Exercise Solutions

Question 1: An electric current of 2.0 A passes through a wire of resistance 25 Ω. How much heat will be developed in 1 minute?

Solution:
Current through the wire= i = 2 A
Resistance of the wire = R = 25 Ω
t = 1 min = 60 s
We know Joule's heating effect, heat developed across the wire,

$H = i^2 Rt$

= 2x2x25x60

= 6000 J

Question 2: A coil of resistance 100 Ω is connected across a battery of emf 6.0V. Assume that the heat developed in the coil is used to raise its temperature. If the heat capacity of the coil is 4.0 J K^{-1}, how long will it take to raise the temperature of the coil by 15°C.

Solution:
Resistance of the coil = R = 100 Ω,
Emf of the battery = V = 6 V,
and ΔT = 15°C

we know, Joule's heating effect heat produced across the coil,

$H = V^2t/R$

Which used to increase the temperature of the coil.

$H = c\Delta T$

$V^2t/R = c\Delta T$

36t/100 = 4x15

t = 166.7 s = 2.8 min

Question 3: The specification on a heater coil is 250 V, 500 W. Calculate the resistance of the coil. What will be the resistance of a coil of 1000 W to operate at the same voltage.

Solution:

We know, $P = V^2/R$

or $R = V^2/P$

$= (25)^2/500$

$= 125\Omega$

Now, P = 1000 W

=> $R = V^2/P = (250)^2/1000 = 62.5\Omega$

Question 4: A heater coil is to be constructed with a nichrome wire ($\rho = 1.0 \times 10^{-8}\ \Omega$ m) which can operate at 500 W when connected to a 250 V supply.

(a) What would be the resistance of the coil?

(b) If the cross-sectional area of the wire is 0.5 mm^2, what length of the wire will be needed?

(c) If the radius of each turn is 4.0 mm, how many turns will be there in the coil?

Solution:

Resistivity = $\rho = 1.0 \times 10^{-8}\ \Omega$ m (given)

We know, $P = V^2/R$

or $R = V^2/P = (250)^2/500 = 125\ \Omega$

(b) We know resistance R,

$R = \rho l/A$

or $l = RA/\rho$

$= [125 \times 0.5 \times 10^{-6}]/[10^{-6}]$

= 62.5 m

(c) Let n be the number of turns in the given coil.

$l = 2\pi r\, n$

where, r = 4.0 mm (Given)

$n = l/2\pi r = 62.5/[2x3.14x4x10^{-3}]$

= 2500 (approx)

Question 5: A bulb with rating 250V, 100 W is connected to a power supply of 220 V situated 10 m away using a copper wire of area of cross section 5 mm^2. How much power will be consumed by the connecting wires? Resistivity of copper = 1.7×10^{-8} Ω m.

Solution:
We know, $R = V^2/P = (250)^2/100 = 625\Omega$

Resistance of the copper wire = $R_c = \rho l/A$

$= [1.7x10^{-8}x10^5]/[5x10^{-6}]$

= 0.034 Ω

The effective resistance = $R_{eff} = R + R_c = 625.034\ \Omega$

The current supplied by the power station by ohm's law:

$i = V/R_{eff} = 220/625.034$ A

Find the power supplied to one side of the connecting wire :

$P' = i^2 R_c$

[Using Joule's heating effect]

$= (220/625.034)^2 \times 0.034$

Total power supplied on both sides:

$2P' = 2 \times (220/625.034)^2 \times 0.034 = 8.4$ mW

Question 6: An electric bulb, when connected across a power supply of 220 W, consumes a power of 60 W. If the supply drops to 180 V, what will be the power consumed? If the supply is suddenly increased to 240 V, what will be the power consumed?

Solution:
We know, $R = V^2/P$
$= (220)^2/60 = 806.67\ \Omega$

The power consumed = P = V'^2/R

when the supply drops to V' = 180 V

P = $(180)^2/806.67$ = 40 W

When supply changes to, V" = 240 V.

The power consumed = P = V''^2/R

P = $(180)^2/806.67$ = 71 W

Question 7: A servo voltage stabilizer restricts the voltage output to 220 V ± 1%. If an electric bulb rated at 220 V, 100 W is connected to it, what will be the minimum and maximum power consumed by it?

Solution:
We know, P = V'^2/R
The resistance of a bulb that is operated at voltage V and consumes power P

= $(220)^2/100$ = 484 Ω

For minimum power to be consumed, output voltage should be minimum.

The minimum output voltage = V' = (220 - 2.2)V = 217.8 V

The current through the bulb = i = V'/R = 217.8/484 = 0.45 A

The power consumed by the bulb = P' = i' V' = 0.45 x 217.8 = 98 W

For maximum power to be consumed, output voltage should be maximum.

V'' = (220 + 2.2)V = 222.2 V

The current through the bulb = i'' = V'' R = 222.2 x 484 = 0.459 A

Power consumed by the bulb = P'' = i'' x V'' = 0.459 x 222.2 = 102 W

Question 8: An electric bulb marked 220 V, 100 W will get fused if it is made to consume 150 W or more. What voltage fluctuation will the bulb withstand?

Solution:
The resistance of the bulb = R = V^2/P

$= (220)^2/100 = 484\ \Omega$

Power fluctuations, P = 150 W (Given)

Or V2 = RP = 150 x 484

Or V = 269.4 V

Bulb will withstand fluctuations up to 270 V.

Question 9: An immersion heater rated 1000 W, 220 V is used to heat 0.01 m^3 of water. Assuming that the power is supplied at 220 V and 60% of the power supplied is used to heat the water, how long will it take to increase the temperature of the water from 15°C to 40°C?

Solution:
Resistance of the immersion heater = $R = V^2/P$

$= (220)^2/1000 = 48.4\ \Omega$

Heat required to raise the temperature of the given mass of water
Q = msθ

where, Mass of water = m = 1100 × 1000 = 10 Kg

Specific heat of water = s = 4200 $Jkg^{-1}\ K^{-1}$ and

Rise in temperature, θ = 25°C

=> Q = 10 x 4200 x 25

= 1050000 J

Also, we are given that, the heat evolve is only 60%.

Let t be the time taken to raise the temperature of water.

So, v^2/R x t x 60% = 1050000 J

=> $(220)^2/48.4$ x t x 60/100 = 1050000 J

or t = 29.17 min

Question 10: An electric kettle used to prepare tea, takes 2 minutes to boil 4 cups of water (1 cup contains 200 cc of water) if the room temperature is 25°C.
(a) If the cost of power consumption is Rs. 1.00 per unit (1 unit = 1000 watt-hour), calculate the cost of boiling 4 cups of water.
(b) What will be the corresponding cost if the room temperature drops to 5°C?

Solution:
(a)
We know, heat required for boiling water, $Q = ms\,\theta$ ...(1)

Where
m = mass of the water = 800 × 1 = 800 gm = 0.8 Kg
s = specific heat of the water = 4200 $Jkg^{-1}\,K^{-1}$
θ = change in temperature = $\theta_2 - \theta_1$ = 75°C [Given: θ_1 = 25°C and θ_2 = 100°C]

(1)=> Q = 0.8 x 4200 x 75 = 25200 J

Cost of boiling 4 cups of water = 1/[1000 x 3600] x 252000 = Rs. 0.7

[Because 1000 watt – hour = 1000 × 3600 watt sec.]

(b) using equation (1)

Here
θ = change in temperature = $\theta_2 - \theta_1$ = 95°C [Given: θ_1 = 5°C and θ_2 = 100°C]

Putting the value in (1), we get

Q = 0.8 x 4200 x 95 = 319200

Cost of boiling 4 cups of water = 1/[1000 x 3600] x 319200 = Rs. 0.09

[Because 1000 watt – hour = 1000 × 3600 watt sec.]

Question 11: The coil of an electric bulb takes 40 watts to start glowing. If more than 40 W is supplied, 60% of the extra power is converted into light and the remaining into heat. The bulb consumes 100 W at 220 V. Find the percentage drop in the light intensity at a point if the supply voltage changes from 220 V to 200 V.

Solution:
Case 1: When supply voltage is 220 V.

Consumed Power = 100 W

Excess power = 100 − 40 = 60 W

Power converted to light = 60% of 60 W = 36 W

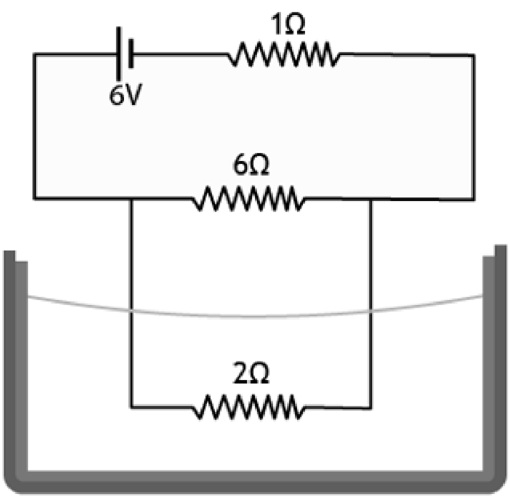
case 2: When supply voltage is 200 V.

Power consumed, P = 200/220 x 100 = 82.64 W
Excess power = 82.64 − 40 = 42.64 W

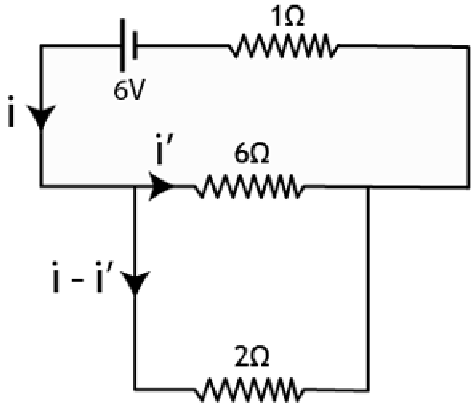
Now,
Power converted to light = 60% of 42.64 W = 25.584 W

% drop in the light intensity = [36 - 25,584]/36 x 100 = 29% (approx)

Question 12: The 2.0 Ω resistor shown in figure is dipped into a calorimeter containing water. The heat capacity of the calorimeter together with water is 2000 J K^{-1}.
(a) If the circuit is active for 15 minutes, what would be the rise in the temperature of the water?
(b) Suppose the 6.0 Ω resistor gets burnt. What would be the rise in the temperature of the water in the next 15 minutes?



Solution:



From figure, R_{eff} = (6x2)/(6+2) + 1 = (5/2) A

Where R_{eff} is effective resistance of the circuit.

let i be the current passing through the circuit,

i = V/R_{eff} = 6/(5/2(= 12/5 A

From ohm's law,
i' x 6 = (i - i') x 2
Where i' be the current through 6Ω resistor.

=> 6i' = (12/5) x 2 - 2i'

=> i' = (3/5) A

and i - i' = 12/5 = 3/5 = 9/5 A

(a) Heat generated in the 2 Ω resistor

H = $(i - i')^2$ Rt

= $(9/5)^2$ x 2 x 15 x 60

= 5832 J

From question, 2000 J of heat raise the temp by 1 K. so, 5832 J of heat raises the temperature of water by (5832/2000) = 2.916 K

(b) When the 6 Ω resistor burn out.

R_{eff} = 1+2 = 3 Ω

And i = (6/3) = 2 A
Where i = current through the circuit

Now, heat generated in 2 Ω resistor = (2)^2 x 2 x 15 x 60 = 7200 J

2000 J of heat raise the temp by 1 K. So, 7200J will raise the temperature by (7200/2000) = 3.6 k

Question 13: The temperatures of the junctions of a bismuth-silver thermocouple are maintained at 0°C and 0.001°C. Find the thermo-emf (Seebeck emf) developed. For bismuch-silver, $a = -46 \times 10^{-6}$ V°C^{-1} and $b = -0.48 \times 10^{-6}$ V°C^{-2}.

Solution:
emf, $E = a\theta + 12b\theta^2$

Given:
Difference in temperature of junctions = θ = 0.001°C,
$a = -46 \times 10^{-6}$ V °C^{-1}
$b = -0.48 \times 10^{-5}$ V °C^{-2}.

On substituting the given values and solving, we have

$E = -4.6 \times 10^{-8}$ V

Question 14: Find the thermo-emf developed in a copper-silver thermocouple when the junctions are kept at 0°C and 40°C. Use the data in table given below.

Metal with lead (Pb)	a μV/°C	b μV/°C
Aluminium	-0.47	0.003
Bismuth	-43.7	-0.47
Copper	2.76	0.012
Gold	2.9	0.0093
Iron	16.6	-0.03
Nickel	19.1	-0.03
Platinum	-1.79	-0.035

Silver	2.5	0.012
Steel	10.8	-0.016

Solution:

emf, $E_{cs} = a_{cs}\theta + 12b_{cs}\theta^2$ ...(1)

From table, a_{cs} = (2.76 - (-43.7)) μV/°C = 46.46 μV/°C and
b_{cs} = (0.012 - (-0.47)) μV/°C = 0.482 μV/°C

and Difference in temperature, θ = 40°C

Substituting all the values in (1)
(1) => $E_{cs} = 1.04 \times 10^{-5}$ V

Question 15: Find the neutral temperature and inversion temperature of copper-iron thermocouple if the reference junction is kept at 0°C. Use the data in table (use previous question table).

Solution:
We know, Neutral temperature = $\theta_n = -a/b$

Using table data,

$a_{Cu\,Fe} = a_{Cu\,Pb} - a_{Fe\,Pb}$

= 2.76 - 16.6

= -13.84 μV/°C

And

$b_{Cu\,Fe} = b_{Cu\,Pb} - b_{Fe\,Pb}$

= 0.012 + 0.030

= 0.042 μV/°C^2

Now,

Neutral temperature = $\theta_n = -a_{Cu\,Fe}/b_{Cu\,Fe}$

= 13.84/0.042

= 330 ^oC

The inversion temperature is double the neutral temperature, i.e. 659°C.

Question 16: Find the charge required to flow through an electrolyte to liberate one atom of (a) a monovalent material and (b) a divalent material.

Solution:
(a) Amount of charge required by 1 equivalent mass of the substance = 96500 C

For monovalent material, equivalent mass = molecular mass

Amount of charge required by 6.023×10^{23} atoms = 96500 C

Amount of charge required by one atom = $96500/[6.023 \times 10^{23}] = 1.6 \times 10^{-19}$ C

(b) For a divalent material:

We know, equivalent mass = (1/2) molecular mass

=> Amount of charge required = $1/2 \times 6.023 \times 10^{23}$ = 96500 C

Amount of charge required by 1 atom = $1.6 \times 2 \times 10^{-19} = 3.2 \times 10^{-19}$ C

Question 17: Find the amount of silver liberated at cathode if 0.500 A of current is passed through $AgNO_3$ electrolyte for 1 hour. Atomic weight of silver is 107.9 g mol^{-1}.

Solution:
Equivalent mass of silver = E_{Ag} = 107.9 g
Current passed through $AgNO_3$ electrolyte for 1 hour = 0.005 A

Now, the ECE of silver,

$Z_{Ag} = E_{Ag}/f = 107.9/96500 = 0.001118$

From faraday's law of electrolysis: m = Zit

Where, m = mass of the substance deposited on the electrode
z = electrochemical equivalence
i = current and t = time taken

m = 0.00118 x 0.500 x 3600 = 2.01 g

Question 18: An electroplating unit plates 3.0 g of silver on a brass plate in 3.0 minutes. Find the current used by the unit. The electrochemical equivalent of silver is 1.12×10^{-6} kg C^{-1}.

Solution:
From faraday's law of electrolysis: m = Zit
Given: Z = 1.12 × 10−6 kg C^{-1}

mass = 3 g = 3 x 10^{-3} Kg and t = 3 min or 180 s

=> 3 x 10^{-3} = 1.12 × 10^{-6} x i x 180

or i = 15 A (approx)

Question 19: Find the time required to liberate 1.0 liter of hydrogen at STP in an electrolytic cell by a current of 5.0 A.

Solution:
We know, Mass of 1 liter hydrogen = m = 2/22.4 g
Current = i = 5A (Given)

From faraday's law of electrolysis: m = Zit

2/22.4 = (5t)/96500

=> t = 29 min (Approx)

Question 20: Two voltameters, one having a solution of silver salt and the other of a trivalent-metal salt, are connected in series and a current of 2A is maintained for 1.50 hours. It is found that 1.00g of the trivalent metal is deposited.
(a) What is the atomic weight of the trivalent metal?
(b) How much silver is deposited during this period? Atomic weight of silver is 107.9 g mol^{-1}.

Solution:

We know, equivalent mass = (1/3) x Atomic weight

E.C.E of the salt = Z = [Equivalent mass]/96500

= [Atomic weight]/[3×96500]

Given: mass of salt deposited = m = 1 g; current = i = 2A and t (time) = 1.5 h = 5400 sec

(a) We know, m = Zit [faraday's law of electrolysis]

1×10^{-3} = [Atomic weight]/[3×96500] x 2 x 5400

or Atomic Weight = 26.8×10^{-3} kg/mole

(b) Using relation between equivalent mass and mass deposited on plates:
$E_1/E_2 = m_1/m_2$

=> 26.8/[3x107.9] = $1/m_2$

=> m_2 = 12.1 g

Question 21: A brass plate having surface area 200 cm^2 on one side is electroplated with 0.10 mm thick silver layers on both sides using a 15 A current. Find the time taken to do the job. The specific gravity of silver is 10.5 and its atomic weight is 107.9 g mol^{-1}.

Solution:
Surface area of the plate = 200 cm^2
Current = i = 15 A
Thickness of silver deposited = 0.1 mm = 0.01 cm
Volume of Ag deposited on one side = 200 × 0.01 cm^3 = 2 cm^3
Specific gravity of silver = 10.5 and
Atomic weight = 107.9 g mol^{-1}

Now,
Mass of silver deposited = m = volume of Ag deposited on both sides x specific gravity x 100

= 4×10^{-3} x 10.5 x 1000

= 42 kg

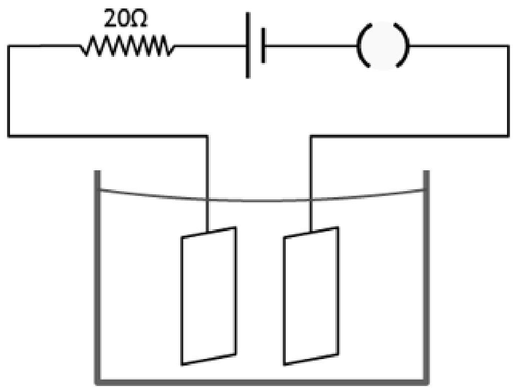
Therefore, m = 42 kg

Again, using formula, m = Zit

=> 42 = Z_{Ag} x 15 x t

=> t = 2504.17 s = 42 min

Question 22: Figure shows an electrolyte of AgCl through which a current is passed. It is observed that 2.68 g of silver is deposited in 10 minutes on the cathode. Find the heat developed in the 20Ω resistor during this period. Atomic weight of silver is 107.9 g mol^{-1}.



Solution:

m = 2.68 g and t = 10 minutes = 600 s

Using the formula, m = Zit

$2.68 \times 10^{-3} = [107 \times 10^{-3}]/96500 \times i \times 600$

=> i = 3.99 or 4 A

Heat developed in the 20 Ω resistor from Joule's heating effect, $H = i^2 Rt$

=> $H = (4)^2 \times 20 \times 600$ = 192000 J = 192 kJ

Question 23: The potential difference across the terminals of a battery of emf 12 V and internal resistance 2 Ω drops to 10 V when it is connected to a silver voltmeter. Find the silver deposited at the cathode in half an hour. Atomic weight of silver is 107.9 g mol^{-1}.

Solution:
Emf of battery, E = 12 V

Voltmeter = V = 10 V and battery's internal resistance = r = 2 Ω

By Kirchhoff's Law in the circuit, E = V + ir

=> i = (E-V)/r = (12-10)/2 = 1 A

Again, we know, m = Zit

=> m = (107.9)/96500 x 1 x 0.5 x 3600

= 2.01 g

Question 24: A plate of area 10 cm^2 is to be electroplated with copper (density 9000 kg m^{-3}) to a thickness of 10 micrometers on both sides, using a cell of 12 V. Calculate the energy spent by the cell in the process of deposition. If this energy is used to heat 100 g of water, calculate the rise in the temperature of the water, ECE of copper = 3×10^{-7} kg C^{-1} and specific heat capacity of water = 4200 J kg^{-1} K^{-1}.

Solution:

ECE of copper = 3×10^{-7} kg C^{-1} and specific heat capacity of water = 4200 J kg^{-1} K^{-1}.

Surface area of the plate = A = 10 cm^2 = 10×10^{-4} m^2
Thickness of copper deposited = t = 10 μm = 10^{-5} m
Density of copper = 9000 kg/m^3

Volume of copper deposited = V = A x (2t)

=> V = 10 x 10^{-4} x 2 x 10 x 10^{-6} = 2 x 10^{-8} m^3

Again, mass of copper deposited = m = Volume x Density

= 2 x 10^{-8} x 9000

=> m = 18 x 10^{-5} Kg

Using formula, m = ZQ

Where, m = mass of the substance
Q = charge
Z = Electrochemical equivalent

Using values, we have

18 x 10^{-5} = 3 x 10^{-7} x Q

=> Q = 6 x 10^{2} C

Now,

Energy spent by the cell = Work done by the cell

=> W = VQ = 12 x 6 x 10^2 = 72 x 10^2 = 7.2 kg

=> W = 7.2 kg

Let $\Delta\theta$ = rise in temperature of water. When this energy used to heat 100 g of water

=> 7.2 x 10^3 = 100 x 10^{-3} x 4200 x $\Delta\theta$

=> $\Delta\theta$ = 17 K