AP Physics C: Electricity and Magnetism

From the 2017 Administration

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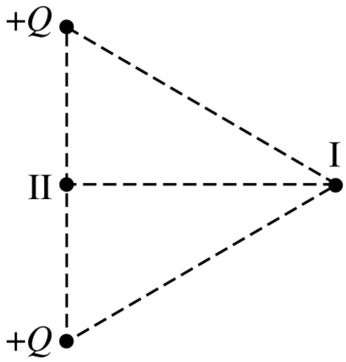
I Multiple Choice Questions

Time: 45 minutes
35 Questions

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

See the instruction for questions 1 to 2.



In the figure above, two small spheres, each with charge $+Q$, are fixed in place at the corners of an equilateral triangle. Point I is at the third corner, and point II is midway between the charges.

1. A small particle with charge $+q$, where $q \ll Q$, is moved from point I to point II at constant speed v by an external force. W_{EXT} is the work done by the external force on the moving charge, and W_{ELEC} is the work done by the electrostatic force. Which of the following correctly identifies the signs of these quantities?

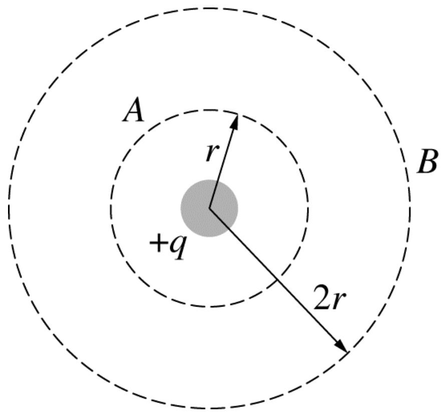
	W_{EXT}	W_{ELEC}
(A)	$+$	$+$
(B)	$+$	$-$
(C)	$-$	$+$
(D)	$-$	$-$

(E) None of the above, since the work done by both the external force and the electrostatic force is zero.

2. Which of the following best describes the relationship between the electric potentials V_{I} and V_{II} at points I and II, respectively?

(A) $V_{\text{I}} < V_{\text{II}}$
(B) $V_{\text{I}} = V_{\text{II}}$
(C) $V_{\text{I}} > V_{\text{II}}$
(D) It cannot be determined without knowing the magnitudes of the charges.
(E) It cannot be determined without knowing the distance between points I and II.

See the instruction for questions 3 to 4.



A small sphere has a charge $+q$. Spherical Gaussian surfaces A and B are concentric with the sphere, as shown in the figure above. The radii of surfaces A and B are r and $2r$, respectively.

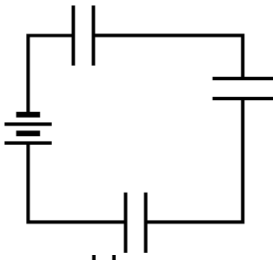
3. The magnitude of the electric flux through A is Φ_A. The magnitude of the electric flux through surface B is Φ_B. The ratio Φ_A/Φ_B is

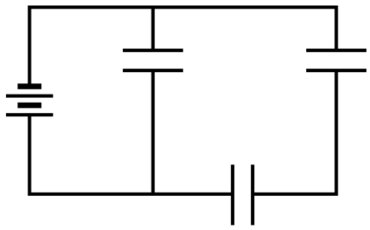
   (A) 4/1 (B) 2/1 (C) 1/1 (D) 1/2 (E) 1/4

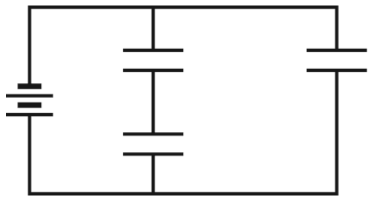
4. The magnitude of the electric field at surface A is E_A. The magnitude of the electric field at surface B is E_B. The ratio E_A/E_B is

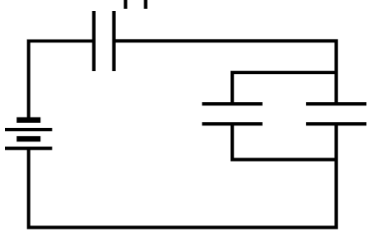
   (A) 4/1 (B) 2/1 (C) 1/1 (D) 1/2 (E) 1/4

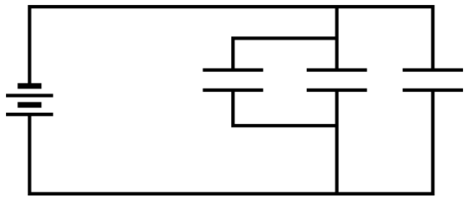
5. Each of the following figures shows three identical capacitors connected to a battery. Which arrangement has the greatest equivalent capacitance?

(A) 

(B) 

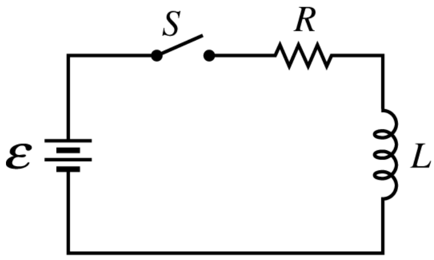
(C) 

(D) 

(E) 

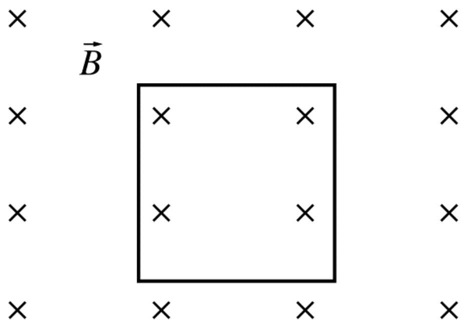
6. A copper wire of length L and diameter D dissipates energy at a rate P_0 when the current in the wire is 10 A. A second copper wire of length L has diameter $2D$. What current in the second wire would dissipate energy at a rate P_0 ?

(A) 2.5 A (B) 5.0 A (C) 10 A (D) 20 A (E) 40 A



7. Time t is the time it takes the current of an LR circuit with an inductor of inductance L and a resistor of resistance R to reach half of its maximum value. What is the new time if the original inductor is replaced with an inductor of inductance $2L$?

(A) $4t$ (B) $2t$ (C) t (D) $t/2$ (E) $t/4$



8. A loop of wire lies in the plane of the page in a region with a uniform magnetic field $\vec{B}$ directed into the page, as shown in the figure above. In which of the following cases, if any, will an emf be induced in the loop at the moment shown in the figure?

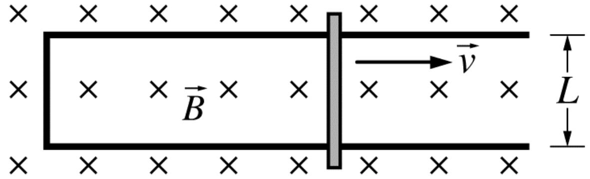
   (A) The loop is moving toward the right.

   (B) The loop is moving toward the top of the page.

   (C) The loop is moving out of the plane of the paper so that the loop's plane remains perpendicular to the magnetic field.

   (D) The loop is moving into the plane of the paper so that the loop's plane remains perpendicular to the magnetic field.

   (E) An emf cannot be induced in the loop without changing its orientation relative to the magnetic field.



Top View

9. A copper rod of resistance R is in electrical contact with a frictionless U-shaped rail of width L and negligible resistance. The rod is pulled to the right at a constant velocity $\vec{v}$. A magnetic field $\vec{B}$ is directed into the page, as shown in the figure above. Under these conditions, the electric power dissipated in the rod is P. If the velocity of the rod is doubled and the magnetic field strength is reduced by half, the power dissipated in the rod is

(A) $P/4$ (B) $P/2$ (C) P (D) $2P$ (E) $4P$

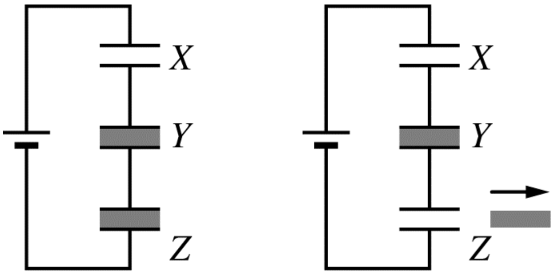
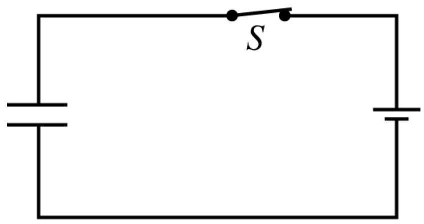


Figure 1   Figure 2

10. Three capacitors are connected in series to an ideal voltage source and charged, as shown in Figure 1 above. The capacitors are identical except that capacitor X has air between its plates, whereas capacitors Y and Z each have a dielectric slab of dielectric constant $\kappa > 1$ between their plates. If the dielectric slab is removed from capacitor Z, as shown in Figure 2, which of the following describes what will happen to the voltage across each capacitor?

	Voltage across Capacitor X	Voltage across Capacitor Y	Voltage across Capacitor Z
(A)	Increases	Increases	Decreases
(B)	Increases	Decreases	Decreases
(C)	Increases	Decreases	Increases
(D)	Decreases	Increases	Decreases
(E)	Decreases	Decreases	Increases

See the instruction for questions 11 to 12.



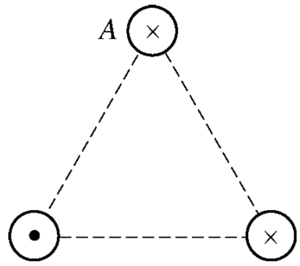
A parallel-plate capacitor connected to a battery is fully charged with the switch S closed, as shown in the circuit above. A slab of dielectric constant $\kappa > 1$ is slowly inserted between the plates of the capacitor.

11. If the switch remains closed when the slab is inserted, what changes, if any, occur?

	Potential Difference Across the Plates	Charge on Positive Plate
(A)	Remains the same	Increases
(B)	Remains the same	Decreases
(C)	Increases	Remains the same
(D)	Decreases	Increases
(E)	Decreases	Remains the same

12. If, instead, the switch is open with the capacitor still fully charged when the slab is inserted, what changes, if any, occur?

	Potential Difference Across the Plates	Charge on Positive Plate
(A)	Remains the same	Increases
(B)	Remains the same	Decreases
(C)	Increases	Remains the same
(D)	Decreases	Increases
(E)	Decreases	Remains the same



13. Three long wires perpendicular to the page are equidistant from each other, as shown in the cross-sectional view above. Two wires carry current into the page, and the third carries current out of the page. All the currents are equal in magnitude. What is the direction of the net magnetic force on wire A due to the other two wires?

(A) Into the page

(B) Toward the bottom of the page

(C) Toward the top of the page

(D) Toward the left

(E) Toward the right

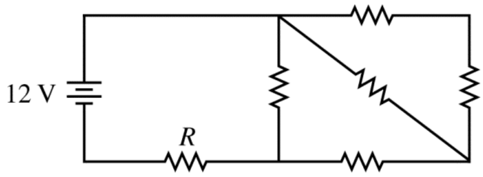
14. A beam of particles travels at a right angle to a uniform magnetic field. Particles can be separated into different trajectories based on which of the following properties?

I. The charge of the particle

II. The mass of the particle

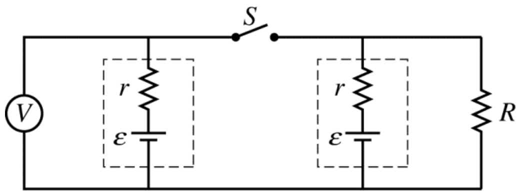
III. The velocity of the particle

(A) I only (B) III only (C) I and II only (D) I and III only (E) I, II and III



15. Six $2\,\Omega$ resistors are connected to a $12\,\text{V}$ battery, as shown in the figure above. What is the current in the resistor labeled R ?

(A) $2.6\,\text{A}$ (B) $3.7\,\text{A}$ (C) $4.0\,\text{A}$ (D) $4.3\,\text{A}$ (E) $6.0\,\text{A}$



16. A resistor of resistance R is connected in a circuit to two identical batteries. The circuit also contains switch S and ideal voltmeter V, as shown in the figure above. The batteries both have an emf ε and internal resistance r. The reading of the voltmeter is noted with the switch in the open position. Which of the following best represents how the voltmeter reading after the switch is closed compares to the reading before the switch is closed?

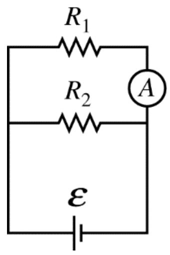
(A) The reading of the voltmeter is the same.

(B) The reading of the voltmeter is higher.

(C) The reading of the voltmeter is lower.

(D) Cannot be determined without knowing the internal resistance of the batteries.

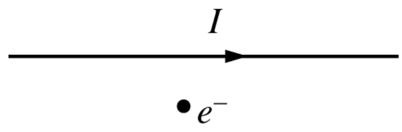
(E) Cannot be determined without knowing the emf of the batteries.



17. In the circuit shown, $R_1 = 6\,\Omega, R_2 = 3\,\Omega$, and the emf $\mathcal{E}$ of the battery is 30 V. The reading of the ammeter A is most nearly

(A) 1.6 A (B) 3.3 A (C) 5.0 A (D) 10 A (E) 15 A

See the instruction for questions 18 to 19.



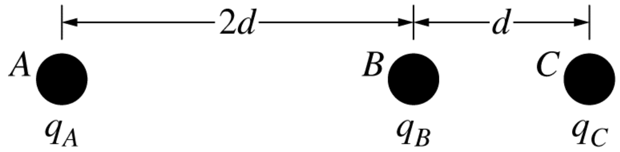
An electron is placed near a wire carrying current I, as shown in the figure above, and released from rest. Both the electron and the wire are in the plane of the page.

18. Which of the following is true about the direction of the magnetic field produced by the current at the position of the electron?
    (A) It is toward the top of the page.
    (B) It is toward the bottom of the page.
    (C) It is out of the page.
    (D) It is into the page.
    (E) It has no direction since there is no magnetic field at that point.

19. Which of the following is true about the direction of the initial magnetic force acting on the electron due to the current in the wire?
    (A) It is toward the top of the page.
    (B) It is toward the bottom of the page.
    (C) It is out of the page.
    (D) It is into the page.
    (E) It has no direction because the magnitude of the initial magnetic force on the electron is zero.

See the instruction for questions 20 to 22.

General instruction (if any) goes here.

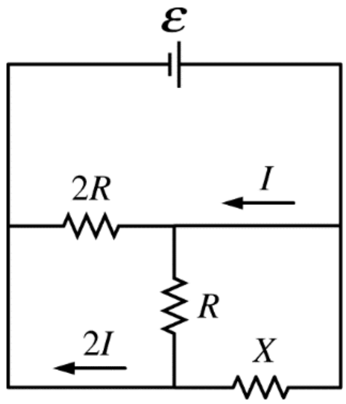


Three small spheres, A, B, and C, have charges with magnitudes q_A, q_B, and q_C, respectively. The three spheres are aligned along a straight line, as shown in the figure above. At the instant shown, the net force on sphere A is zero.

20. The ratio q_C/q_B is
    (A) 9/4 (B) 1/1 (C) 4/9 (D) 1/4 (E) 1/9

21. Which of the following statements must be true of the signs of the charges?
    (A) Only charges q_A and q_B have the same sign.
    (B) Only charges q_A and q_C have the same sign.
    (C) Only charges q_B and q_C have the same sign.
    (D) Charges q_B and q_C have different signs.
    (E) Charges q_A, q_B, and q_C all have the same sign.

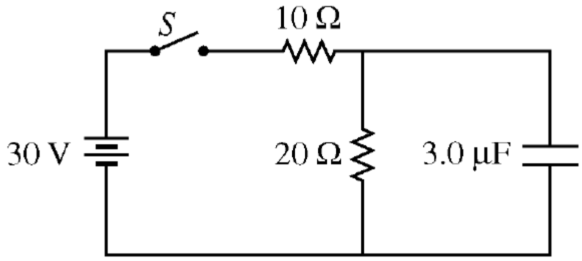
22. Which of the following is true about the sign of charge q_A ?
    (A) The sign of charge q_A must be the same as that of q_B.
    (B) The sign of charge q_A must be the same as that of q_C.
    (C) The sign of charge q_A must be the same as that of either q_B or q_C, whichever has the greater magnitude.
    (D) The sign of charge q_A must be the same as that of either q_B or q_C, whichever has the lesser magnitude.
    (E) It is possible that q_A could be either positive or negative.



23. Three resistors are connected to an ideal battery, as shown in the figure above. The battery has an emf ε. Two of the resistors have known resistances R and $2R$. The third resistor has unknown resistance X. The current in two of the branches is shown. What is the value of the unknown resistance X ?

(A) $R/5$ (B) $R/4$ (C) $R/2$ (D) R (E) $2R$

See the instruction for questions 24 to 25.



An uncharged 3.0μF capacitor is placed in a circuit with an ideal battery, two resistors, and an open switch S, as shown in the figure above. The switch is then closed.

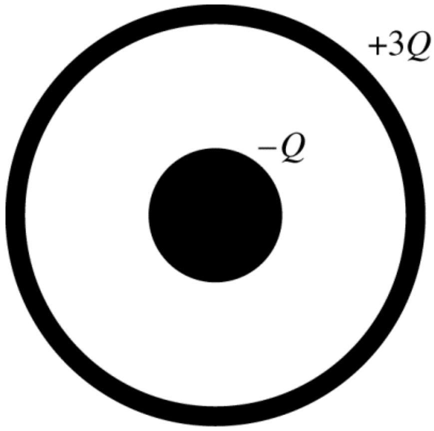
24. What is the current in the 10 Ω resistor immediately after the switch is closed?
(A) Zero (B) 1.0 A (C) 1.5 A (D) 3.0 A (E) 10 A

25. What is the current in the 20 Ω resistor a long time after the switch is closed?
(A) Zero (B) 1.0 A (C) 1.5 A (D) 3.0 A (E) 10 A

26. A parallel-plate capacitor connected to an ideal battery has charge $+Q$ on its top plate. The energy stored in the capacitor is U_C. While the capacitor remains connected to the battery, the separation between the two plates is doubled. Which of the following gives the new charge on the top plate and the new energy stored in the capacitor?

	Charge	Potential Energy
(A)	$+2Q$	$2U_C$
(B)	$+2Q$	$U_C/2$
(C)	$+Q$	U_C
(D)	$+Q/2$	$2U_C$
(E)	$+Q/2$	$U_C/2$

See the instruction for questions 27 to 28.

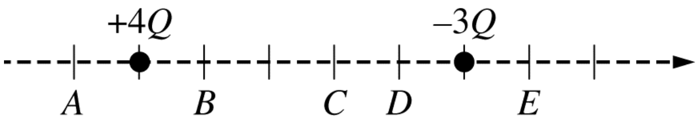


A hollow conducting sphere is surrounded by a larger concentric spherical conducting shell, as shown above. The inner sphere has a net charge of $-Q$, and the outer sphere has a net charge of $+3Q$.

27. What is the net charge on the inner surface of the spherical shell?
    (A) $-Q$ (B) Zero (C) $+Q$ (D) $+2Q$ (E) $+3Q$

28. What is the net charge on the outer surface of the spherical shell?
    (A) Zero (B) $+Q$ (C) $+2Q$ (D) $+3Q$ (E) $+4Q$

See the instruction for questions 29 to 30.



Two small spheres are arranged along a line and carry charges of $+4Q$ and $-3Q$, as shown in the figure above. The vertical lines are equally spaced.

29. At which of the labeled points does the electric field point toward the right with the smallest magnitude?

    (A) A (B) B (C) C (D) D (E) E

30. At which of the labeled points does the electric potential have the largest positive value?

    (A) A (B) B (C) C (D) D (E) E

31. Object A and object B are separated by distance d. Object A has charge $+q$, and object B has charge $-2q$. Object A has a force of magnitude F exerted on it by object B. What are the magnitude and direction of the force exerted on object B?

	Magnitude	Direction
(A)	$F/2$	Away from object A
(B)	F	Away from object A
(C)	$2F$	Away from object A
(D)	F	Toward object A
(E)	$2F$	Toward object A

32. A variable voltage source is connected to an inductor of inductance L. The voltage V as a function of time t is given by the equation $V(t) = \beta t^2$, where β is a constant in units of $\mathrm{V/s^2}$. The current in the inductor at time $t = 0$ is zero. Which of the following equations gives the magnitude of the current in the inductor as a function of time?

(A) $I(t) = 0$

(B) $I(t) = \dfrac{2\beta}{L} t$

(C) $I(t) = \dfrac{\beta}{L} t^2$

(D) $I(t) = \dfrac{\beta}{3L} t^3$

(E) $I(t) = \dfrac{\beta}{L} t^2 \sin(\omega t)$

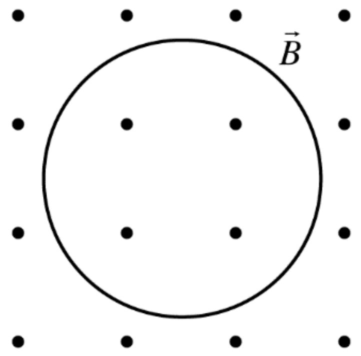


Figure 1

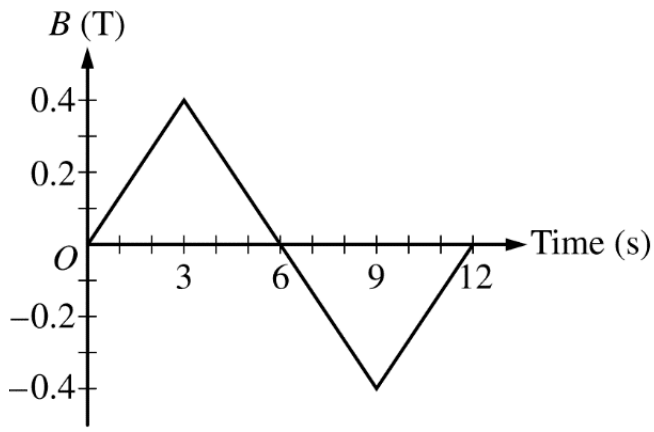
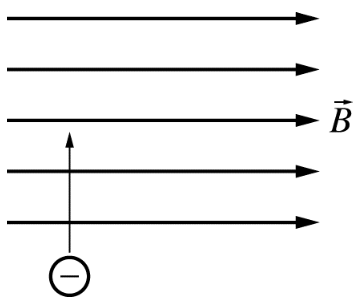


Figure 2

33. A metal wire of resistance $10\,\Omega$ is bent into a circular hoop of radius 0.10 meter and placed in a uniform magnetic field, as shown in Figure 1 above. The magnetic field strength B as a function of time is shown in Figure 2, where positive refers to a magnetic field directed out of the page. What are the magnitude and direction of the current induced in the ring at time $t = 6\,\text{s}$?

	Magnitude	Direction
(A)	3.8 mA	Clockwise
(B)	3.8 mA	Counterclockwise
(C)	0.42 mA	Clockwise
(D)	0.42 mA	Counterclockwise
(E)	Zero	No direction



34. A negatively charged ion is moving toward the top of the page when it enters a region of space with a uniform magnetic field $\vec{B}$ directed to the right, as shown above. The direction of the force that the magnetic field exerts on the ion is

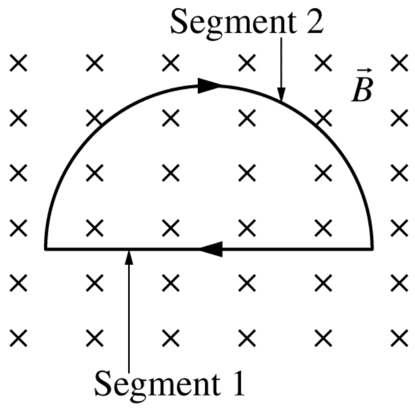
(A) toward the top of the page

(B) to the right

(C) to the left

(D) out of the page

(E) into the page



35. A semicircular loop with a clockwise current is placed in a uniform magnetic field that is directed into the page, as shown in the figure above. $\vec{F}_1$ is the net force on segment 1 , the straight portion of the loop. $\vec{F}_2$ is the net force on segment 2 , the curved portion of the loop. Which of the following correctly indicates the directions and relative magnitudes of the forces $\vec{F}_1$ and $\vec{F}_2$?

	Direction of $\vec{F}_1$	Direction of $\vec{F}_2$	Magnitudes
(A)	Toward the bottom of the page	Toward the top of the page	$\lvert\vec{F}_1\rvert = \lvert\vec{F}_2\rvert$
(B)	Toward the bottom of the page	Toward the top of the page	$\lvert\vec{F}_1\rvert < \lvert\vec{F}_2\rvert$
(C)	Toward the bottom of the page	Toward the top of the page	$\lvert\vec{F}_1\rvert > \lvert\vec{F}_2\rvert$
(D)	Toward the top of the pag	Toward the bottom of the page	$\lvert\vec{F}_1\rvert = \lvert\vec{F}_2\rvert$
(E)	Toward the top of the pag	Toward the bottom of the page	$\lvert\vec{F}_1\rvert < \lvert\vec{F}_2\rvert$