^2}\left(1-\frac{\sqrt{2}}{4}\right)(\mathbf{i}+\mathbf{j})\end{aligned}$$

力的大小为

$$F=\frac{q^2}{4a^2}\left(1-\frac{\sqrt{2}}{4}\right)\sqrt{2}=\left(\frac{\sqrt{2}}{4}-\frac{1}{8}\right)\frac{q^2}{a^2}。$$

选（E）。

47. An ideal transformer has a primary coil of $N_p$ turns and a secondary coil of $N_s$ turns. An altering voltage $V_p$ is applied to the primary coil of the transformer. Which of the following statements is NOT correct?

(A) In the primary coil of the transformer, the

voltage lags the current.

(B) The coefficient of mutual inductance between the primary and secondary coils is proportional to the product $N_pN_s$ .

(C) When the secondary coil is open, the power factor of the transformer is zero.

(D) When the secondary coil is open, the secondary voltage is $V_s = V_p(\frac{N_p}{N_s})$ .

(E) If a resistance R is placed across the secondary coil, the reflected impedance at the terminals of the primary coil will be $Z_p = R(\frac{N_p}{N_s})^2$.

解：由于原线圈具有自感系数，而没有电容，所以总阻抗是电感性的。所以电压的相位超前于电流。选项（A）不对。（B）、（C）、（D）为明显的结论。对于（E），因为

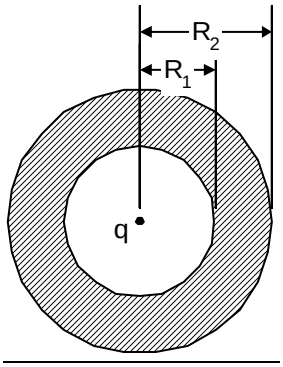
$$\frac{U_P}{U_S} = \frac{N_P}{N_S}\ ,\ \frac{I_P}{I_S} = \frac{N_S}{N_P}\ ,$$

所以

$$Z_p = \frac{U_P}{I_P} = \left(\frac{N_P}{N_s}\right)^2 \frac{U_S}{I_S} = R\left(\frac{N_P}{N_s}\right)^2 。$$

选（A）。

Questions 48-49




A conducting sphere of radius $R_2$ has a concentric spherical cavity of radius $R_1$, as shown above. The sphere has no net charge. However, there is a charge q in the center of the cavity.

48. What is the surface charge density on the inner surface of the sphere?

(A) $-\frac{q}{4\pi R_1^{\ 2}}$

(B) $-\frac{q}{8\pi R_1^{\ 2}}$

(C) $-\frac{q}{4\pi R_2^{\ 2}}$

(D) $-\frac{q}{8\pi R_2^{\ 2}}$

(E) $-\frac{R_2^{\ 2}q}{4\pi R_1^{\ 2}}$

解：导体球内壁上总的感应电荷为–q，由于导体球净电荷为零，相应的球外壳上分布又总的电荷为+q。由球对称性的分析可以得知，球壁上的感应电荷都是均匀分布的。因此球内的面电荷密度为

$$\sigma = \frac{1}{4\pi R_1^{\ 2}}。$$

选（A）。

49. What is the potential of the sphere? (Assume that the potential is zero at an infinite distance away)

(A) $\frac{q}{R_1}$

(B) $\frac{q}{R_2}$

(C) $\frac{qR_2}{R_1^2}$

(D) $\frac{qR_1}{R_2^2}$

(E) $\frac{qR_2}{R_1}$

解：球外电场分布等价于球心处点电荷产生的电场分布，导体球的电势等于点电荷在距自身 $R_2$ 远

处产生的电势。选（B）。
注意此题由答案的四个选项来看，显然命题者采用的是 Gauss 单位制，不必细究。

50. In which of the following circumstances must the displacement current be zero?
(A) If the magnetic field is zero
(B) If the electric field is constant in time
(C) When there is an open circuit
(D) In a metal
(E) In an insulator

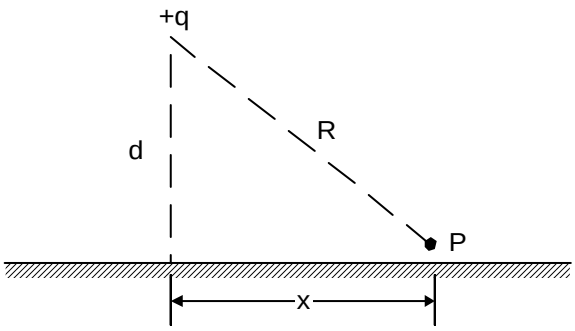
解：根据位移电流的定义式

$$J_D = \frac{\partial D}{\partial t},$$

显然当静场时

$$\frac{\partial D}{\partial t} = 0 \text{ 或 } \frac{\partial E}{\partial t} = 0,$$

位移电流为零。选（B）。




51. A point charge +q is located a distance d above a grounded conducting plane. The magnitude , in MKS units, of the electric field at point P just above the surface is

(A) $\frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$

(B) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{R^2}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{2qd}{R^3}$

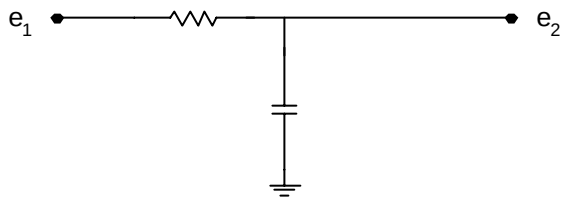
(D) $\frac{1}{4\pi\varepsilon_0}\frac{2qx}{R^3}$

(E) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{xd^2}$

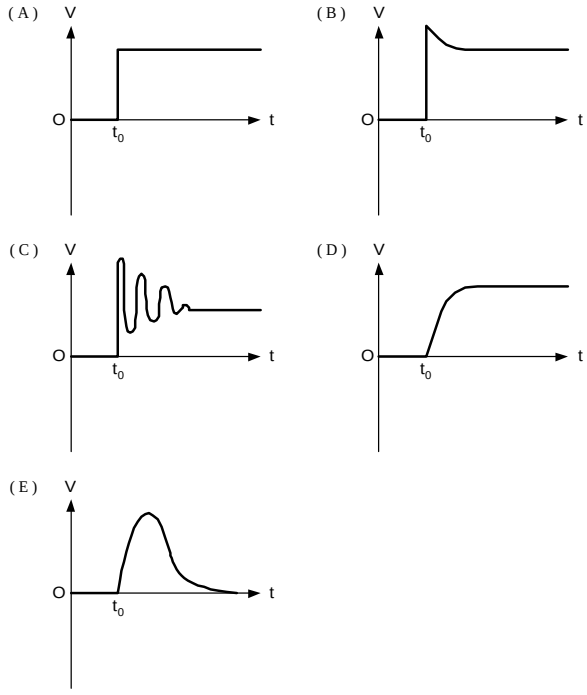
解：显然是用电像法。q 的感应电荷的电像带电荷 −q，位置与 q 相对于接地平面成镜像对称。再根据对称性分析，P 点的电场强度水平分量为零，只有垂直向下的分量。

$$E_P = 2 \cdot \frac{q}{4\pi\varepsilon_0 R^2} \cdot \frac{d}{R},$$

选（C）。
关于电像法：无穷大平面附近点电荷的电像法一定要熟练掌握，带点球壳的共轭电像法只需了解。




52. In the circuit illustrated above, the point marked $c_1$ is raised instantaneously at time $t_0$ from zero to a fixed positive potential. If $c_2$ is connected to a high-impedance D.C. oscilloscope input, the graph of its voltage V as a function of time t will most resemble which of the following?




解：这是电容的直流放电暂态线路，电路的时间常数为 RC，电容两端的电压随时间指数增长，定

性就可判断应选（D)。
严格求解电路微分方程的结果是

$$V = V_0\left(1 - e^{-\frac{t-t_0}{RC}}\right),$$

其中 t > $t_0$。

53. A parallel-plate capacitor has a charge of $10^{-5}$ coulomb. The potential difference across the capacitor is $10^4$ volts when the plates have a vacuum between them. If a second capacitor has the identical dimensions and the same charge as the first one but has a dielectric of K = 5 between the plates, the potential difference across this second capacitor would be most nearly

(A) 0V
(B) 2000V
(C) 10,000V
(D) 20,000V
(E) 50,000V

解：平行板电容器的电容

$$C = \frac{\varepsilon_r \varepsilon_0 S}{d},$$

而$U = \frac{Q}{C}$。对电介质 K = 5 的第二个电容器，其电容为第一个的 5 倍。带同样多电荷的情况下，相应两极板间的电势差是第一个电容器的 1/5。选（B)。

54. A spherical cloud of charge of radius R has a uniform charge density ρ. At a distance r from the center of the charge distribution, with r < R, the magnitude of the electric field is

(A) $\frac{\rho r^3}{3\varepsilon_0 R^2}$

(B) $\frac{\rho r^2}{3\varepsilon_0 R}$

(C) $\frac{\rho r}{3\varepsilon_0}$

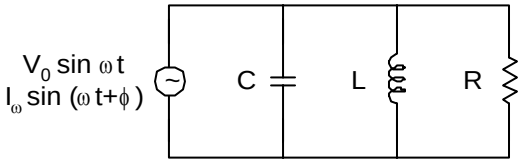
(D) $\frac{\rho R^2}{3\varepsilon_0 r}$

(E) $\frac{\rho R^3}{3\varepsilon_0 r^2}$

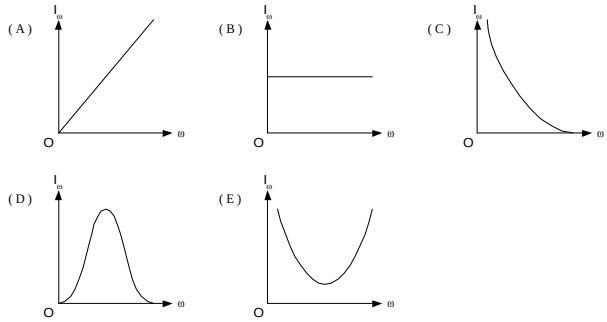
解：在球的内部，只有半径 r 以内的电荷对 r 远处的电场有贡献，其余均匀电荷的分布总贡献为零。因此

$$E = \frac{\rho \frac{4}{3}\pi r^3}{4\pi\varepsilon_0 R^2} = \frac{\rho r^3}{3\varepsilon_0 R^2}。$$

选（A)。




55. In the circuit shown above, the maximum generator voltage $V_0$ is fixed. Which of the following graphs best represents the amplitude I of the current in the generator as a function of the frequency ω?



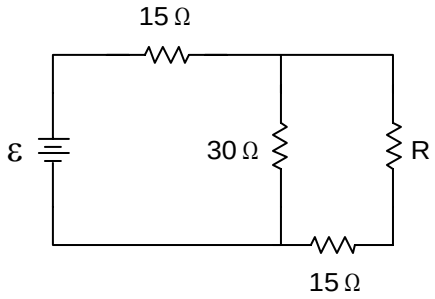

解：RCL 并联谐振电路。简单定性分析一下很快就能得到答案：ω→0 时，电感相当于短路，因此 I→∞；类似当ω→∞时，电容相当于短路，因此 I→∞；当中某个频率ω的时候曲线必然存在拐点。因此选（E)。
定量的计算结果，等效阻抗

$$\frac{1}{z} = \frac{1}{R} + \frac{1}{j\omega L} + j\omega C,$$

电流

$$I = \frac{V}{Z} = \frac{Z}{R} + iZ\left(\omega C - \frac{1}{\omega L}\right),$$

当 $\omega=\dfrac{1}{\sqrt{LC}}$ 时回路中的总电流最小。




56. A battery with emf ε and negligible internal resistance is connected in the circuit shown above. The value of the resistance R required to maximize the power dissipated in R is

(A) 10 Ω
(B) 15 Ω
(C) 25 Ω
(D) 30 Ω
(E) 45 Ω

解：此题的最佳解法应当是利用等效电压源定理，将电路中除 R 以外的部分看成一个等效电压源，其内阻为

$$15+15//30=25\Omega。$$

然后根据外接电阻与电源内阻相等时，输出功率最大，选（C）。

一般的解法，是求函数

$$P_R=\left(\varepsilon\frac{30//(15+R)}{15+30//(15+R)}\frac{R}{15+R}\right)^2/R$$

的极大值，较繁。

57. A certain electric field is given in spherical coordinate by

$$\vec{E}(t)=Ar^{-\frac{3}{2}}\vec{r}$$

where A is a constant and $\vec{r}$ is a unit vector radically outward. The charge density ρ(r) is proportional to

(A) $r^{\frac{1}{2}}$

(B) $r^{-\frac{1}{2}}$

(C) $r^{-\frac{3}{2}}$

(D) $r^{-\frac{5}{2}}$

(E) $r^{-\frac{7}{2}}$

解：直接由 Maxwell 方程的微分形式求解电荷密度

$$\rho=\nabla\cdot\vec{D}=\varepsilon\nabla\cdot\vec{E}\propto\nabla\cdot\frac{\vec{r}}{r^{3/2}}=\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\cdot r^{-3/2}\right)\propto r^{-5/2}$$

。

选（C）。

58. A circular ring of radius 10 centimeters is made out of a wire of radius 1 millimeter. The ring carries a steady current. The magnetic field due to that current is measured at the center of the ring, where its magnitude is found to be $B_c$, and at the surface of the wore, where its magnitude is found to be $B_s$. The ratio $B_s/B_c$ is most nearly

(A) 300
(B) 30
(C) 3
(D) 1/3
(E) 1/30

解：电流线圈中心的磁场方向垂直于线圈平面，

$$B_c=\frac{\mu_0 I}{2R}。$$

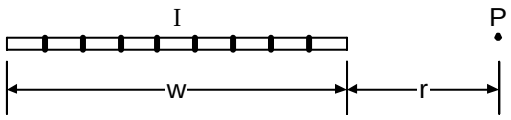
电缆线圈表面的磁场沿切向，可由 Ampere 环路定理求出

$$B_S=\frac{\mu_0 I}{2\pi r}。$$

所以

$$\frac{B_S}{B_C}=\frac{2R}{2\pi r}=\frac{100}{\pi}\approx 30。$$

选（B）。



59. The diagram above represents the cross section of a very long, thin strip of conductor of width w. The strip carries a total current I uniformly distributed and directed into the plane of the page. What is the magnitude of magnetic field due to I at point P in the plane of the strip a distance r from the closer edge?

(A) $\frac{\mu_0 I}{2\pi r}$

(B) $\frac{\mu_0 I}{2\pi(r-w)}$

(C) $\frac{\mu_0 I}{2\pi(r+w/2)}$

(D) $\frac{\mu_0 I}{2\pi w}\ln\left(\frac{r+w}{r}\right)$

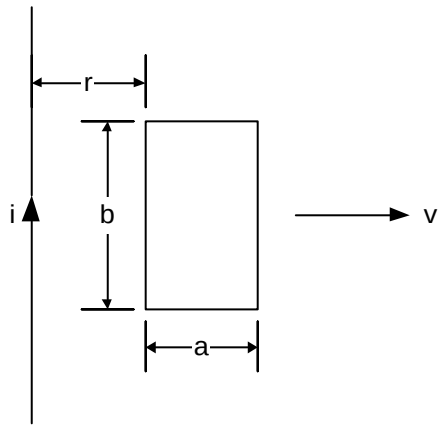
(E) $\frac{\mu_0 I}{2\pi r}\ln\left(\frac{r-w}{r}\right)$

解：只能利用微元法积分求解。以到替代的最左端为原点建立向右的 x 轴。

$$B=\frac{\mu_0}{2\pi}\int_0^w \frac{I}{w(w+r-x)}dx=-\frac{\mu_0 I}{2\pi w}\ln(w+r-x)\Big|_0^w$$

。

实际计算中只需判断是 r 的指数关系即可，(E)为负值显然不对。选（D)。




60. A rectangular loop of wire resistance R has the dimensions shown above. A long wire with current i is located in the plane of the loop a distance r from one side of the loop as shown. If the loop is pulled radically away from the wire at constant speed v , the current in the loop is

(A) $\frac{\mu_0 ivab}{2\pi R}\cdot\frac{1}{r}$

(B) $\frac{\mu_0 ivab}{2\pi R}\cdot\frac{1}{r^2}$

(C) $\frac{\mu_0 ivab}{2\pi R}\cdot\frac{1}{(r+a)}$

(D) $\frac{\mu_0 ivab}{2\pi R}\cdot\frac{1}{r(r+a)}$

(E) $\frac{\mu_0 ivab}{2\pi R}\cdot\frac{1}{r^2(r+a)}$

解：矩形线圈的两条短边运动没有切割磁力线，不产生感生电动势。两条长边产生的感生电动势方向相反，总和为

$$\varepsilon=vb(B_1-B_2)=\frac{\mu_0 i}{2\pi}vb\left(\frac{1}{r}-\frac{1}{r+a}\right)。$$

选（D)。

61. The plane of a square wire loop 0.2 meter on a side is perpendicular to a 0.008 tesla magnetic field. If the magnetic field reduced to zero in 0.04 second, the average voltage induced in the loop during the time interval is

(A) 0.008 V
(B) 0.04 V
(C) 0.2 V
(D) 3.2 V
(E) 32 V

解：根据 Faraday 的电磁感应定律，感生电动势的大小

$$\bar{\varepsilon}=\frac{\Delta\Phi}{\Delta t}=\frac{S\Delta B}{\Delta t}=\frac{0.2^2\times 0.008}{0.04}\approx 0.008\text{V}。$$

选（A)。

62. A parallel-plate capacitor containing a removable

dielectric is fully charged . If the dielectric is removed with the charging battery disconnected, how do the total charge and energy stored by the capacitor change?

| | Charge | Energy |
|---|---|---|
| (A) | Decreases | Decreases |
| (B) | Decreases | Increases |
| (C) | Stays the same | Decreases |
| (D) | Stays the same | Increases |
| (E) | Increases | Decreases |

解：由于电路是断开的，因此电容器上储存的电量保持不变。除去极板间电介质后，电容器的电容变为原来的 $1/\varepsilon_r$，而总能量

$$E=\frac{Q^2}{2C}$$

变大。选（D）。

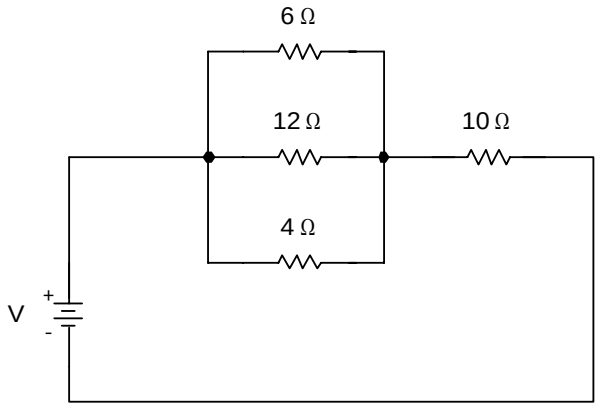
63. An electron moves at constant speed in auniform magnetic field. If the initial velocity of the electron is parallel to the magnetic field, the electron describes a path that is a

(A) straight line
(B) helix
(C) circle
(D) parabola
(E) hyperbola

解：电子的初速度平行于磁场，因此所受的 Lorentz 力

$$\mathbf{F}=-e\mathbf{v}\times\mathbf{B}=0\text{。}$$

因此电子不受力，做匀速直线运动。选（A）。




64. The current in the 6-ohm resistpr in the circuit shown above is 0.5 ampere. The voltage V applied to the circuit is most nearly

(A) 6 V
(B) 8 V
(C) 16 V
(D) 18V
(E) 23 V

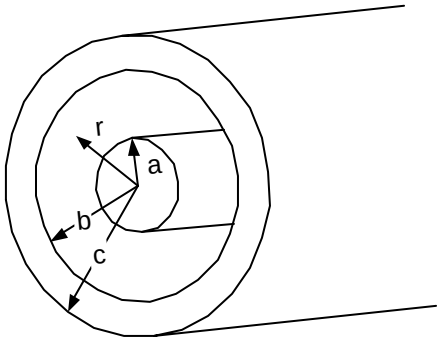
解：6Ω电阻上的电压降为 3V，因此，回路中的总电流

$$I=0.5+\frac{3}{12}+\frac{3}{4}=1.5\text{A}\text{，}$$

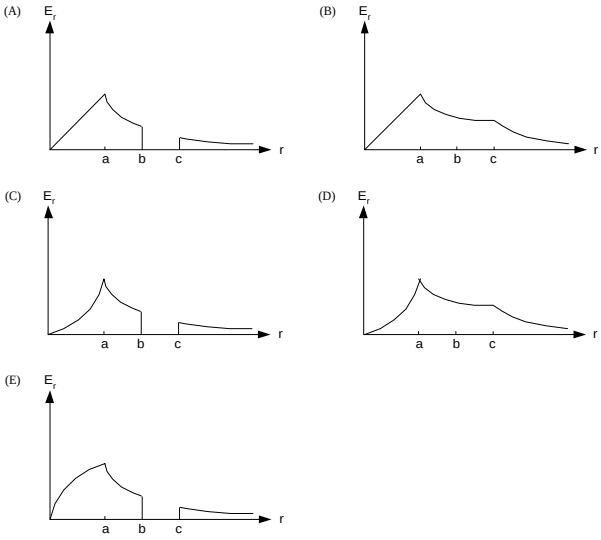
电源总电压

$$V=3+1.5\times10=18\text{V}\text{。}$$

选（D）。




65. The cylinder shown above has radius a and uniform volume density ρ. It is surrounded by a concentric cylinderical shell, which is a conductor with inner and outer radii b and c, respectively. Which of the following graphs displays the radial electric field $E_r$ as a function of r, the distance from the axis?



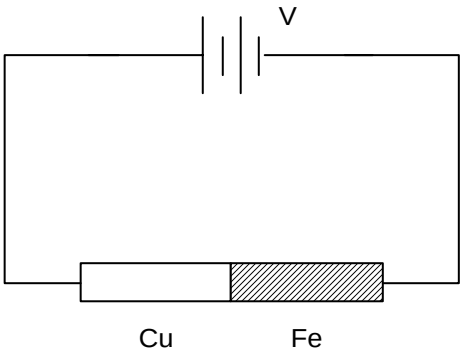

解：b < r < c 是在导体内部，因此 $E_r = 0$。在 r < a

的区域内，由对称性电场强度沿径向，其大小可由 Gauss 定理求出

$$E=\frac{\rho r}{2\varepsilon_0}\propto r\text{。}$$

选（A）。

Questions 66-67




Two rods are joined end-to-end, as shown above. Both have a cross-sectional area of 0.01 $cm^2$. Each is I meter long. One rod is copper with a resistivity of $1.7\times10^{-6}$ ohm·centimeter; the other is iron with a resistivity of $10^{-5}$ ohm·centimeter.

66. What voltage is required to produce a current of 1 ampere in the rods?

(A) 0.117 V
(B) 0.0145 V
(C) 0.0117 V
(D) 0.00145 V
(E) $1.7\times10^{-6}$ V

解：两段金属棒串联的总电阻

$$R=\rho_{Cu}\frac{l}{s}+\rho_{Fe}\frac{l}{s}=\left(1.7\times10^{-6}+10^{-5}\right)\times\frac{100}{0.01}=0.117\Omega$$

，

由 Ohm 定理可求出电流 I = U/R。选（A）。

67. What is the surface charge density that builds up at the copper-iron interface when there is a current of 1 ampere in the rods?

(A) Zero
(B) $1.7\times10^{-8}$ coulomo/$m^2$
(C) $10^{-10}$ coulomo/$m^2$
(D) $7.0\times10^{-13}$ coulomo/$m^2$
(E) $2.7\times10^{-13}$ coulomo/$m^2$

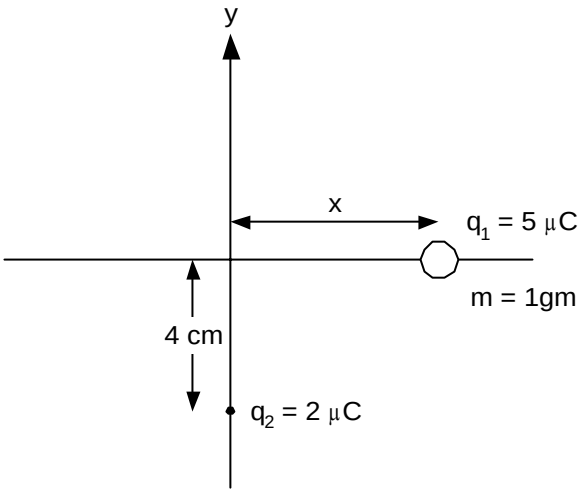
解：在界面两端分别应用 Ohm 定理的微分形式有

$$j=\frac{I}{s}=\sigma E\Rightarrow E=\rho\frac{I}{s}\text{，}$$

根据边界关系有

$$\begin{aligned}\sigma_s&=D_{Fe}-D_{Cu}=\varepsilon_0\left(E_{Fe}-E_{Cu}\right)\\&=\varepsilon_0\left(\rho_{Fe}-\rho_{Cu}\right)\frac{I}{s}\\&\sim10^{-11}\times10^{-7}/10^{-6}=10^{-12}\end{aligned}\text{。}$$

选（D）。



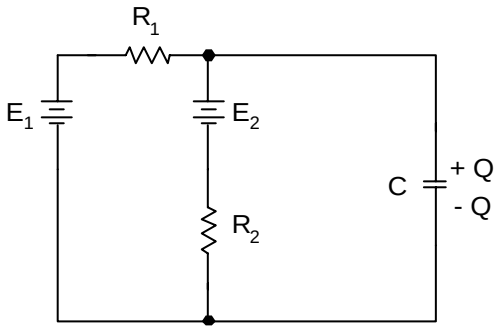

68. A bead of charge $q_1$ = 5 microcoulombs and mass 1 gram slides without friction on a wire along the x-axis, as shown above. Another charge $q_2$ = 2 microcoulombs is fixed at x = 0, y = –4 centimeters. If $q_1$ is released from rest at x = 3 centimeters, its speed at x = $\infty$ is most nearly

(A) 6 m/s
(B) 60 m/s
(C) 190 m/s
(D) 1900 m/s
(E) 6000 m/s

解：根据能量守恒，当 $q_1$ 运动到无穷远处时初始的电场势能完全转化为动能。

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{\sqrt{x^2+y^2}}=\frac{1}{2}mv^2\text{，}$$

由此可解得 v。选（C）。




69. A capacitor is charged with two batteries, as shown above. If initially there is no charge on C, which of the following expressions gives the time dependence of Q?

(A) $Q_0[1-e^{-t(R_1+R_2)C}]$

(B) $Q_0[1-e^{-t(R_1+R_2)/R_1R_2C}]$

(C) $Q_0e^{-t(R_1+R_2)/R_1R_2C}$

(D) $Q_0e^{-t(R_1+R_2)C}$

(E) $Q_0e^{-t/\sqrt{R_1R_2}C}$

解：利用等效电压源定理简化电路，等效的电源内阻

$$R=R_1//R_2=\frac{R_1R_2}{R_1+R_2}。$$

电容充电的时间常数

$$\tau=RC=\frac{R_1R_2C}{R_1+R_2}。$$

选（B）。

70. Positive charge is brought from far away and gradually assembled on the surface of an initially uncharged sphere of radius R. The work required to place total charge Q on a sphere in this manner is

(A) $\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R^2}$

(B) $\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R^2}$

(C) $\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R}$

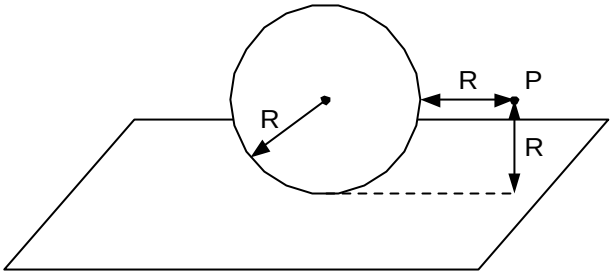
(D) $\frac{3}{5}\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R}$

(E) $\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R}$

解：设想每次移动很小的一份电荷 dq 到球壳上，积分可得总共做的功

$$W=\int_0^Q\frac{1}{4\pi\varepsilon_0}\frac{qdq}{R}=\frac{1}{8\pi\varepsilon_0}\frac{q^2}{R}\Big|_0^Q=\frac{1}{8\pi\varepsilon_0}\frac{Q^2}{R}。$$

选（A）。




71. A thin insulating spherical shell of radius R just touches a thin infinite insulating plane, as shown above. Both the shell and the plane have a uniform charge density of σ coulombs per square meter. What is the magnitude of the electric field at point P, which is a distance R above the plane and a distance R from the outside of the sphere?

(A) $\frac{\sigma}{4\varepsilon_0}$

(B) $\sqrt{\frac{2\sigma}{4\varepsilon_0}}$

(C) $\frac{2\sigma}{4\varepsilon_0}$

(D) $\frac{\sigma}{4\varepsilon_0}$

(E) $\frac{\sqrt{5}\sigma}{4\varepsilon_0}$

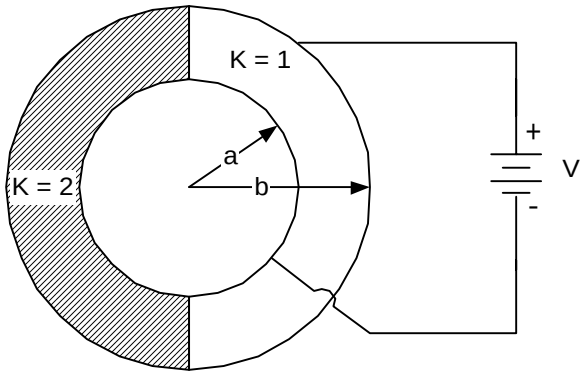
解：P 点的电场强度由两个部分组成：球壳的贡献沿水平方向向右，

$$E_{//}=\frac{1}{4\pi\varepsilon_0}\frac{\sigma 4\pi R^2}{(2R)^2}=\frac{\sigma}{4\varepsilon_0}\ ;$$

无穷大带电平面的贡献垂直向上，

$$E_{\perp}=\frac{\sigma}{2\varepsilon_0}。$$

合场强的大小由二者的合成计算。选（E）。




72. A capacitor is formed of two concentric conducting spherical shells. Half of the space between the shells is filled with air, and the other half is filled with a dielectric of dielectric constant K = 2. The capacitor is charged with a battery of emf V connected as shown above. The total charge stored on the inner sphere is

(A) $-V6\pi\varepsilon_0 ab/(b-a)$

(B) $+V6\pi\varepsilon_0 ab/(b-a)$

(C) $-V6\pi\varepsilon_0 ab/(b+a)$

(D) $-V6\pi\varepsilon_0/\ln(b/a)$

(E) $+V6\pi\varepsilon_0/\ln(b/a)$

解：由对称性可以判断，极板间的电场是沿径向的，且在两种介质中的分布是一致的：

$$E(r)=\frac{a\sigma_1}{K_1\varepsilon_0 r}=\frac{a\sigma_2}{K_2\varepsilon_0 r},$$

由

$$\int_a^b Edr=V,$$

$$\frac{a\sigma_1}{K_1\varepsilon_0}\ln\frac{b}{a}=\frac{a\sigma_2}{K_2\varepsilon_0}\ln\frac{b}{a}=V,$$

解得

$$Q=-2\pi R^2(\sigma_1+\sigma_2)=-\frac{V6\pi\varepsilon_0}{\ln\left(\frac{b}{a}\right)}。$$

选（D）。


73. The circuit shown above contains a resistor whose resistance is R with an uncertainty ΔR and a battery of emf ε with an uncertainty Δε. The uncertainties are uncorrelated. What is the uncertainty in the power dissipated in the resistor?

(A) $(\frac{\Delta\varepsilon}{\varepsilon}+\frac{\Delta R}{R})\frac{\varepsilon^2}{R}$

(B) $\sqrt{(\frac{\Delta\varepsilon}{\varepsilon})^2+(\frac{\Delta R}{R})^2}\ \frac{\varepsilon^2}{R}$

(C) $(\frac{\Delta\varepsilon}{\varepsilon}-\frac{\Delta R}{R})\frac{\varepsilon^2}{R}$

(D) $[2(\frac{\Delta\varepsilon}{\varepsilon})+\frac{\Delta R}{R}]\frac{\varepsilon^2}{R}$

(E) $\sqrt{4(\frac{\Delta\varepsilon}{\varepsilon})^2+(\frac{\Delta R}{R})^2}\ \frac{\varepsilon^2}{R}$

解：功率

$$P=\frac{\varepsilon^2}{R},$$

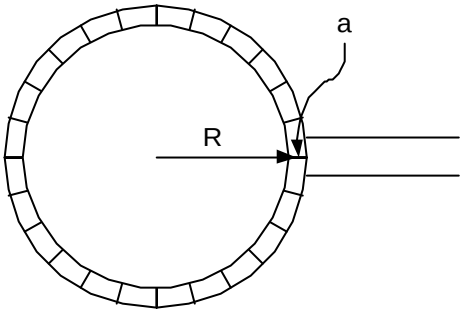
写成对数形式后求导得

$$\frac{dP}{P}=2\frac{d\varepsilon}{\varepsilon}+\frac{dR}{R}。$$

利用相对误差的合成公式有

$$\Delta P = P\sqrt{\left(2\frac{d\varepsilon}{\varepsilon}\right)^2+\left(\frac{dR}{R}\right)^2}\text{。}$$

选（E）。




74. The inductor shown above is formed by winding wire N times around a toroidal piece of iron of permeability μ. The major radius of the toroid is R and the minor radius is a, with a << R. What is the inductance if this inductor?

(A) $\frac{\mu_0 N a^2}{2R}$

(B) $\frac{\mu N a^2}{2R}$

(C) $\frac{\mu N^2 a^2}{2R}$

(D) $\frac{\mu N^2 R}{2}$

(E) $\frac{\mu_0 N^2 a^2}{2R}$

解：环内的磁场沿切向，其大小可由 Ampere 环路定理求出，

$$B = \frac{\mu NI}{2\pi R}\text{。}$$

利用电感的定义式之一

$$\Phi = LI$$

可得

$$L = \frac{\Phi}{I} = \frac{NBs}{I} = \frac{\mu N^2 a^2}{2R}\text{。}$$

选（C）。

75. An alpha particle and a proton follow the same circular path in a uniform magnetic field. What is the ratio, $v_\alpha/v_p$ , of their nonrelativistic velocities?

(A) 1/4

(B) 1/2

(C) 1

(D) 2

(E) 4

解：在非相对论情形下，Lorentz 力提供粒子作圆周运动所需的向心力

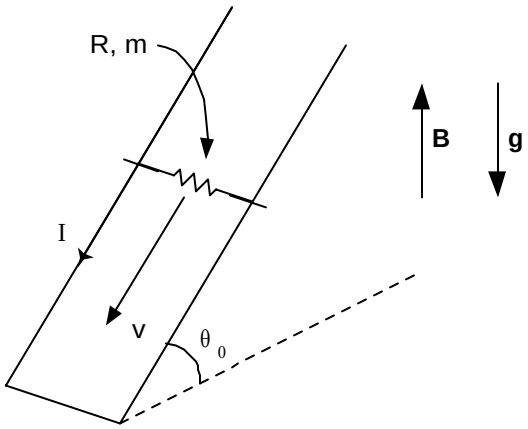
$$m\frac{v^2}{R} = qvB\text{，}$$

$$v = \frac{qBR}{m}\text{，}$$

因此两种粒子的回旋速度比

$$\frac{v_\alpha}{v_p} = \frac{q_\alpha m_p}{q_p m_\alpha} = \frac{1}{2}\text{。}$$

选（B）。




76. A resistor R of mass m is released from rest and slides without friction on conducting rails connected to form a complete circuit, as shown above. Initially, the current I is zero. The rails are inclined at an angle $\theta_0$ to the horizontal. A vertical magnetic field B is present, as well as gravity. Consider the time dependences

(1) $\alpha(1-e^{-\beta t})$, (2) $\alpha t-\beta$, (3) $\alpha(1+e^{-\beta t})$

where α and β are positive and time-independence. What are the time dependence of the current I and

the speed v of the resistor?

(A) v and I both have time dependence (1)

(B) v and I both have time dependence (2)

(C) v and I both have time dependence (3)

(D) v has time dependence (1), I has time dependence (3)

(E) v has time dependence (2), I has time dependence (3)

解：由于杆下滑产生的感生电动势为

$$E = Blv\ ,$$

感生电流

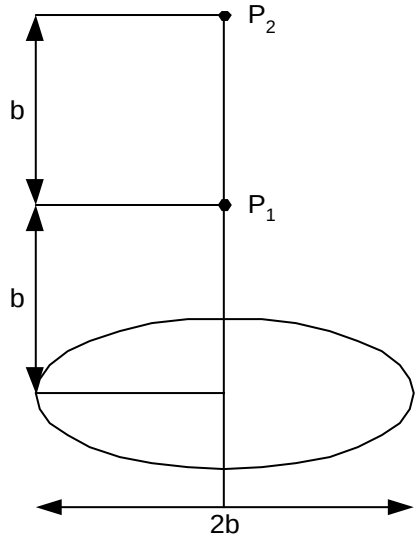
$$I = \frac{Blv}{R} \propto v\ 。$$

杆所受的 Ampere 力沿水平方向，其分量形成阻止杆加速下滑的阻力。最终杆会达到一个收尾速度匀速下滑。定性的分析即可得结果。一般的运动方程形式如下

$$m\frac{dv}{dt} = mg\sin\theta_0 - \frac{B^2l^2v}{R}\cos\theta_0\ ,$$

解为指数形式。选（A）。

Questions 77-78 concern a uniformly charged wire that has the form of a circular loop with radius b. Consider two points on the axis of the loop. $P_1$ is at a distance b from the loop's center, and $P_2$ is at a distance 2b from the loop's center. The potential V is zero, very far from the loop. At $P_1$ and $P_2$ the potentials are $V_1$ and $V_2$, respectively.




77. What is $V_2$ in terms of $V_1$?

(A) $\frac{V_1}{3}$

(B) $\frac{2V_1}{5}$

(C) $\frac{V_1}{2}$

(D) $\sqrt{\frac{2}{5}}V_1$

(E) $4\pi V_1$

解：显然环上每一点对轴线上电势的贡献相同。所以轴线上距离环心为 L 的点的电势为

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{\sqrt{L^2+b^2}}。$$

所以 $V_2$ 和 $V_1$ 的关系为

$$\frac{V_2}{V_1} = \frac{\sqrt{{L_{p1}}^2+b^2}}{\sqrt{{L_{p2}}^2+b^2}} = \frac{\sqrt{2}}{\sqrt{5}} = \sqrt{\frac{2}{5}}。$$

选（D）。

78. How much work would be required to move a charge q from $P_1$ to $P_2$?

(A) $\frac{qV_2}{V_1}$

(B) $qV_2$

(C) $q\log_e\left(\frac{V_2}{V_1}\right)$

(D) $qV_1V_2$

(E) $q(V_2-V_1)$

解：从 $P_2$ 点到 $P_1$ 点，电势能改变为 $q(V_2-V_1)$。

而机械能没有发生变化，所以外界做功应等于电势能的变化。选（E）。

79. In electrostatic problems, the electric field always satisfies the equation

(A) $\nabla\cdot\mathbf{E} = \nabla\times\mathbf{E}$

(B) $\nabla \cdot \mathbf{E} = 0$
(C) $\nabla \times \mathbf{E} = 0$
(D) $\nabla (E^2) = 0$
(E) $\nabla (\nabla \cdot \mathbf{E}) = \nabla \times \mathbf{E}$
解：由 Maxwell 方程组

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}。$$

而对于静电场，

$$\frac{\partial \mathbf{B}}{\partial t} = 0,$$

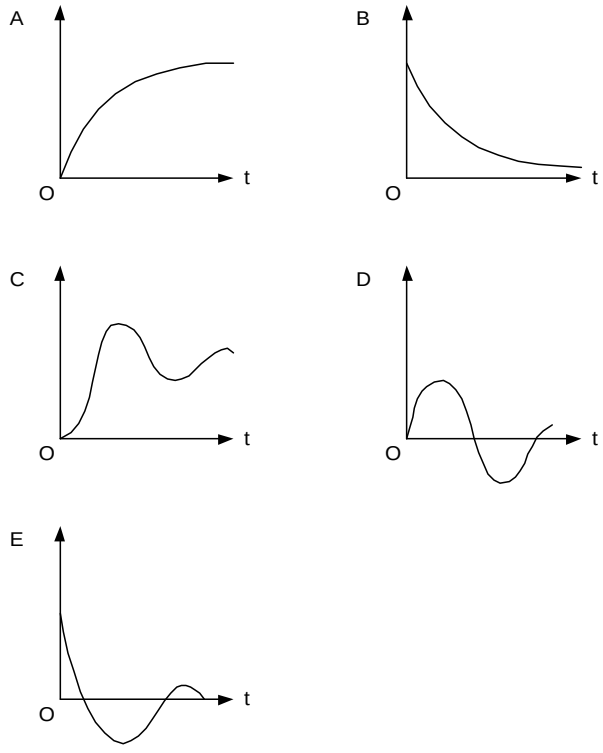
所以

$$\nabla \times \mathbf{E} = 0。$$

选（C）。

Questions 80-81

The graphs below represent variables of an electrical circuit as functions of time t after the circuit switch is closed. In each case the circuit specified contains circuit elements connected in series with each other and with a battery. Any capacitor is uncharged at the beginning. Select the graph that most nearly shows the nature of the time dependence of the indicated variable.




80. Which graph represents the potential drop across the resistor as a function of time in an inductance-resistance circuit?
(A) A
(B) B
(C) C
(D) D
(E) E
解：由于电感在电流变化时会产生感应电压，阻碍电流改变。所以当开关合上瞬间，电流无法突变，保持为 0。电阻上无电流通过，电压为零。之后电流逐渐增大。当开关合上很长时间以后，电路趋于稳定。电感上不再有压降，电阻上电压趋于电源电压。选（A）。
或者进行计算，

$$L\frac{dI}{dt} + RI = \mathrm{E}。$$

解此微分方程，并考虑初条件 I（0）=0，得

$$I = \frac{\mathrm{E}}{R}(1 - e^{-\frac{R}{L}t})。$$

正是图线（A）所代表的函数关系。

81. Which graph represents the charge on the capacitor as a function of time in an underdamped inductance-resistance-capacitance circuit?
(A) A
(B) B
(C) C
(D) D
(E) E
解：由于电容的初始电荷为 0，排除（B）、（C）。当电路趋于稳定时，电池的全部点压降在电容上，有一个稳定的电荷分布，排除（D）。由于欠阻尼，电容上的电荷有振荡，排除（A）。选（C）。

Questions 82-83 are based on the following information.

A long, thin, vertical wire has a net positive charge λ per unit length. In addition, there is a current I in the wire. A charged particle moves with speed u in a straight-line trajectory, parallel to the wire and at a distance r from the wire. Assume that the only forces on the particle are those that result from the charge on and the current in the wire and that u is much less than c, the speed of light.

82. Suppose that the current in the wire is reduced to 1/2. Which of the following changes, made simultaneously with the change in the current, is necessary if the same particle is to remain in the same trajectory at the same distance r from the wire?

(A) Doubling the charge per unit length on the wire only
(B) Doubling the charge on the particle only
(C) Doubling both the charge per unit length on the wire and the charge on the particle
(D) Doubling the speed on the particle
(E) Introducing an additional magnetic field parallel to the wire

解：先计算一下导线所产生的电磁场。对于 r 处的电场强度，由高斯定理，作一包围导线的圆柱体面，高度为 h，则

$$2\pi rh\cdot E=\lambda h/\varepsilon_0,$$

$$E=\frac{\lambda}{2\pi\varepsilon_0 r}。$$

方向垂直导线朝外。对于磁场，由安培环路定理

$$2\pi rB=\mu_0 I\ ,$$

$$B=\frac{\mu_0 I}{2\pi r}。$$

方向为在垂直于导线的平面内，符合右手定则。带电粒子做直线运动，受力平衡，

$$\mathbf{E}q=q\mathbf{v}\times\mathbf{B}。$$

将 E 和 B 的表达式带入，得

$$\frac{\lambda}{\varepsilon_0}=\mu_0 Iv,$$

这就是带电粒子平衡的条件。

对于本小题，电流减半。为继续维持平衡，可以把粒子的速度加倍，或把电荷密度减半。选（D）。

83. The particle is later observed to move in a straight-line trajectory, parallel to the wire but at a distance 2r from the wire. If the wire carries a current I and the charge per unit length is still λ, the speed of the particle is

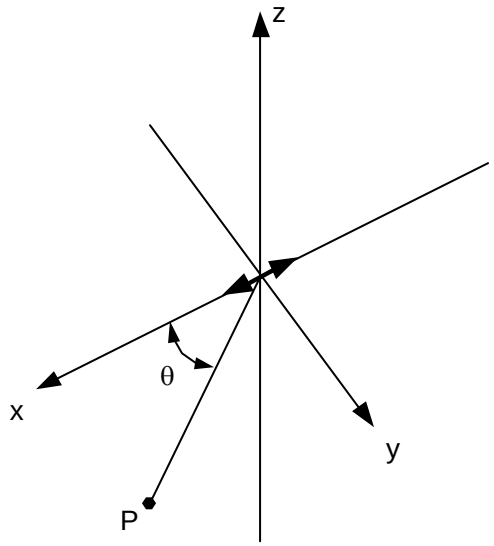
(A) 4u
(B) 2u
(C) u
(D) u/2
(E) u/4

解：在前面的推导中看到，带电粒子平衡条件并不涉及它所处的位置 r。原因是电场和磁场随距离衰减的函数关系是相同的。所以速度应维持不变。选（C）。

84. If the outward electric flux through the surface of a cube is negative, then one can be certain that the cube contains

(A) a net negative charge
(B) a net positive charge
(C) only negative charges
(D) only positive charges
(E) both positive and negative charges

解：选（A）。Gauss 定理的必然结果。




85. A charged particle oscillates harmonically along the x-axis as shown above. The radiation from the particle is detected at a distant point P, which lies in the xy-plane. The electric field at P is in the

(A) ±z direction and has a maximum amplitude at θ=90°
(B) ±z direction and has a minimum amplitude at θ=90°
(C) xy-plane and has a maximum amplitude at

θ=90°

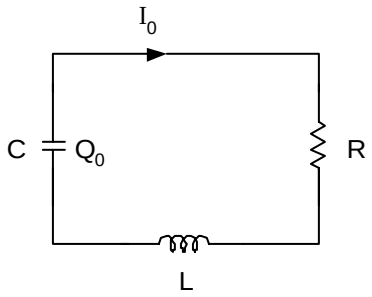
(D) xy-plane and has a minimum amplitude at θ=90°

(E) xy-plane and has a maximum amplitude at θ=45°

解：取 x 轴为极轴（$\mathbf{e}_r$ 的方向），则空间中某点的电场强度可表为

$$\mathbf{E}(\mathbf{r},t) = -\frac{\mu_0 q\omega^2 a}{4\pi}\frac{\cos(kr-\omega t)}{r}\sin\theta\mathbf{e}_\theta ,$$

可见 **E** 的方向（平行于 $\mathbf{e}_\theta$）在 xy 平面内，并且θ=90°有最大值。选（C）。




86. The circuit above is shown at time t = 0, when a charge $Q_0$ is stored on the capacitpr C and a current $I_0$ is in the inductor L. Which of the following statements is NOT true?

(A) If $\frac{R}{2L} < \frac{1}{\sqrt{LC}}$, the charge on the capacitor will undergo a damped oscillation in time.

(B) If $\frac{R}{2L} >> \frac{1}{\sqrt{LC}}$, the current in the inductor will decay to zero with time as a simple exponential $e^{-(R/2L)t}$.

(C) If $\frac{R}{2L} << \frac{1}{\sqrt{LC}}$, and effects of order $\frac{R}{2L\sqrt{LC}}$ are negligible, the total energy stored in the circuit will decay with time as $e^{-(R/L)t}$

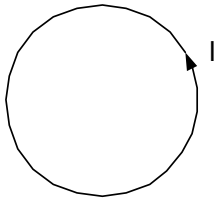
(D) If $\frac{R}{2L} > \frac{1}{\sqrt{LC}}$, the current in the resistor can change sign once as it decays, or can decay to zero without changing sign, depending on the values of $Q_0$ and $I_0$.

(E) If $I_0 = 0$, then for fixed values of L and C, the charge will decay to zero as quickly as possible without oscillation when $R^2 = \frac{4L}{C}$.

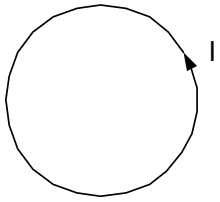
解：RLC 电路的阻尼度定义为

$$\lambda = \frac{R}{2}\sqrt{\frac{C}{L}}。$$

λ > 1、λ = 1、λ < 1 分别对应过阻尼、临界阻尼和阻尼振荡。（D）选项条件保证λ > 1，是过阻尼情形，电流不可能改变符号。选（D）。




(1) Wire Loop in Normal Resistive State




(2) Superconducting Loop

87. The diagrams above show two noninteracting wire loops of identical size each carrying a current I in the counterclockwise direction as indicated. The only difference between (1) and (2) is that loop (2) is superconducting. Which of the following is a correct statement about the magnetic induction vectors $B_1$ and $B_2$ at the respective centers of loop (1) and loop (2)?

(A) $B_1$ is identical to $B_2$ and both are directed out of the page.

(B) $B_1$ is identical to $B_2$ and both are directed into the page.

(C) $B_2$ is zero because the magnetic field cannot penetrate a superconductor.

(D) $B_1$ is directed into the page but $B_2$ is directed out of the page to satisfy boundary conditions on the surface of the superconductor.

(E) $B_1$ is directed out of the page but $B_2$ is directed into the page to satisfy boundary conditions on the surface of the superconductor.

解：磁场分布只由电流分布决定，与线圈超导不

超导没有关系，当然如果是在线圈内部就另当别论。选（A）。

88. A monochromatic plane wave of visible light is normally incident from air on a thick highly polished metal sheet. Which of the following statements is NOT correct?

(A) The 1/e penetration depth of radiation in the metal is less than the wavelength of visible light.

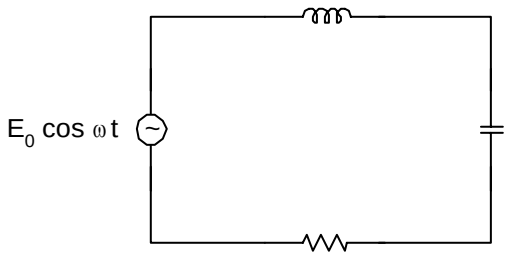
(B) The reflected wave is 180° out of phase with the incident wave.

(C) More than half the energy of the wave in the metal is stored in the magnetic field.

(D) The pressure of the wave on a copper sheet is decreased if the sheet is blackened.

(E) The fraction of energy absorbed in a silver sheet is larger than that absorbed in a zinc sheet of the same dimensions.

解：导体越接近于理想情况，入射波被吸收部分所占的比例越小，从而吸收的能量少。由于银的导电能力强于锌，更接近于理想导体，所以应吸收较少的能量。选（E）。




89. An AC source is connected to an LRC circuit, as shown above. Energy is stored in the capacitor and inductor, and is dissipated in the resistor. At what times is the energy dissipated at the maximum rate?

(A) When the stored energy is all in electric fields.

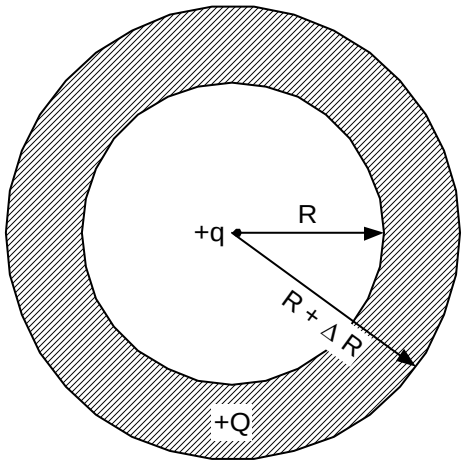
(B) When the stored energy is all in magnetic fields.

(C) When the stored energy is equally divided between electric fields and magnetic fields.

(D) When no energy is stored.

(E) Under none of the conditions above.

解：能量全部耗散在电阻上，电路中电流最大时能量耗散率最大，电流最大的时候磁场能量最大。选（B）。




90. A particle with positive charge q is at the center of a spherical shell of inner radius R and outer radius R+ΔR, as shown above. The shell carries a positive charge Q that is uniformly distributed throughout the shell. What is the work done on the particle in bringing it from r = 0 to r = R?

(A) 0

(B) $\frac{1}{4\pi\varepsilon_0}\frac{qQ}{R}$

(C) $-\frac{1}{4\pi\varepsilon_0}\frac{qQ}{R}$

(D) $\frac{1}{8\pi\varepsilon_0}\frac{qQR^2}{(R+\Delta R)^3-R^3}$

(E) $-\frac{1}{8\pi\varepsilon_0}\frac{qQR^2}{(R+\Delta R)^3-R^3}$

解：壳上电荷+Q 对内部电场无贡献，q 不受力，做功为零。选（A）。