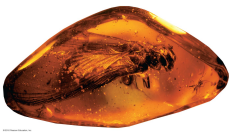


11th Physics 5 : Electricity 2018-19

Coulomb's Law $F = \left| k \frac{q_1 q_2}{r^2} \right|$

F: Electrostatic Force [N]
k : Coulomb Constant = 8.99 x 10^9 Nm^2/C^2
q_1 , q_2 : Magnitude of Charge [C]
r : Distance between Two Charges [m]

Newton's Law of Universal Gravitation

$$F = G \frac{m_1 m_2}{r^2}$$

F: Universal Gravitational Force 万有引力[N]
G : Universal Gravitational Constant
= 6.672 x 10^{-11} Nm^2/kg^2
m_1 , m_2 : Mass [kg]
r : Distance between Two Masses [m]

$E = \frac{F}{q}$ E : Electric Field [N/C]

$V = \frac{U}{q}$ V: Potential Difference [V]

Ohm's Law $I = \frac{V}{R}$ or $V = I R$

V: Voltage [V]
I: Current [A]
R: Resistance [Ω]

$P = V I = R I^2 = \frac{V^2}{R}$

P: Power [W]

$W = P t$ W: electric Energy [J], [Wh]

$R = \rho \frac{\ell}{S}$ ρ : Resistivity [Ω・m]

$R = R_1 + R_2 + \cdots + R_n$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots\cdots + \frac{1}{R_n}$$

Elementary Charge	e = 1.60 x 10^{-19} C
Electron mass	m_e = 9.11 x 10^{-31} kg
Proton mass	m_p = 1.673 x 10^{-27} kg
Neutron mass	m_n = 1.675 x 10^{-27} kg
Coulomb's Law constant	k = 8.99 x 10^9 N・m^2/C^2
Gravitational Acceleration Rate	g = 9.80 m/s^2
Universal gravitational constant	G = 6.67 x 10^{-11} N・m^2/kg^2
Avogadro's Number	N_A = 6.022 x 10^{23} mol^{-1}

PhysicsLab-026	Electric Charge - Static Electricity & Electroscope

[Lab-1] Generating frictional electricity

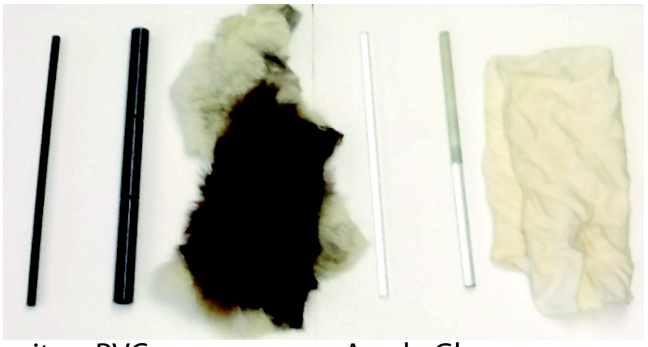
Typical combinations:

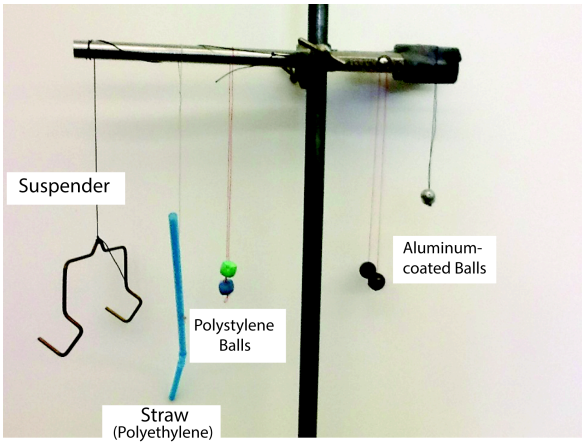
PVC (–) / Fur (+)

Ebonite (–) / Fur (+)

Glass (+) / Silk (–)

Acryl resin / Silk



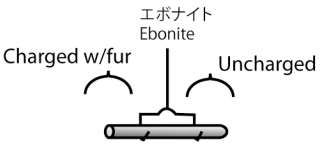
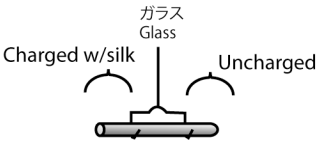
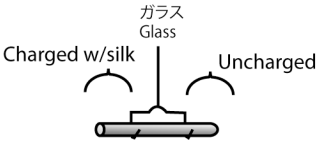
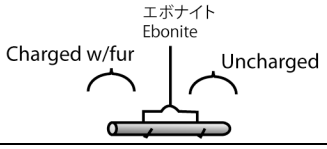
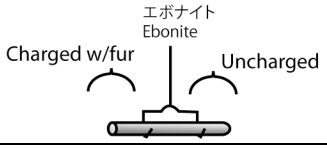


	A **PVC rod** is rubbed with **fur** and then brought near the followings. What happens?
3	Suspended **aluminum coated ball**
4	Suspended **polystyrene foam ball**

	A **glass rod** is rubbed with **silk** and then brought near the followings. What happens?
3	Suspended **aluminum coated ball**
4	Suspended **polystyrene foam ball**

[Lab-2-a] Reaction between two charged insulators

[Lab-2-b] Reaction between a charged and an uncharged insulators

		Charged side	Uncharged side
Charged PVC w/**Fur** 			
Charged PVC w/**Fur** 			
Charged Glass w/**Silk** 			
Charged Acryl w/**Silk** 			
Charged Acryl w/**Fur** 			

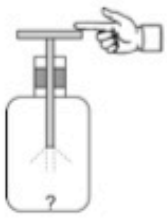
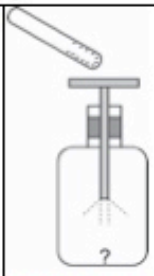
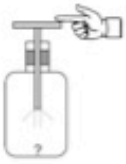
[Lab-2-b] Reaction between a charged insulator and water

Charged PVC w/**Fur** 	Water 			Charged Glass w/**Silk** 	Water 	

[Lab-2-c] Reaction between a charged insulator and a conductor (metal)

ged w/**Fur** 	金具 Suspender 			Charged k 	金具 Suspender 	

[Lab-3] Leaf Electroscope

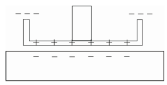
2-a	 Grounding	 Get it closer slowly not to make it dischaged				
2-b	 Grounding	 Get it closer slowly not to make it dischaged	 Grounding	 Remove grounding	 Move the rod away	Identify the sign of charge
2-c	 Grounding	 Get it closer slowly →Discharge				Identify the sign of charge
2-d	 Grounding	 contact				Identifyi the sign of charge

[Lab-4-a] **Tray generator**

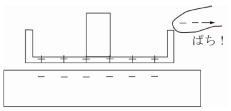
Aluminum tray with a plastic cup,

Polystyrene board, Saran wrap, Fur(tissue)

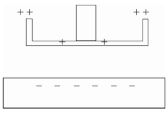
1. Rub



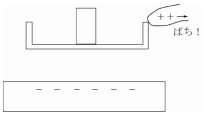
2 Bring close



3 Ground

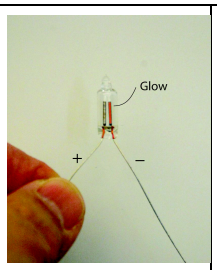


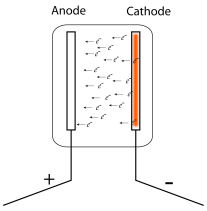
4 Separate



5 Ground

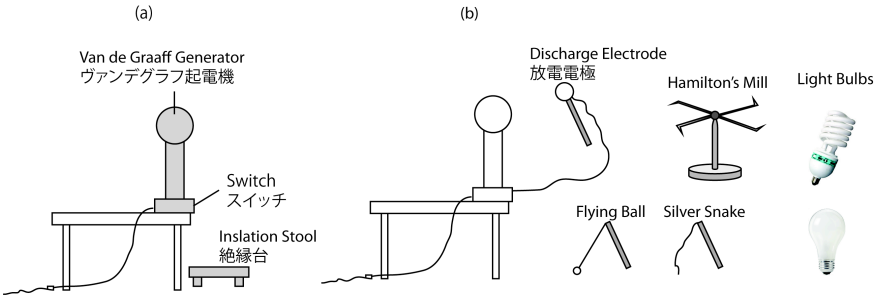
[Lab-4-b] Identifying the **sign of charge** with a **Neon lamp**



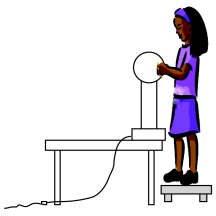


A neon lamp is a neon gas discharge lamp consisting of two electrodes.　The electron-emitting side (cathode) glows.

[Lab-5-1]　**Van de Graaff Generator** -1

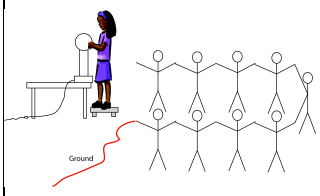


[Lab-5-2]　**Van de Graaff Generator** -2



人が絶縁台に乗ってから電源を入れる

Riding up the stool, then power-up



実験が終了したら電源を切る。アースで電気を逃がしてから絶縁台を降りる

Power off, take grounding and step down.

I. Electric Charge

1. Frictional Charging and Electric Charge

Amber --- "Elektron"

[Q1] The effects of electric charge have been known as early as 600 B.C. in Greece about amber. Explain what the Greeks noticed.

[Q2] Explain about other materials that show the effects of electric charge like amber.

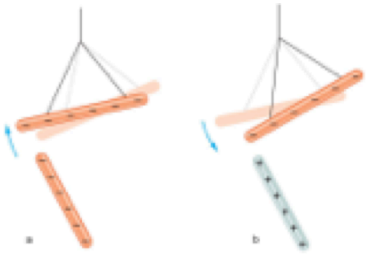
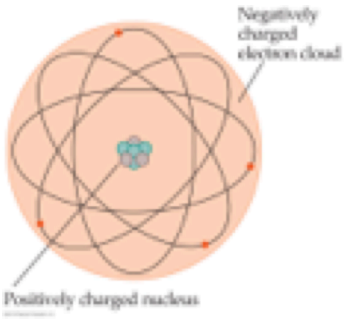


Fig. 2

[Q4] Explain how "Two Kinds of Charges" were defined. Also explain how the definition is related to the modern science.

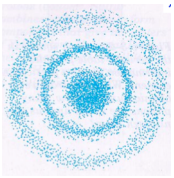
[Q5] What is "Elementary charge"?



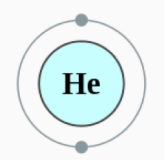
[Q6] State both the sign and magnitude of the charge on a proton, an electron, and a neutron in terms of e, the elementary charge.

[Q7] Which net charge could be found on an object?
(1) 8.00×10^{-20} C (2) 2.40×10^{-19} C (3) 3.20×10^{-19} C (4) 6.25×10^{-18} C

[Q8] Coulomb, C, is the unit of electric charge. How many electrons are there in -1 C of electrons?



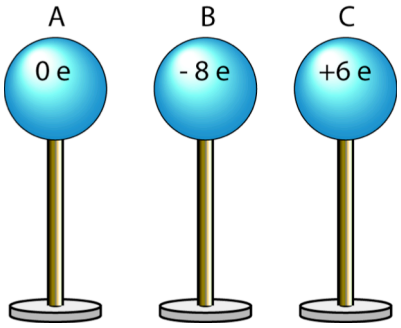
[Q9] Find the amount of positive electric charge in one mole of helium atoms.



2.　Charge Separation

[Q10] How is it that rubbing a piece of amber with fur gives the amber a charge?　Explain the original idea in history and also the modern idea.

[Q11]　Explain about, insulators, conductors and semiconductors.　Show examples.

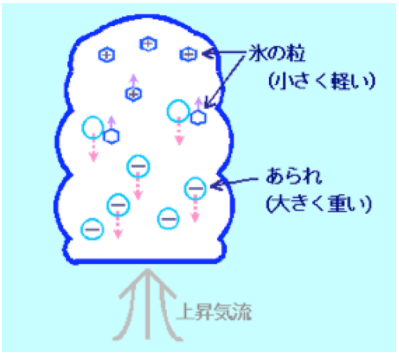


[Q12] The diagram shows the initial charges and positions of three metal spheres, A, B and C on insulating stands. A is brought into contact with B and then removed.　Then B is brought into contact with C and removed.　What is the charge on C?　(PS115)

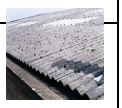
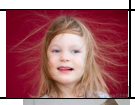
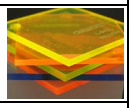
[Q13] An electrically neutral amber is rubbed with electrically neutral fur, and the amber is charged.　As the result being charged does the mass of the amber increase, decrease, or stay the same in principle?　Explain.

[Q14] In dry weather we experience electricity shocks when we take of a sweater or we touch a metal knob.　What causes such static shocks?　空気が

[Q15] Lightning bolt.　“Spoke” in Saturn’s ring.



[Q15] The table is called Triboelectric Series, which presents relative charging due to rubbing. Predict what happens when rubber, PVC, Acrylic resin or Teflon is rubbed with fur.　How about when Acrylic resin is rubbed with nylon or silk?

Most Positive (+)		
Air	Aircraft/air friction	
Dry human skin		
Asbestos		
Rabbit fur		
Glass		
Mica		
Human Hair	Fly-away hair 	
Nylon		
Plexiglass (Acrylic resin)	Acrylic resin and Acrylic fiber are different materials	
Wool		
Lead		
Cat fur		
Silk		
Aluminum		
Paper		
Cotton	Best for non-static cloth	
Steel		
Wood		

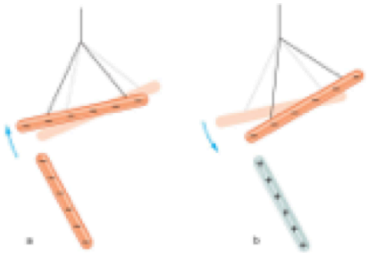
Amber		
Ebonite (Hard rubber)		
Nickel, Copper		
Brass, Silver		
Gold. Platinum		
Sulfur		
Rayon		
Polyester fiber		
Celluloid		
Polystyrene		
Orlon (Acrylic fiber)		
Saran		
Polyurethane		
Polyethylene		
PVC		
Silicone		
Teflon		
Most Negative (-)		

+ More Positive

− More Negative

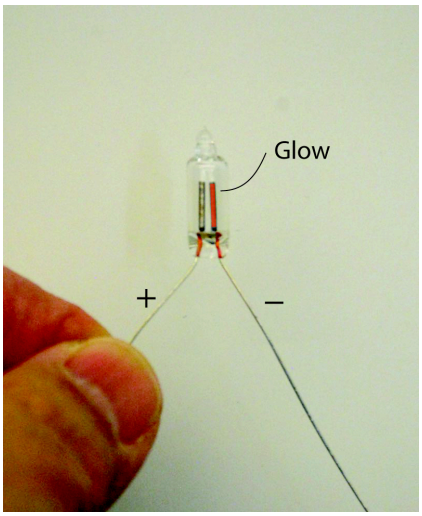
3. Interaction between Charged Materials

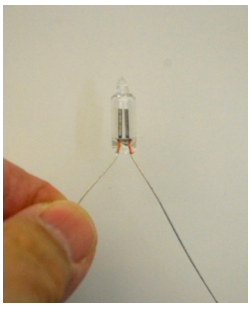
[Q5] Explain about "Like Charges Repel; Unlike Charges Attract."



[Q6-Lab] Verify the kind of charge on a acryl rod when it is rubbed with fur. Also verify the kind of charge on a acryl rod when it is rubbed with silk.

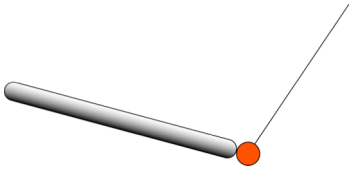
[Q7 – Lab] The kind of charge generated can also be determined using a neon lamp.



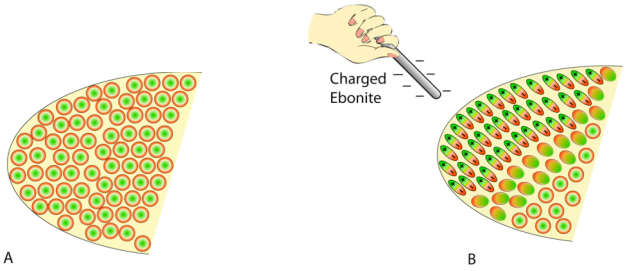


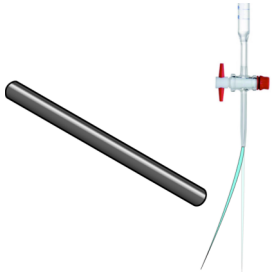
4. Interaction between Charged Material and Insulators --- Polarization

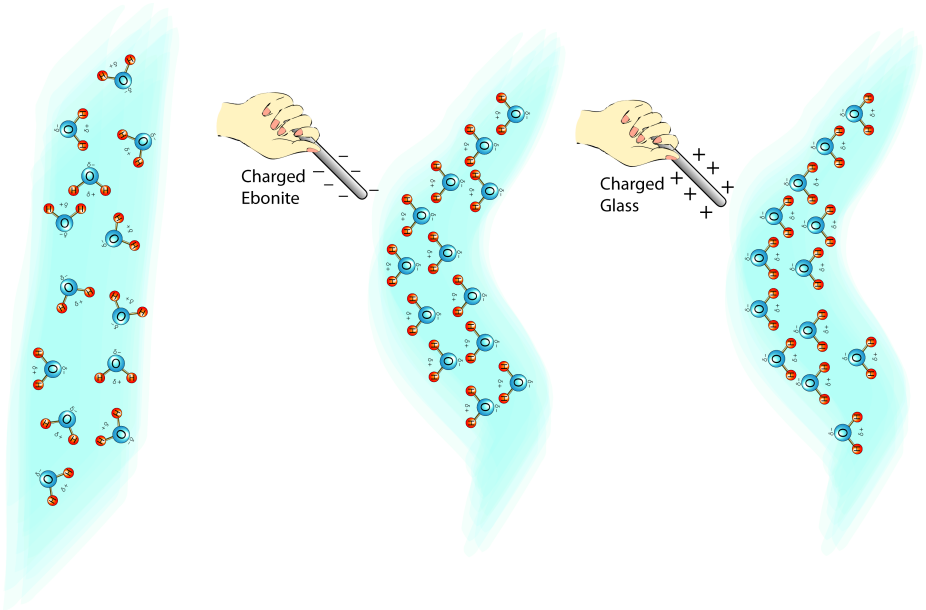
[Q8] **Explain why a PVC rod that has been rubbed with fur** attracts small polystyrene balls, small bits of paper or water stream, even though the balls, paper or water are uncharged?



[Theory] (Dielectric) Polarization

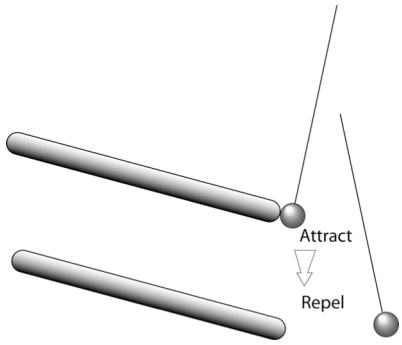




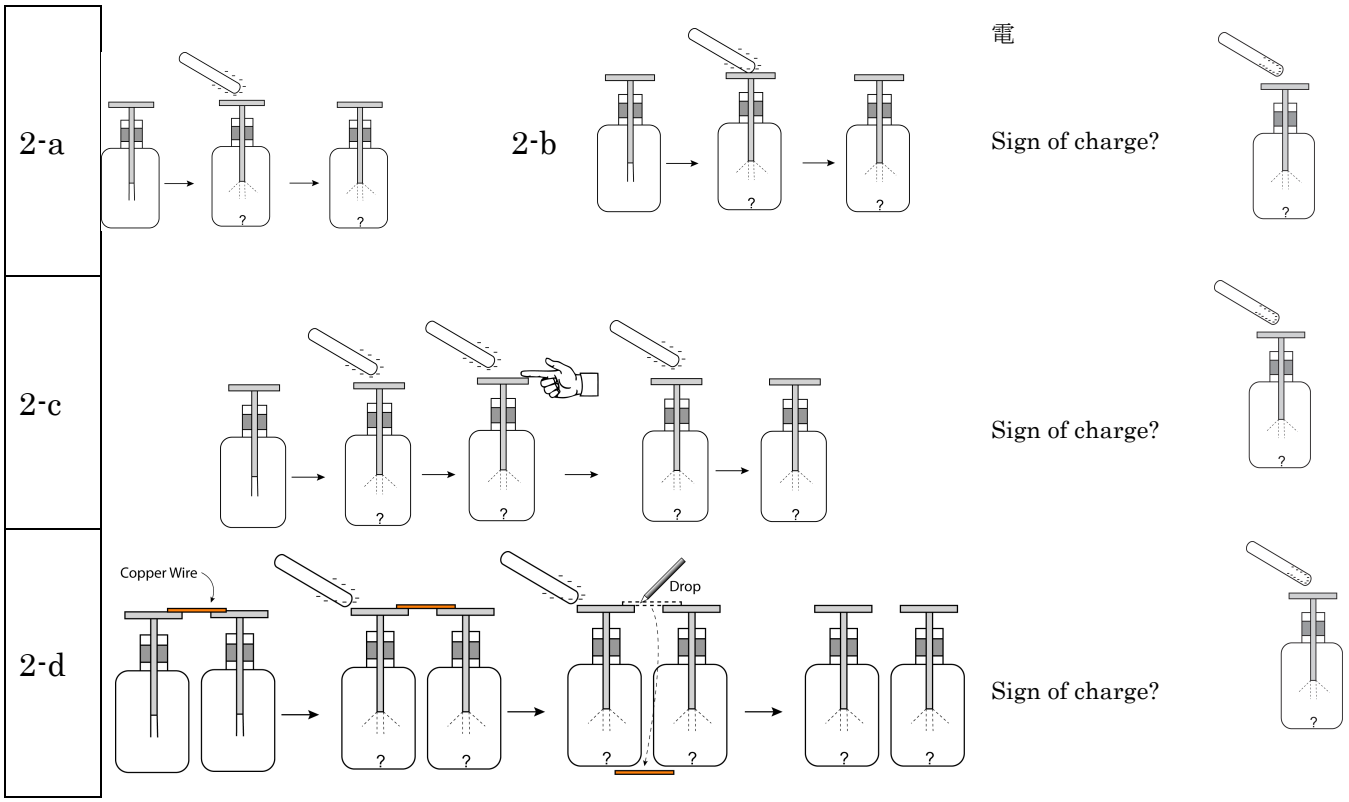


5. Interaction between Charged Material and Conductors --- Induction

[Q7] **Explain why a PVC rod that has been rubbed with fur** attracts small aluminum-coated balls and then repels them, even though the balls are uncharged in the beginning?

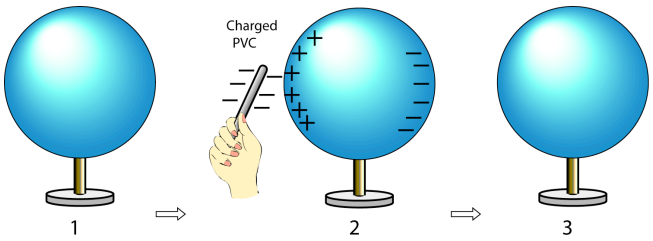


[Q20] The figure shows an experiment using an electroscope. Draw the leaves, open or closed, and the distribution of charges.

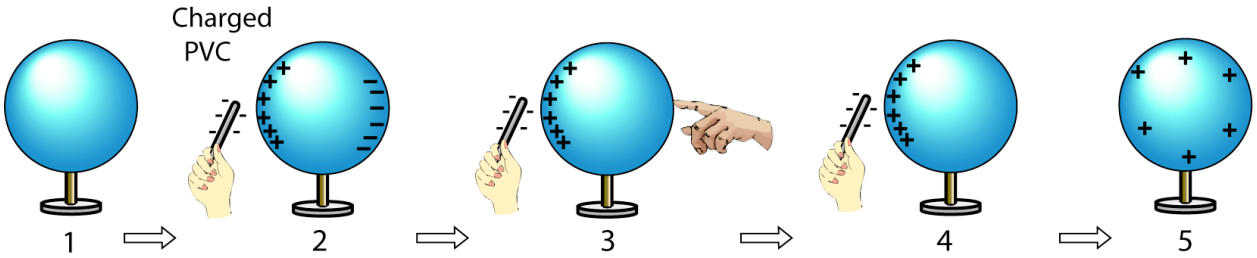


[Theory] Electrostatic Induction

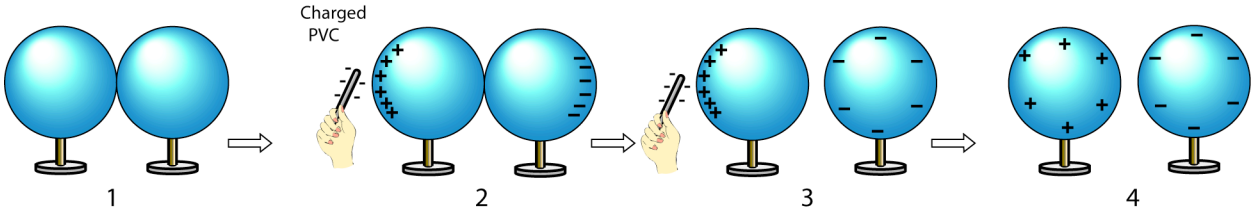
a)



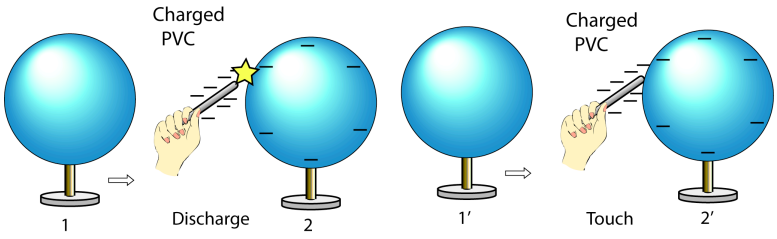
b)



c)



d)



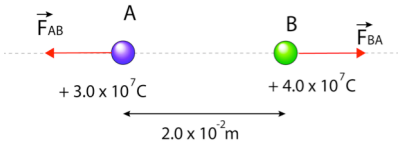
II. Coulomb's Law

Coulomb's Law $$F = k\frac{|q_1||q_2|}{r^2} \quad (5)$$

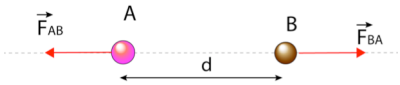
$$k = 8.99 \times 10^9 \ N \cdot m^2/C^2 \quad (6)$$

[Q1] As you learned in the lab of static electricity, the force of attraction or repulsion is exerted between two electric charges. Then, if a particle A has ten times more charge in magnitude than another particle B, which force is larger, the force A exerts B or B exerts A?

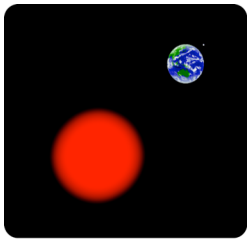
[Q2] A point charge A of +3.0 x 10^{-7} C is placed 2.0 x 10^{-2} m from a second point charge B of +4.0 x 10^{-7} C. Calculate the magnitude of the electrostatic force between A and B.



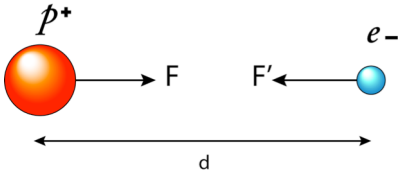
[Q3] The electrostatic force of attraction between two small spheres that are 1.0 m apart is 3.0 N. What is the electrostatic force if the distance is decreased to 0.30 m?



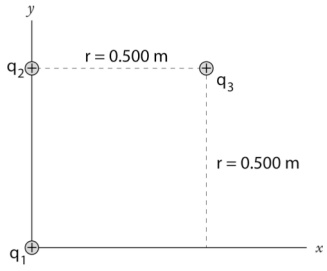
[Q4] Describe some of the similarities and differences between Coulomb's law and Newton's law of gravity.



[Q5] An electron and a proton, initially separated by a distance d, are released from rest simultaneously. The two particles are free to move. When they collide, are they (a) at the middle point of their initial separation, (b) closer to the initial position of the proton, or (c) closer to the initial position of the electron?

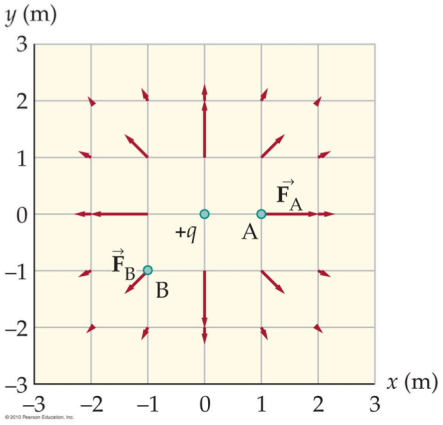


[Q6] Three charges, each equal to +2.90 μ C, are placed at three corners of a square 0.500 m on a side, as shown in the diagram. Find the magnitude and direction of the net force on charge q_3.



III. Electric Field

The positive charge +q at the origin of this coordinate system exerts a different force on a "positive test charge q_0 " at every point in space. "A force per charge, F/ q_0 " at every point is independent of q_0.



Electric Field, $\vec{E}$	$\vec{E} \equiv \frac{\vec{F}}{q_0}$	[N/C]	(8)
	$\vec{F} = Q\vec{E}$		(9)

[Q18] (a) Find the electric field at a point where a force of 12 N exerts on a charge of 3C.
(b) A charge of −0.5C is placed on this point. Find the force exerted on the charge.

[Q19] A uniform electric field has a magnitude of 4.60×10^4 N/C and points in the positive x direction. Find the magnitude and direction of this field exerts on a charge of (a) +2.80 μ C and (b) -9.30 μ C.

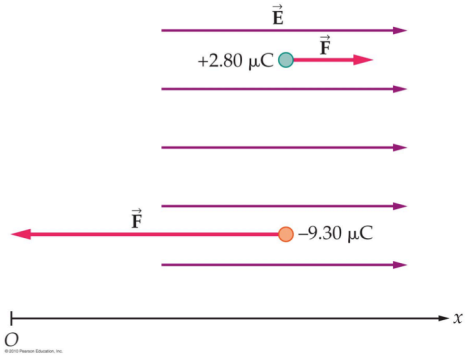


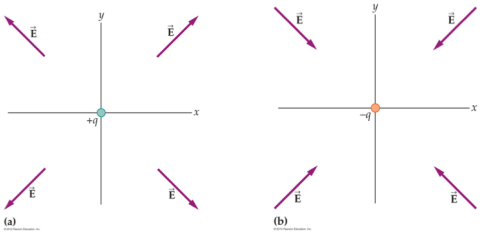
Fig. 19

1 . Electric Field of a Point Charge

Magnitude of Electric Field Due to a Point Charge

$$E = k\frac{|q|}{r^2} \qquad (10)$$

[Q20] A charge of is at the origin O. Find the magnitude of direction of the magnetic field at the point of x = +0.3 m.



The direction of the electric field.

[Q21] Find the electric field produced by a 1.0 μ C point charge at a distance of (a) 0.75 m and (b) 1.5 m.

[Q24] What is the magnitude of the electrostatic force experienced by one elementary charge at a point in an electric field where the magnitude of the electric field strength is 3.0 x 10^3 N/C?

2. Superposition of Fields

[Q22] In the figure at the right, $\vec{E}_1$, $\vec{E}_2$ and $\vec{E}_3$are electric fields at point P due to the three charges, q1, q2 and q3, respectively. Find the net electric field at point P using the graph method.

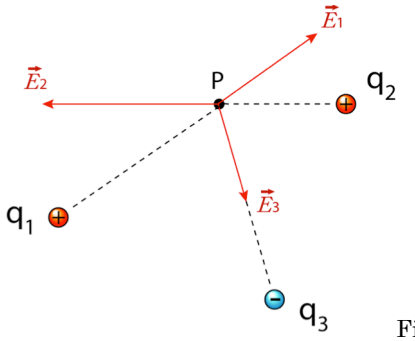


Fig. 22

[Q23] Two charges are placed at two of the vertices, B and C, of an equilateral triangle of side 0.60 m. Charge B is -2.0×10^{-10}C; charge C is 2.0×10^{-10}C.
(a) Find the magnitude and direction of the net field at A.
(b) Find the magnitude and direction of the net field at D, the middle point between B and C.

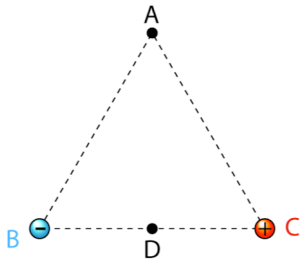


Fig. 23

[Q24] Two charges, q_1 and q_2, 、は同じ大きさの電荷を持ち図のような位置にある。点 P の電場は垂直上向きである。電荷、q_1 と q_2、についてどれが正しいか。
(a)　q_1が正で q_2が負。(b) q_1が負で q_2が正。　(c) q_1 と q_2とも同符号。

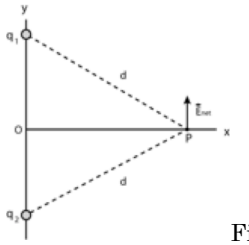


Fig. 22

[Q25] 同じ電荷量+2.90 μC の電荷が 2 個図のような位置にある。点 3 の電場の大きさと向きを求めよ。

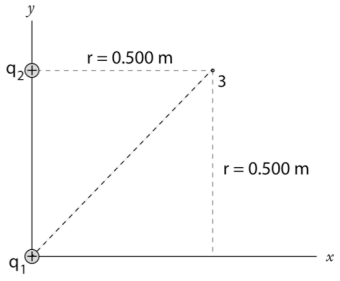
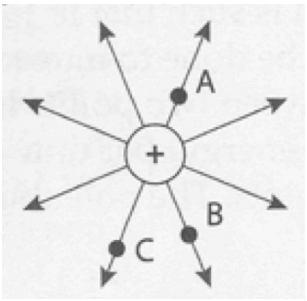


Fig.23

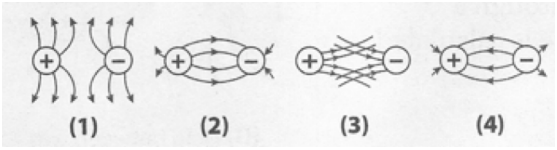
2. Electric Field Lines

[Q25] The diagram shows some of the electric field lines of around a positive point charge. Which point has the greatest magnitude of the electric field?

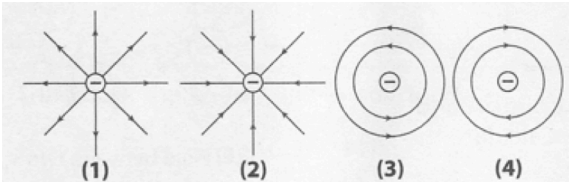


[Q26] A charged particle is placed in an electric field E. If the charge on the particle is doubled, how is the magnitude of the force exerted on the particle by the field changed?

[Q27] Which diagram best illustrates the electric field around two unlike charges?

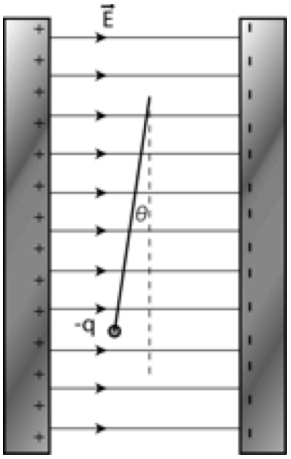


[Q28] Which diagram best represents the electric field of a point negative charge?



3. Electric Field of a Parallel-Plate Capacitor

[Q29] The electric field between the plates of a parallel-plate capacitor if horizontal, uniform, and has magnitude E. A small object of mass 0.0250 kg and charge $-3.10\,\mu$C is suspended by a thread between the plates, as shown in the figure. The thread makes an angle of 10.5° with the vertical. (a) Find the tension of the thread. (b) Find the magnitude of the electric field.



IV. Electric Potential Energy and Electric Potential

9. Electric Potential Energy of a Charge

$$\Delta U = -W = -qEd \qquad (21)$$

10. Electric Potential

$$V \equiv \frac{U}{q_0} \text{ [V]} \qquad (22) \qquad q_0 > 0$$

$$U = qV \qquad (23)$$

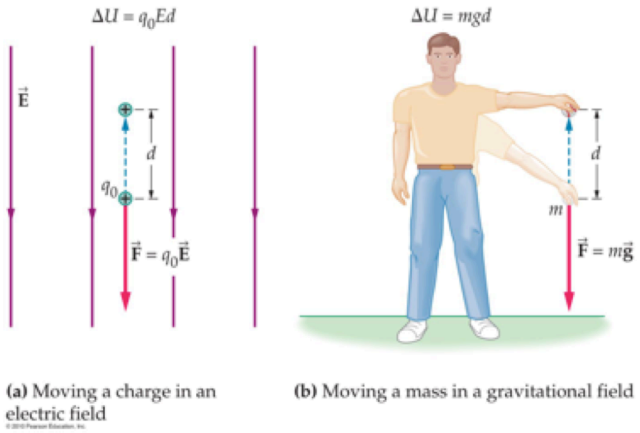
$$1 \text{ V} = 1 \text{ J/C} \qquad (24)$$

11. Electric Field and Electric Potential

$$E = \frac{V}{d} \qquad (25)$$

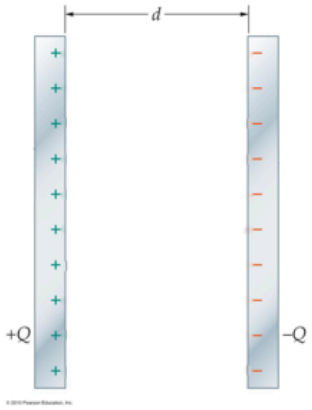
$$1 \text{ N/C} = 1 \text{ V/m} \qquad (26)$$

[Q1] The figure shows the comparison between gravitational and electric forces. There is some similarities between the two forces. Explain.



(a) Moving a charge in an electric field (b) Moving a mass in a gravitational field

[Q2] The figure shows a parallel-plate capacitor. Draw electric field lines .
Explain about the electric field and electric potential.



9. Electric Potential Energy of a Charge

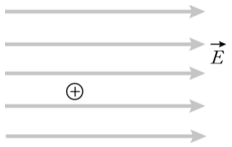
$$\Delta U = -W = -qEd \quad (21)$$

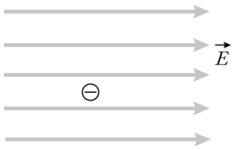
10. Electric Potential 電位

$$\Delta V \equiv \frac{\Delta U}{q_0} = \frac{-W}{q_0} \text{ [V]} \quad (22) \qquad q_0 > 0$$

1 V = 1 J/C (23)

[Q2] A positive charge of 3.2 x 10^{-19} C experiences a force due to the electric field $\vec{E}$ and moves through a potential difference of 30 V. Find the work done by the electric field.





[Q3] Find the change in electric potential energy, ΔU, as a charge of (a) 2.20 x 10^{-6} C or (b) −1.10 x 10^{-6} C moves from a point A to a point B, given that the change in electric potential between these point is $\Delta V = V_B - V_A = 24.0V$.

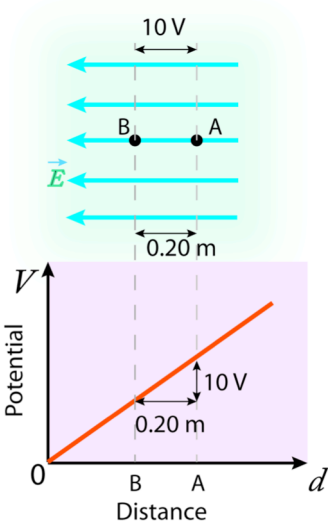
2. Electric Field and Electric Potential

$$E = \frac{V}{d} \quad (24)$$

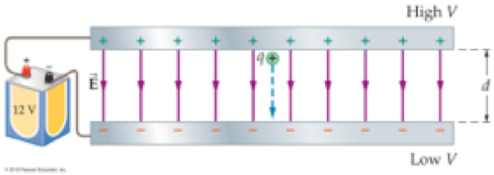
$$1\ \text{N/C} = 1\ \text{V/m} \quad (25)$$

Uniform Electric Field

[Q6] Two points placed 0.20 m apart in the direction of a uniform electric field, where the electric potential of A is higher than that of B. (a) Find the magnitude of the electric field.
(b) When a positive charge of 3.4 x 10^{-7} C is placed in the electric field, find the force exerted by the electric field on the charge.
(c) When the charge travels from A to B, find the work done by the force of the electric field.



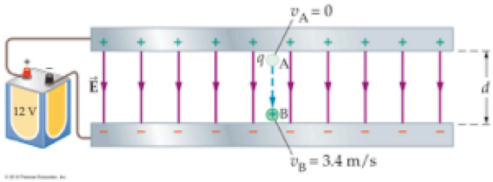
[Q8] A uniform electric field is established by connecting the plates of a parallel-plate capacitor to a 12-V battery. (a) If the plates are separated by 0.75 cm, what is the magnitude of the electric field in the capacity? (b) A charge of +6.24 x 10^{-6} C moves from the positive plate to the negative plate. Find the change in electric potential energy for this change.



X.　Energy Conservation

$$K + U = K' + U',\ \frac{1}{2}m v^2 + qV = \frac{1}{2}m v'^2 + qV' \quad (26)$$

[Q10] (a) 質量 m = 1.75 x 10^{-5}kg で電荷量 q = 5.20 x 10^{-5} C の粒子が点Aで放たれた。粒子が別の点 B に動いたときに電位が 60.0 V 減少した。点 B における速さを求めよ。(b) 同じ粒子の点Aにおける初速度が 5.00 m/s であるとき点 B における速さを求めよ。



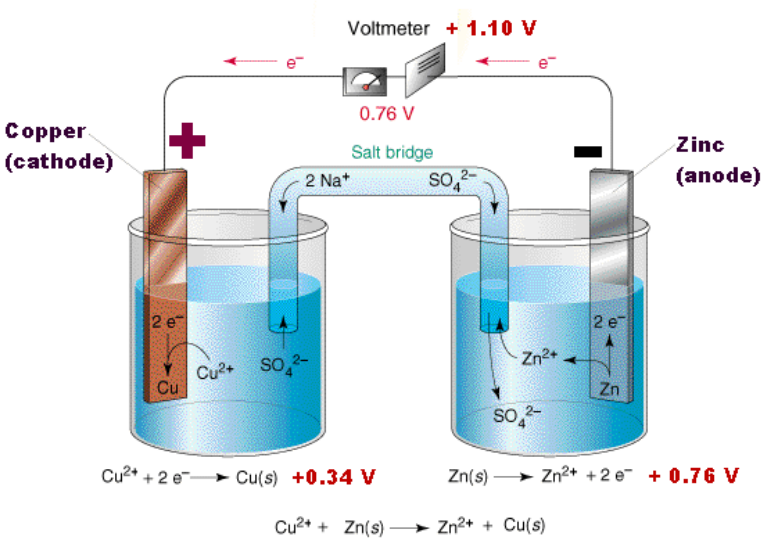
[Q11] 金属板間の距離が 0.75 cm の平行平板コンデンサーに 12 V の電池をつないで一様電場を作った。+6.24 x 10^{-6} C の電荷が正極板から放たれ負極板に着いたときの速さが 3.4 m/s である。(a) 電荷の質量はいくらか。(b) 着いたときの運動エネルギーはいくらか。

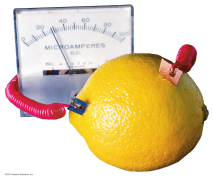
[Q12] 2 枚の広い電極を 0.20 m 離し、この電極間に電位差を 4.0 V かけた。この電場の中に電子を静かに置く。
(a) 電場の大きさと、電子が電場から受ける力を求めよ。
(b) 電子が負極板から正極板に移動したとき、電場が電子にした仕事はいくらか。
(c) 正極に達したときの電子の速さはいくらか。

[Q13] 質量 2.5 x 10^{-26} kg で 1.6 x 10^{-19} C の正の電荷をもつイオンが、正の極板から初速 0 で動きだし、2000 V の電位差の負の極板に達した。
(a) 正のイオンが電場からされた仕事はいくらか。
(b) この仕事がすべてこのイオンの運動エネルギーになったとすると、負極板に達したときのイオンの速さはいくらか。

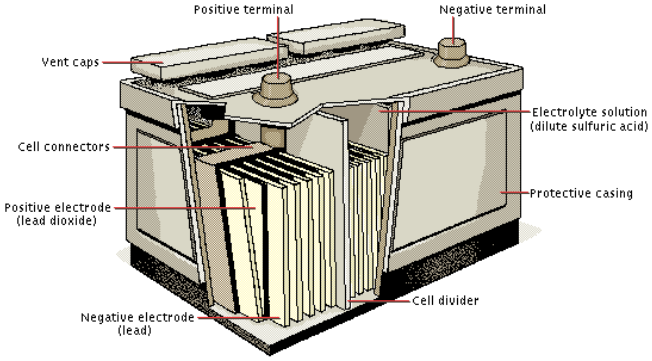
Galvanic Cells, Batteries

[Q1] Typical Structure of a galvanic cell

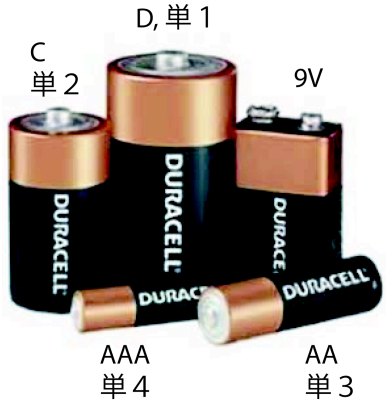


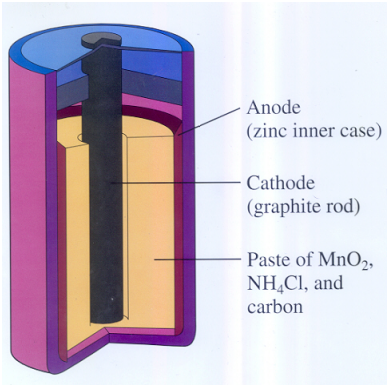


[Q3] Car battery



[Q2] Dry batteries





Leaking

— Electric Circuits

— Quantities in Electricity

[Q31] The disk drive in a portable CD player is connected to a battery that supplies it with a current of 0.22 A. How many electrons pass through the drive in 4.5 s?

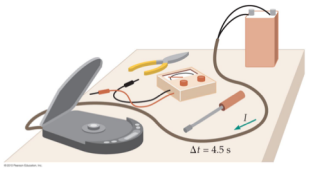
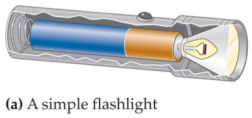


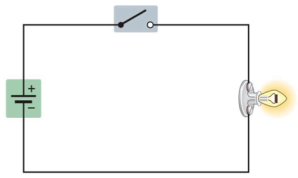
Fig. 31

[Q32] Explain about two kinds of electric circuits, direct-current (DC) circuits and alternating-current (AC) circuits.

[Q33] The figure shows a simple flashlight and its circuit design. Explain about the symbols in the circuit.



(a) A simple flashlight



(b) Circuit diagram for flashlight

Fig. 33

[Q34] Explain about the direction of current and electron flow using Fig. 13.

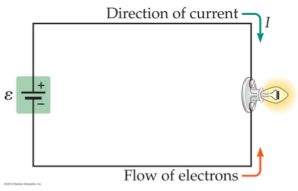


Fig. 34

[Q35] (a) An electric device operates on a 120V. If the power consumed by the device is 1500W, what is the current in it? (b) When the above device operates during 8.0 hours, find the electric energy consumed in kWh.

Fig. 35

— Ohm's Law and Resistance

[Q36] A potential difference of 24 V is applied to a 150 Ω resistor. How much current flows through the resistor? Find also the electric energy consumed.

Resistivity (20℃)

Substance	Resistivity, ρ (Ω • m)
Insulators	
Quartz (fused)	7.5×10^{17}
Rubber	$1 \text{ to } 100 \times 10^{13}$
Glass	$1 \text{ to } 10{,}000 \times 10^{9}$
Semiconductors	
Silicon*	0.10 to 60
Germanium*	0.001 to 0.5
Conductors	
Lead	22×10^{-8}
Iron	9.71×10^{-8}
Tungsten	5.6×10^{-8}
Aluminum	2.65×10^{-8}
Gold	2.20×10^{-8}
Copper	1.68×10^{-8}
Silver	1.59×10^{-8}

[Q37] Find the resistance at 20℃ of copper wire where it has a cross-sectional area of 1.0 mm² and a length of 10 m. Use the value of resistivity in the table.

[Q38] Wire 1 has a length L and a circular cross section of Diameter D. Wire 2 is constructed from the same material as wire 1 and has the same shape, but its length is 2L, and its diameter is 2D. By what factor does the resistance of Wire 2 change in comparison with Wire 1?

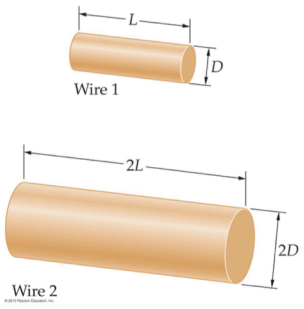


Fig. 38

Electric Circuits

1. Electric current is like water current. Water flows when there is a potential difference. Electric current also flows when there is an electric potential difference (voltage).

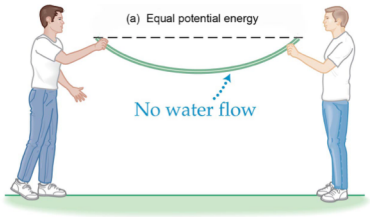


Fig 1-a

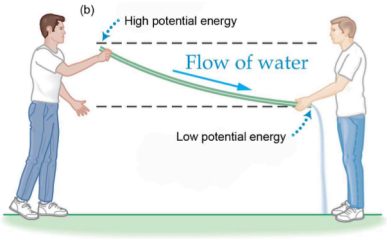


Fig 1-b

2. A basic electric circuit consist of a battery and a resistor. A battery creates electromotive force (Emf), E [V], and a resistor has a resistance, R [Ω], that consumes electric energy.

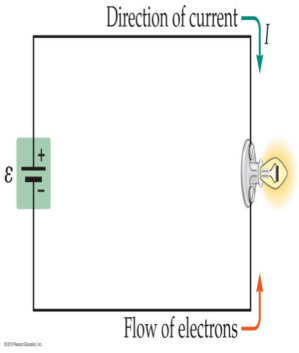


Fig. 2

3. In the basic circuit consisting of a battery and a resistor, the current of the circuit is calculated by the Ohm's Law.

$$I = \frac{V}{R}$$

I: Current 電流 [A]

V: Voltage 電圧 [V]

R: Resistance 抵抗 [Ω]

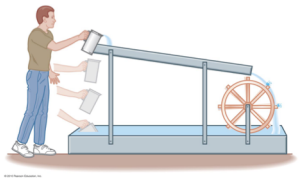


Fig. 3

3. Power produced by a battery and dissipated by the resistor.

$P = VI = RI^2 = \frac{V^2}{R}$

P: Power [W]

$W = Pt$ W: electric Energy [J], [Wh]

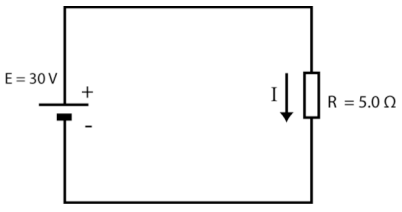
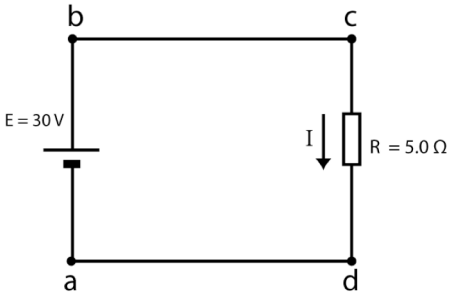


Fig. 4

[Q1] A circuit consists of R=5.0Ω resistor connected in series to a 30 V battery.　Find the followings: the current through the resistor, the voltage drop at the resistor, the power produced by the battery, the power dissipated at the resistor and the potential at b ~ d when the potential of the point a is 0.

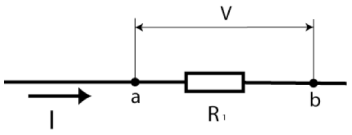


1) A battery produces electromotive force (emf), E [V].　The voltage (= potential difference) applied the resistor, V, is equal to E in this simplest case.

2) Current I [A] is determined by V [V] and resistance R [Ω].

$$I = \frac{V}{R}$$

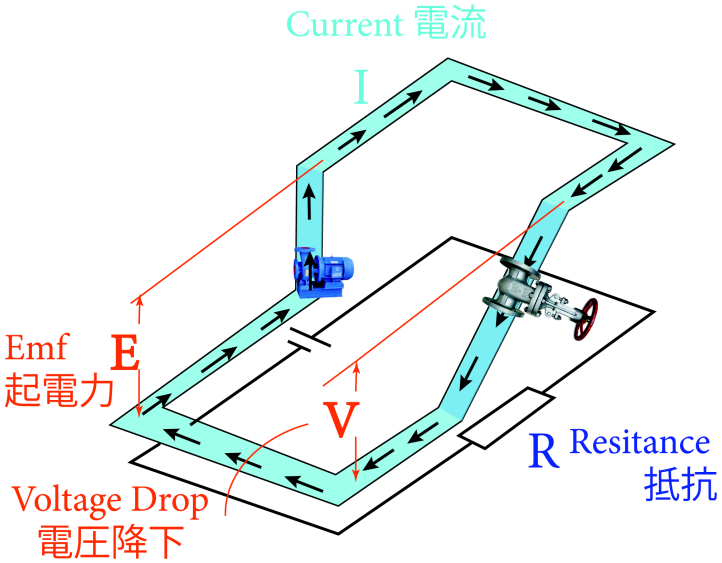
3) When a current flows through a resistance a voltage drop always occurs.　The potential drop V [V] is determined by the Ohm's Law.



4) Power produced by a battery and dissipated by the resistor.

$$P = VI = RI^2 = \frac{V^2}{R}$$

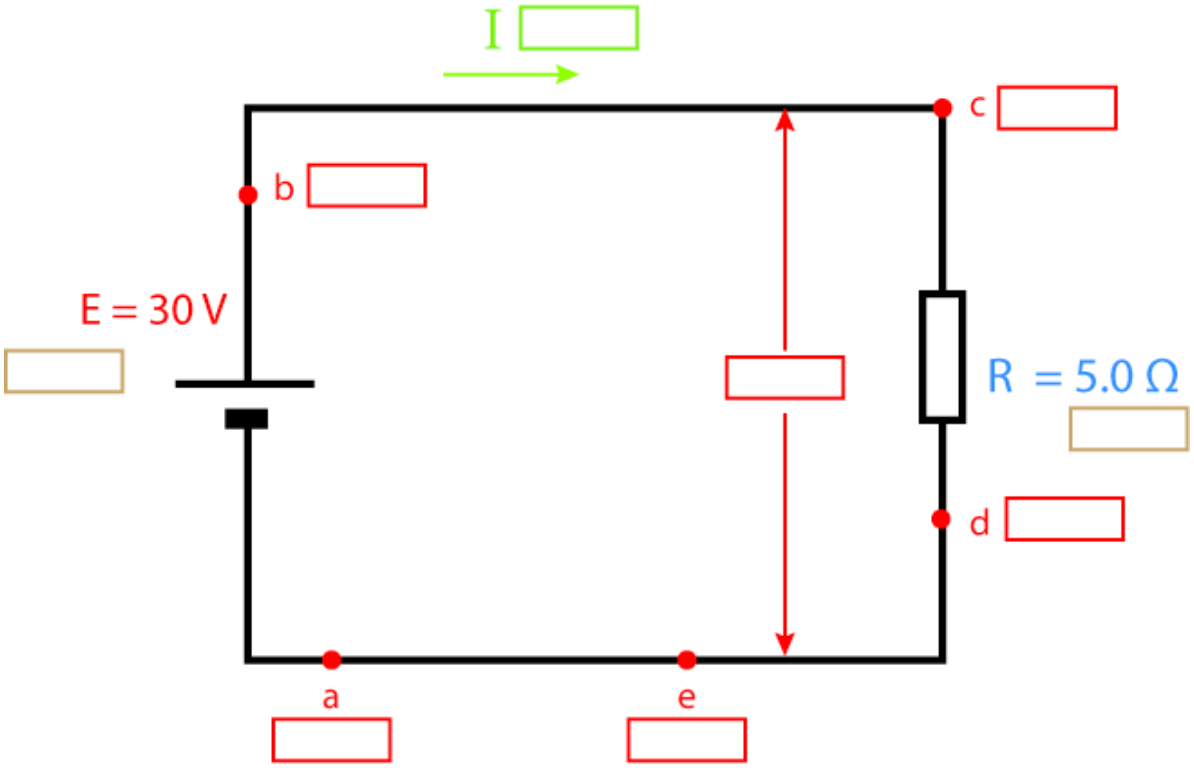
5) Potential in each point.



Aqueduct Model
1）Pump　=　Battery
　Height of water raised by a pump = emf
2）Height of water　=Potential

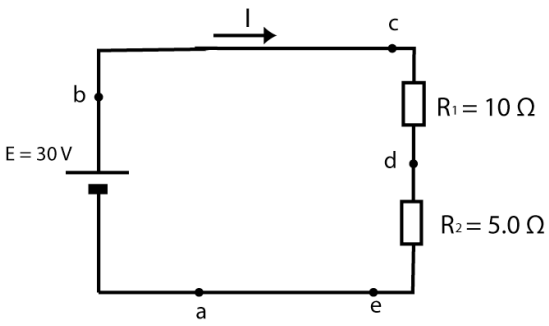
3）水流の流量　=　電流
4）調節弁　=　抵抗
　弁で落ちる水の高さ＝電圧降下

水量（電流）は、ポンプが持ち上げる水の高さ（起電力）と調節弁（抵抗）で決まる。


I
c
b
E = 30 V
R = 5.0 Ω
d
a
e

– Series Connection

[Q2] A circuit consists of two resistors connected in series to a 30 V battery.　Find the followings: 1) the current through each resistance, 2) the potential difference between the both sides of each resistance or the voltage drop at the resistor, 3) the power produced by the battery and the power dissipated at the resistor and, 4) the potential values of b, c, d and e if the potential of the point a is assumed to be 0 V.



２個の抵抗と 30 V の電池からなる回路がある。次を求めよ。

1. 各抵抗を流れる電流
2. 各抵抗の両端の電位差（電圧降下）
3. 電池で生じる電力、抵抗が消費する電力、
4. 点 a の電位を 0 V としたとき、b, c, d, e の電位

1) Calculate the equivalent resistor.　合成抵抗の計算

$$R = R_1 + R_2 + \cdots + R_n$$

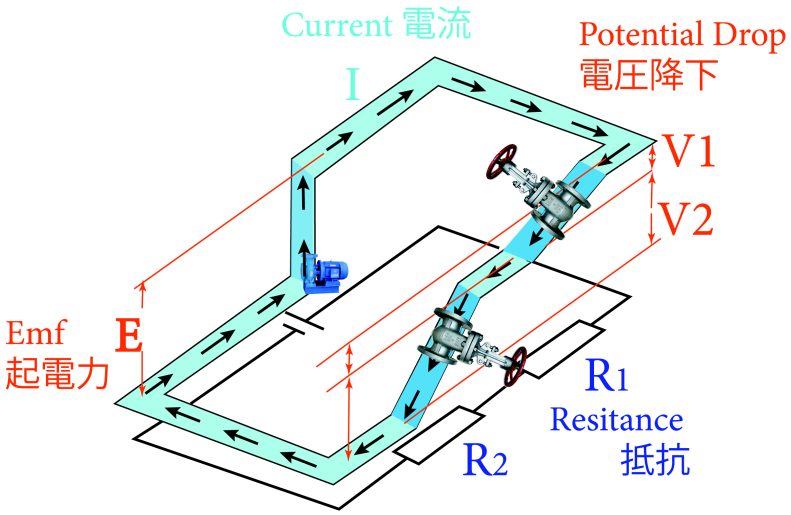
2) Find the total current, I_{total}.　全電流の算出　$I = \frac{V}{R}$

3) Find the voltage drops　電圧降下の算出　$V = IR$

4) Power produced by a battery and dissipated by the resistor.
電池が生産する電力と抵抗が消費する電力

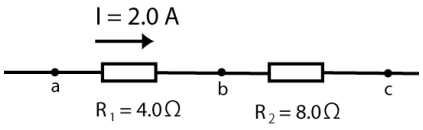
$P = VI = RI^2 = \frac{V^2}{R}$

5) Find the potentials　電位の算出

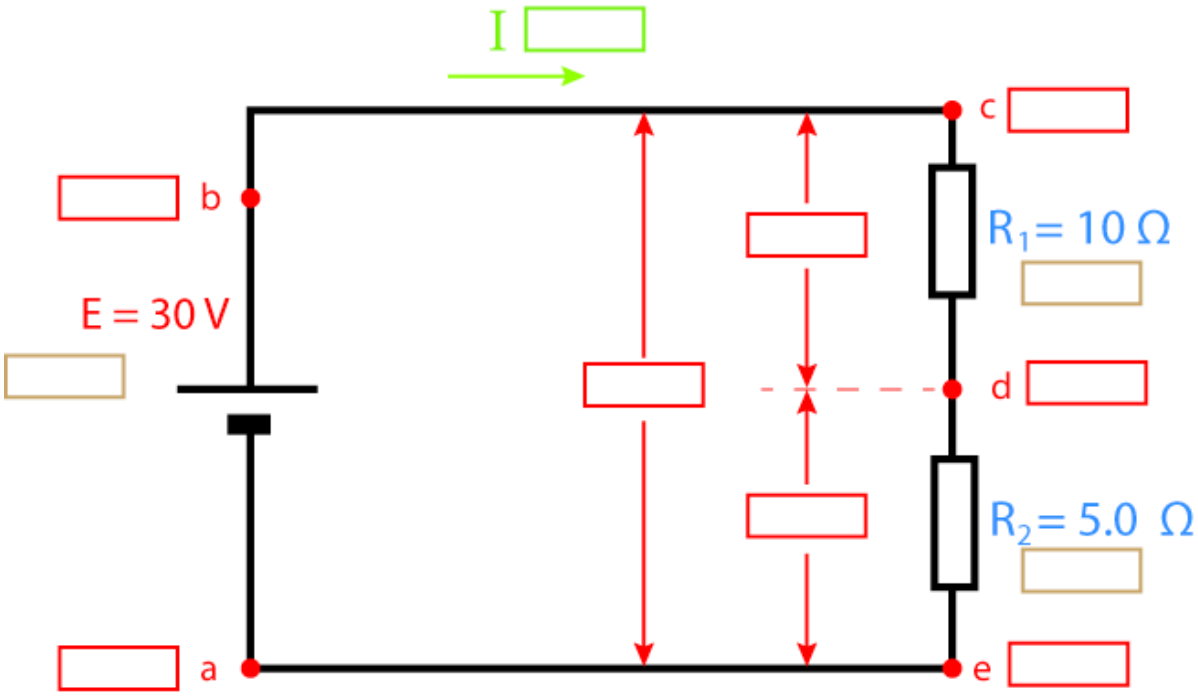


水路のモデルと比較しよう

[Q3] A 4.0 Ω resistor and 8.0 Ω resistor are connected in series, as shown in the figure.　If the current through the 4 Ω resistor is 2.0 A, what is the current through the 8.0 Ω　resistor?
右図に示すように、4.0 Ω の抵抗が 8.0 Ω の抵抗と直列に接続されている。もし、4.0 Ω の抵抗に 2.0A の電流が流れている時 8.0 Ω の抵抗に流れる電流はいくらか。



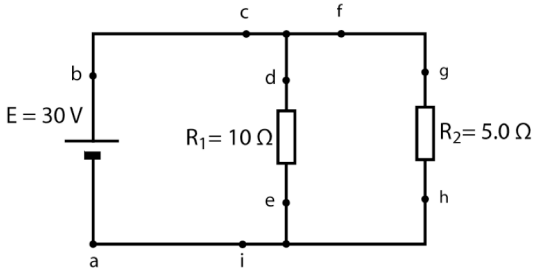
[Q4] In the previous circuit, what is the potential difference (voltage) between the points, b and c?
前の回路で、点 b と c の間の電位差（電圧）はいくらか。


I
c
b
$R_1 = 10\ \Omega$
E = 30 V
d
$R_2 = 5.0\ \Omega$
a
e

– Parallel Connection

[Q5] A circuit consists of two resistors connected in series to a 30 V battery.　Find the followings: 1) the current through the point b, 2) the potential difference between the both sides of each resistance or the voltage drop at the resistor, 3) the current through each resistance, 4) the power produced by the battery and the power dissipated at the resistor and, 5) the potential values of b~i if the potential of the point a is assumed to be 0 V.
２個の抵抗と 30 V の電池からなる回路がある。次を求めよ。

1　点 b を流れる電流
2　各抵抗の両端の電位差（電圧降下）
3　各抵抗を流れる電流
4　電池で生じる電力、抵抗が消費する電力、
5　点 a の電位を 0 V としたとき、b~i の電位



1) Calculate the equivalent resistor.　合成抵抗の計算　$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots\cdots + \frac{1}{R_n}$

2) Find the “total current”.　「全電流」の算出　$I = \frac{V}{R}$

3) Find the voltage drops　電圧降下の算出　$V = I R$

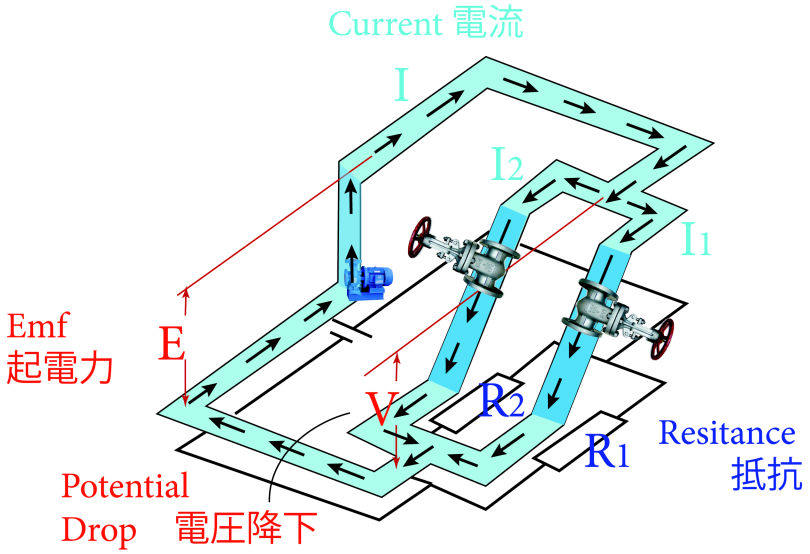
4) Find the current flowing through each resistance.各抵抗を流れる電流の算出　$I_n = \frac{V}{R_n}$

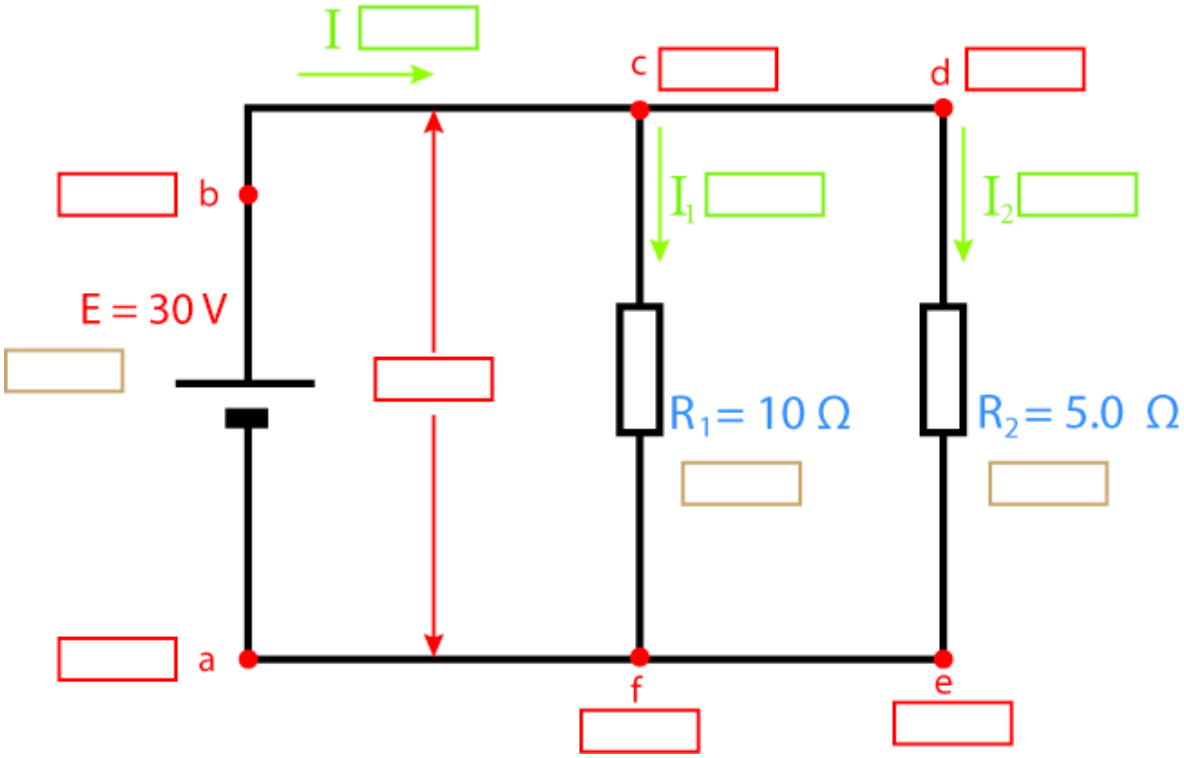
5) Power produced by a battery and dissipated by the resistor.
電池が生産する電力と抵抗が消費する電力

P　＝　V I =　R I²　＝　$\frac{V^2}{R}$

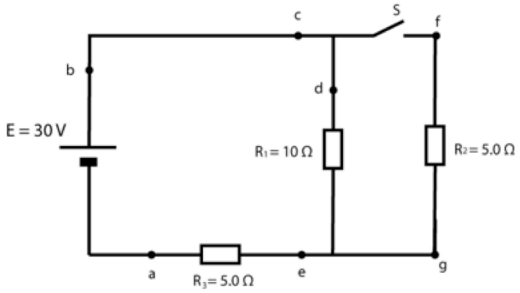
6) Find the potentials　電位の算出

水路のモデルと比較しよう




I
c
d
b
I_1
I_2
E = 30 V
R_1= 10 Ω
R_2= 5.0 Ω
a
f
e

– Mixed Connection



[Q6] When the switch S is closed, determine the followings: 1) the current through the point b, 2) the potential difference between the both sides of each resistor or the voltage drop at the resistor, 3) the current through each resistance, 4) the power produced by the battery and the power dissipated at the resistor and, 5) the potential values of b~g if the potential of the point a is assumed to be 0 V.
２個の抵抗と 30 V の電池からなる回路がある。次を求めよ。
1　点 b を流れる電流
2　各抵抗の両端の電位差（電圧降下）
3　各抵抗を流れる電流
4　電池で生じる電力、抵抗が消費する電力、
5　点 a の電位を 0 V としたとき、b~g の電位

1)　Calculate the equivalent resistor.　合成抵抗の計算（計算の順序が大事）

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots\cdots + \frac{1}{R_n} \qquad R = R_1 + R_2 + \cdots + R_n$$

2) Find the “total current”.　「全電流」の算出　$I = \frac{V}{R}$

3) Find the voltage drops　電圧降下の算出　$V = IR$

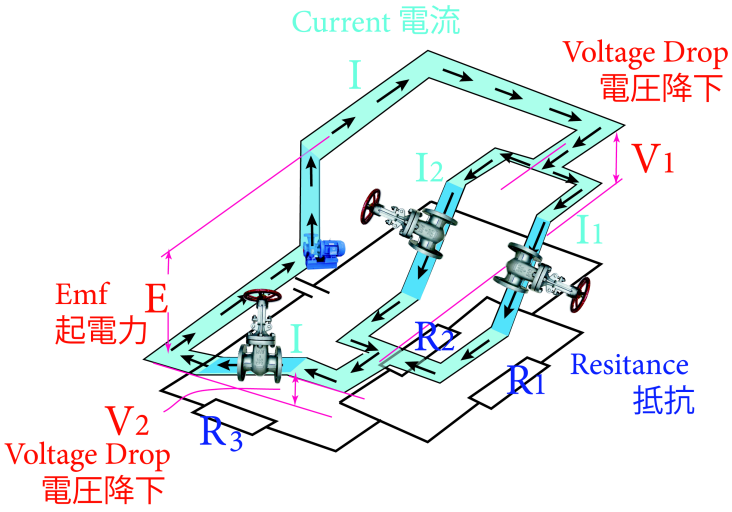
4) Find the potentials　電位の算出

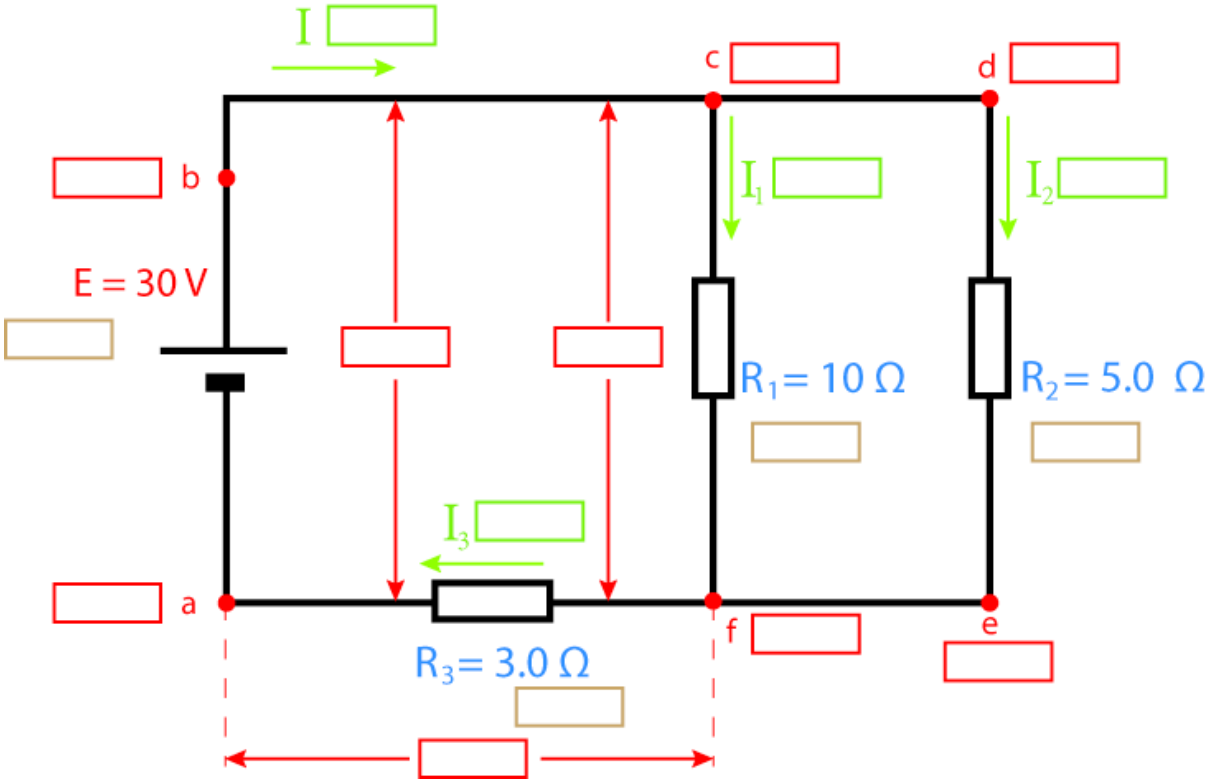
5) Find the current flowing through each resistance.各抵抗を流れる電流の算出　$I_n = \frac{V_n}{R_n}$

5) Power produced by a battery and dissipated by the resistor.
電池が生産する電力と抵抗が消費する電力

$P = VI = RI^2 = \frac{V^2}{R}$

水路のモデルと比較しよう



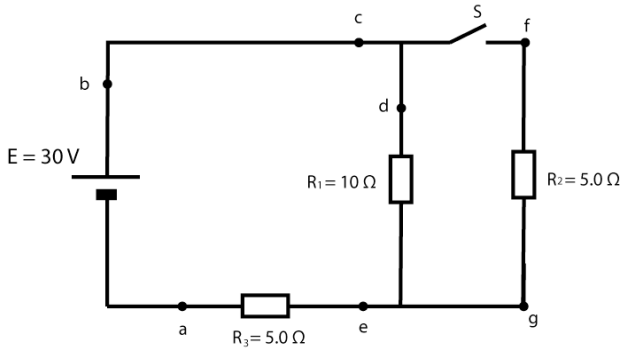

I
c
d
b
I_1
I_2
E = 30 V
R_1= 10 Ω
R_2= 5.0 Ω
I_3
a
f
e
R_3= 3.0 Ω

【Q45】 Consider the circuit shown, where the potential at the point "a" is assumed as 0 V.
示した回路で点 a の電位(potential)を 0V とする。
A)　When the switch S is open, determine the followings:　スイッチ S が開いているとき次を求めよ。

	Switch: open, スイッチ：開	Equations 式	Answer 答
(A-1)	The current at the point "**e**" 点 **e** に流れる電流値		
(A-2)	The potential difference between "**d**" and "**e**" 二点、**d** と **e** 間の電位差（電圧）		
(A-3)	The potential at the point "**e**" 点 **e** の電位（potential）		
(A-4)	The power produced at the **battery** **電池**で発生する電力		

B)　When the switch S is closed, determine the followings:　スイッチ S が閉じているとき次を求めよ。

	Switch: closed, スイッチ：閉	Equations 式	Answer 答
(B-1)	The current at the point "**e**" 点 **e** に流れる電流値		
(B-2)	The potential difference between "d" and "e" 二点、**d** と **e** 間の電位差（電圧）		
(B-3)	The potential at the point "**e**" 点 **e** の電位（potential）		
(B-4)	The power consumed at the 5.0Ω resistor R_2. **5.0Ω抵抗 R_2** で消費される電力		



[Q44] The diagram, Fig. 44, shows a circuit.　In order to measure the current and voltage drop of the resistor R, which connections are right? Write A for ammeter and V for voltmeter in the circles shown. No letter should be written in the circle(s) in wrong connection(s).
図の回路で、抵抗 R を流れる電流と電圧降下を測定するためにはどの接続が正しいか。図の円の中に電流計はA、電圧計は V と書き入れよ。間違った接続の円の中には字を書いてはならない。

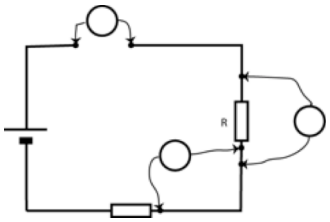
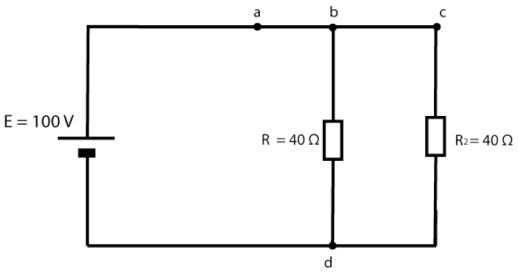
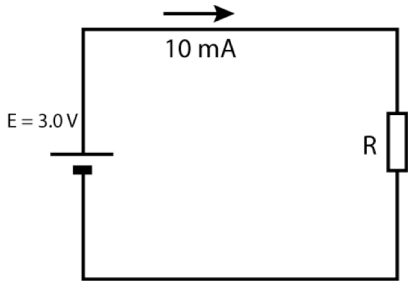


Fig. 44

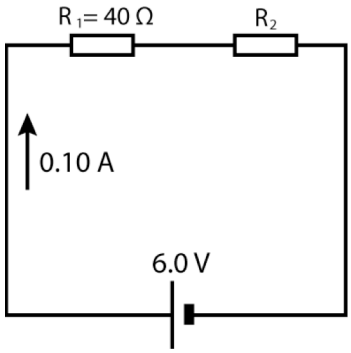
[Q46] (1) Find the equivalent resistance between b and d.
bd 間の合成抵抗はいくらか。
(2) Find the current through the point a.
点 a を流れる電流を求めよ。
(3) Find the current through R_2.
抵抗 R_2を流れる電流を求めよ。
(4) If the point c snaps, find the current through the point d.
もし点 c が断線した時、点 d を流れる電流はいくらか。
(5) What happens in this circuit if the two points, c and d, are short-circuited??
もし点 c と d が短絡（ショート）したら、回路にはどのようなことが起こるか。 (I16)



[Q47] (1) You want to measure the current and voltage drop of the resistor R.　Show how to connect an ammeter and voltmeter.　(2) Find the resistance of the resistor R.　(3) How much power is dissipated in R?　(1) 抵抗 R にかかる電圧と流れる電流を電流計と電圧計を使って測定したい。接続方法を図示せよ。
(2) 抵抗 R の大きさはいくらか。
(3) R で消費される電力はいくらか。　(I17)



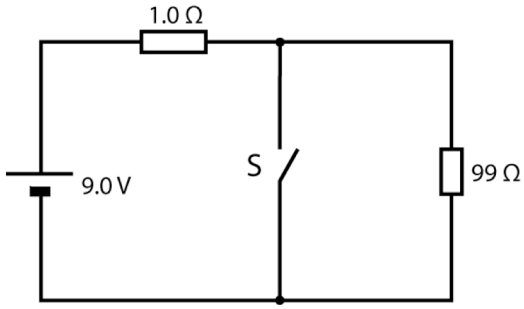
[Q48] A 6.0 V battery, a 40 Ω　resistor, R_1, and another resistor of unknown resistance, R_2, are connected as shown.　Find the resistance of R_2 when the current through R_1 is 0.10 A.
起電力 6.0 V の電池と 40 Ω の抵抗 R_1 と未知の大きさの抵抗 R_2 を図のように接続した。40 Ω の抵抗に流れる電流は 0.10 A であった。未知の抵抗 R_2 の大きさを求めよ。(I17)



[Q49]

(1) When the switch S is open, find the current through the 1.0 Ω resistor and also the power it dissipates.
スイッチが開いているとき、1.0 Ω の抵抗を流れる電流と、消費される電力を求めよ。

(2) When the switch is closed, find the current through the 1.0 Ω resistor and also the power it dissipates.　What factor does it change in comparison with the case above?
スイッチが閉じているとき、1.0 Ω の抵抗を流れる電流と、消費される電力を求めよ。スイッチが開いているときの何倍か。(I17)



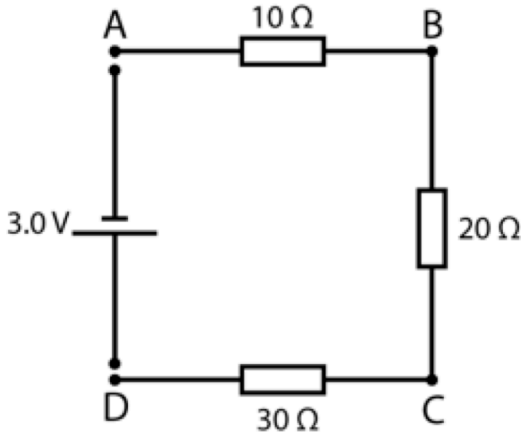
[Q50] The three resistors and a battery are connected as shown.

(1) Find the potential differences, V(A-B), V(A-C) and V(A-D).
AB 間、AC 間、AD 間の電圧はいくらか。

(2) The points A and C are short-circuited.　Find the potential differences, V(A-B), V(A-C) and V(A-D).
A と C を短絡した。AB 間、AC 間、AD 間の電圧はいくらか。

(3) The points B and D are short-circuited.　Find the potential differences, V(A-B), V(A-C) and V(A-D).
B と D を短絡した。AB 間、AC 間、AD 間の電圧はいくらか。

(4) The points A and C, and also the points B and D are short-circuited at the same time.　Find the potential differences, V(A-B), V(A-C) and V(A-D).
A と C 、B と D を同時に短絡した。AB 間、AC 間、AD 間の電圧はいくらか。(I17)



1. Frictional Electricity　まさつ電気
Static Electricity　静電気
Charging　帯電
Charge　電荷、帯電
Insulators and Conductors　絶縁体と導体
(Electrical) Polarization　分極
(Electrostatic) Induction　静電誘導
Transfer of Charges　電荷の移動
Law of Conservation of Charge　電荷の保存則
Electoscope　箔検電器
Electron, Proton　電子、陽子
Elementary Charge　電気素量
Coulomb's Law　クーロンの法則

2. Electric Fields　電場
Electric Field Lines　電気力線
Grounding　アース
Parallel Plates　平行平板
Potential Difference　電位差
Electronvolt (eV)

4. Current　電流
Ampere　アンペア
DC and AC　直流と交流
Battery　電池
EMF, Power Supply　起電力、電源
Voltage　電圧
Volt　ボルト
Power　電力
Electric Energy　電力量
Circuits　回路
Resistor　抵抗
Resistance　抵抗(値)
Ohm's Law　オームの法則
Voltage Drop　電圧降下
Resistivity　抵抗率
Series Connection　直列接続
Parallel Connection　並列接続
Joule Heat　ジュール熱
Discharge　放電
Free Electrons　自由電子
Breaking Down　断線
Short　ショート

Elementary Charge	$e = 1.60 \times 10^{-19}$ C
Electron mass	$m_e = 9.11 \times 10^{-31}$ kg
Proton mass	$m_p = 1.673 \times 10^{-27}$ kg
Neutron mass	$m_n = 1.675 \times 10^{-27}$ kg
Coulomb's Law constant	$k = 8.99 \times 10^{9}$ N・m^2/C^2
Gravitational Acceleration Rate	$g = 9.80$ m/s^2
Universal gravitational constant	$G = 6.67 \times 10^{-11}$ N・m^2/kg^2
Avogadro's Number	$N_A = 6.022 \times 10^{23}$ mol^{-1}