Thermodynamics — Full Worked Session

Every skill in the unit, worked one problem at a time

Set up → solve → answer
78 problems

Lesson `ap2.thermo.session`

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Average KE at 100 K

Find the average translational kinetic energy of a gas molecule at $T = 100\ K$ ($k = 1.38 \times 10^{-23}$).

$$\bar{K} = \tfrac{3}{2}kT = \tfrac{3}{2}(1.38 \times 10^{-23})(100) \qquad \text{kinetic theory}$$

$$\bar{K} = 2.07 \times 10^{-21}\ \text{J} \qquad \text{per molecule}$$

Answer

2.07×10^{-21} J

Average KE at 200 K

Find the average translational kinetic energy of a gas molecule at $T = 200$ K ($k = 1.38 \times 10^{-23}$).

$$\bar{K} = \tfrac{3}{2}kT = \tfrac{3}{2}(1.38 \times 10^{-23})(200) \qquad \text{kinetic theory}$$

$$\bar{K} = 4.14 \times 10^{-21}\ \text{J} \qquad \text{per molecule}$$

Answer

4.14×10^{-21} J

Average KE at 273 K

Find the average translational kinetic energy of a gas molecule at $T = 273$ K ($k = 1.38 \times 10^{-23}$).

$$\bar{K} = \tfrac{3}{2}kT = \tfrac{3}{2}(1.38 \times 10^{-23})(273) \qquad \text{kinetic theory}$$

$$\bar{K} = 5.65 \times 10^{-21}\ \text{J} \qquad \text{per molecule}$$

Answer

5.65×10^{-21} J

Average KE at 300 K

Find the average translational kinetic energy of a gas molecule at $T = 300$ K ($k = 1.38 \times 10^{-23}$).

$$\bar{K} = \tfrac{3}{2}kT = \tfrac{3}{2}(1.38 \times 10^{-23})(300) \quad \text{kinetic theory}$$

$$\bar{K} = 6.21 \times 10^{-21}\ \text{J} \quad \text{per molecule}$$

Answer

6.21×10^{-21} J

Average KE at 350 K

Find the average translational kinetic energy of a gas molecule at $T = 350$ K ($k = 1.38 \times 10^{-23}$).

$$\bar{K} = \tfrac{3}{2}kT = \tfrac{3}{2}(1.38 \times 10^{-23})(350) \qquad \text{kinetic theory}$$

$$\bar{K} = 7.25 \times 10^{-21}\ \text{J} \qquad \text{per molecule}$$

Answer

7.25×10^{-21} J

Average KE at 400 K

Find the average translational kinetic energy of a gas molecule at $T = 400$ K ($k = 1.38 \times 10^{-23}$).

$$\bar{K} = \tfrac{3}{2}kT = \tfrac{3}{2}(1.38 \times 10^{-23})(400) \qquad \text{kinetic theory}$$

$$\bar{K} = 8.28 \times 10^{-21}\ \text{J} \qquad \text{per molecule}$$

Answer

8.28×10^{-21} J

Average KE at 500 K

Find the average translational kinetic energy of a gas molecule at $T = 500$ K ($k = 1.38 \times 10^{-23}$).

$$\bar{K} = \tfrac{3}{2}kT = \tfrac{3}{2}(1.38 \times 10^{-23})(500) \qquad \text{kinetic theory}$$

$$\bar{K} = 1.03 \times 10^{-20}\ \text{J} \qquad \text{per molecule}$$

Answer

1.03×10^{-20} J

Average KE at 600 K

Find the average translational kinetic energy of a gas molecule at $T = 600$ K ($k = 1.38 \times 10^{-23}$).

$$\bar{K} = \tfrac{3}{2}kT = \tfrac{3}{2}(1.38 \times 10^{-23})(600) \qquad \text{kinetic theory}$$

$$\bar{K} = 1.24 \times 10^{-20}\ \text{J} \qquad \text{per molecule}$$

Answer

1.24×10^{-20} J

Average KE at 1000 K

Find the average translational kinetic energy of a gas molecule at $T = 1000$ K ($k = 1.38 \times 10^{-23}$).

$$\bar{K} = \tfrac{3}{2}kT = \tfrac{3}{2}(1.38 \times 10^{-23})(1000) \qquad \text{kinetic theory}$$

$$\bar{K} = 2.07 \times 10^{-20}\ \text{J} \qquad \text{per molecule}$$

Answer

2.07×10^{-20} J

0 °C to kelvin

H1

Convert 0° C to kelvin.

$$T_K = T_C + 273 = 0 + 273 \qquad \text{absolute scale}$$

$$T_K = 273\ \text{K}$$

Answer

273 K

25 °C to kelvin

H1

Convert 25°C to kelvin.

$$T_K = T_C + 273 = 25 + 273 \qquad \text{absolute scale}$$

$$T_K = 298\ \text{K}$$

Answer

298 K

37 °C to kelvin

Convert 37°C to kelvin.

$$T_K = T_C + 273 = 37 + 273 \qquad \text{absolute scale}$$

$$T_K = 310\ \text{K}$$

Answer

310 K

100 °C to kelvin

Convert $100^\circ C$ *to kelvin.*

$$T_K = T_C + 273 = 100 + 273 \qquad \text{absolute scale}$$

$$T_K = 373\ \text{K}$$

Answer

373 K

-40 °C to kelvin

H1

Convert $-40°C$ to kelvin.

$$T_K = T_C + 273 = -40 + 273 \qquad \text{absolute scale}$$

$$T_K = 233\ \text{K}$$

Answer

233 K

500 °C to kelvin

Convert $500^\circ C$ *to kelvin.*

$$T_K = T_C + 273 = 500 + 273 \qquad \text{absolute scale}$$

$$T_K = 773\ \text{K}$$

Answer

773 K

Heat for water, 2.0 kg

How much heat raises 2.0 kg of water ($c = 4186$) by $30^\circ C$?

$$Q = mc\Delta T = 2.0(4186)(30) \qquad \text{specific-heat law}$$

$$Q = 2.51 \times 10^5 \text{ J}$$

Answer

2.51×10^5 J

Heat for water, 0.5 kg

How much heat raises 0.5 *kg of water* ($c = 4186$) *by* $60^\circ C$*?*

$$Q = mc\Delta T = 0.5(4186)(60) \qquad \text{specific-heat law}$$

$$Q = 1.26 \times 10^5 \text{ J}$$

Answer

1.26×10^5 J

Heat for aluminum, 3.0 kg

How much heat raises 3.0 *kg of aluminum* ($c = 900$) *by* $40^\circ C$*?*

$$Q = mc\Delta T = 3.0(900)(40) \qquad \text{specific-heat law}$$

$$Q = 1.08 \times 10^5 \text{ J}$$

Answer

1.08×10^5 J

Heat for copper, 1.5 kg

H2

How much heat raises 1.5 *kg of copper* ($c = 385$) *by* $50^\circ C$*?*

$$Q = mc\Delta T = 1.5(385)(50) \qquad \text{specific-heat law}$$

$$Q = 2.89 \times 10^4 \text{ J}$$

Answer

2.89×10^4 J

Heat for lead, 0.2 kg

How much heat raises 0.2 *kg of lead* ($c = 128$) *by* $80^\circ C$*?*

$$Q = mc\Delta T = 0.2(128)(80) \qquad \text{specific-heat law}$$

$$Q = 2.05 \times 10^3 \text{ J}$$

Answer

2.05×10^3 J

Heat for iron, 2.5 kg

How much heat raises 2.5 *kg of iron* ($c = 450$) *by* $20^\circ C$*?*

$$Q = mc\Delta T = 2.5(450)(20) \qquad \text{specific-heat law}$$

$$Q = 2.25 \times 10^4 \text{ J}$$

Answer

2.25×10^4 J

Temp rise, water

Adding 8.37×10^4 J to 1.0 kg of water ($c = 4186$) raises its temperature by how much?

$$\Delta T = \frac{Q}{mc} = \frac{8.37 \times 10^4}{1.0 \cdot 4186} \quad \text{rearrange}$$

$$\Delta T = 20.0\ ^\circ\text{C}$$

Answer

20.0 °C

Temp rise, aluminum

Adding 9.00×10^4 J to 2.0 kg of aluminum ($c = 900$) raises its temperature by how much?

$$\Delta T = \frac{Q}{mc} = \frac{9.00 \times 10^4}{2.0 \cdot 900} \qquad \text{rearrange}$$

$$\Delta T = 50.0\ ^\circ\text{C}$$

Answer

50.0 °C

Temp rise, copper

Adding 9.62×10^3 J to 0.5 kg of copper ($c = 385$) raises its temperature by how much?

$$\Delta T = \frac{Q}{mc} = \frac{9.62 \times 10^3}{0.5 \cdot 385} \qquad \text{rearrange}$$

$$\Delta T = 50.0\ ^\circ\text{C}$$

Answer

50.0 °C

Identify specific heat

H2

A 0.3 kg block warms by $50^\circ C$ when 5.78×10^3 J is added. Find its specific heat.

$$c = \frac{Q}{m\Delta T} = \frac{5.78 \times 10^3}{0.3 \cdot 50} \qquad \text{rearrange}$$

$$c = 385 \text{ J/kg} \cdot \text{K}$$

Answer

385 J/kg · K

Identify specific heat

A 0.5 kg block warms by 40°C when 1.80×10^4 J is added. Find its specific heat.

$$c = \frac{Q}{m\Delta T} = \frac{1.80 \times 10^4}{0.5 \cdot 40} \qquad \text{rearrange}$$

$$c = 900\ \text{J/kg} \cdot \text{K}$$

Answer

900 J/kg · K

Latent heat, 0.5 kg

How much heat is needed to melt ice: 0.5 *kg at its transition* ($L_f = 3.34 \times 10^5$ *J/kg*)*?*

$$Q = mL = 0.5(3.34 \times 10^5) \qquad \text{phase change: } T \text{ constant}$$

$$Q = 1.67 \times 10^5 \text{ J}$$

Answer

1.67×10^5 J

Latent heat, 1.0 kg

How much heat is needed to melt ice: 1.0 *kg at its transition* ($L_f = 3.34 \times 10^5$ *J/kg)?*

$$Q = mL = 1.0(3.34 \times 10^5) \qquad \text{phase change: } T \text{ constant}$$

$$Q = 3.34 \times 10^5 \text{ J}$$

Answer

3.34×10^5 J

Latent heat, 2.0 kg

How much heat is needed to melt ice: 2.0 *kg at its transition* ($L_f = 3.34 \times 10^5$ *J/kg*)*?*

$$Q = mL = 2.0(3.34 \times 10^5) \qquad \text{phase change: } T \text{ constant}$$

$$Q = 6.68 \times 10^5 \text{ J}$$

Answer

6.68×10^5 J

Latent heat, 1.5 kg

How much heat is needed to melt ice: 1.5 *kg at its transition* ($L_f = 3.34 \times 10^5$ *J/kg)?*

$$Q = mL = 1.5(3.34 \times 10^5) \qquad \text{phase change: } T \text{ constant}$$

$$Q = 5.01 \times 10^5 \text{ J}$$

Answer

5.01×10^5 J

Latent heat, 0.3 kg

How much heat is needed to boil water: 0.3 *kg at its transition* ($L_v = 2.26 \times 10^6$ *J/kg)?*

$$Q = mL = 0.3(2.26 \times 10^6) \qquad \text{phase change: } T \text{ constant}$$

$$Q = 6.78 \times 10^5 \text{ J}$$

Answer

6.78×10^5 J

Latent heat, 0.5 kg

How much heat is needed to boil water: 0.5 *kg at its transition* ($L_v = 2.26 \times 10^6$ *J/kg)?*

$$Q = mL = 0.5(2.26 \times 10^6) \qquad \text{phase change: } T \text{ constant}$$

$$Q = 1.13 \times 10^6 \text{ J}$$

Answer

1.13×10^6 J

Latent heat, 0.8 kg

How much heat is needed to boil water: 0.8 *kg at its transition* ($L_v = 2.26 \times 10^6$ *J/kg)?*

$$Q = mL = 0.8(2.26 \times 10^6) \qquad \text{phase change: } T \text{ constant}$$

$$Q = 1.81 \times 10^6 \text{ J}$$

Answer

1.81×10^6 J

Latent heat, 1.0 kg

H3

How much heat is needed to boil water: 1.0 *kg at its transition* ($L_v = 2.26 \times 10^6$ *J/kg)?*

$$Q = mL = 1.0(2.26 \times 10^6) \qquad \text{phase change: } T \text{ constant}$$

$$Q = 2.26 \times 10^6 \text{ J}$$

Answer

2.26×10^6 J

Conduction through copper

Heat conducts through copper ($k = 400$), area $A = 0.01\ m^2$, thickness $L = 0.5\ m$, across $\Delta T = 50\ K$. Rate?

$$P = \frac{kA\Delta T}{L} = \frac{400 \cdot 0.01 \cdot 50}{0.5}$$

Fourier conduction

$$P = 400.0\ \text{W}$$

energy per second

Answer

400.0 W

Conduction through aluminum

Heat conducts through aluminum ($k = 200$), area $A = 0.02\ m^2$, thickness $L = 0.4\ m$, across $\Delta T = 30\ K$. Rate?

$$P = \frac{kA\Delta T}{L} = \frac{200 \cdot 0.02 \cdot 30}{0.4}$$ Fourier conduction

$$P = 300.0\ \text{W}$$ energy per second

Answer

300.0 W

Conduction through iron

Heat conducts through iron ($k = 80$), area $A = 0.05\ m^2$, thickness $L = 1.0\ m$, across $\Delta T = 100\ K$. Rate?

$$P = \frac{kA\Delta T}{L} = \frac{80 \cdot 0.05 \cdot 100}{1.0}$$

Fourier conduction

$$P = 400.0\ \text{W}$$

energy per second

Answer

400.0 W

Conduction through glass

Heat conducts through glass ($k = 1.0$), area $A = 0.10\ m^2$, thickness $L = 0.2\ m$, across $\Delta T = 20\ K$. Rate?

$$P = \frac{kA\Delta T}{L} = \frac{1.0 \cdot 0.10 \cdot 20}{0.2}$$

Fourier conduction

$$P = 10.0\ \text{W}$$

energy per second

Answer

10.0 W

Conduction through foam

H4

Heat conducts through foam ($k = 0.04$), area $A = 0.50\ m^2$, thickness $L = 0.1\ m$, across $\Delta T = 25\ K$. Rate?

$$P = \frac{kA\Delta T}{L} = \frac{0.04 \cdot 0.50 \cdot 25}{0.1}$$

Fourier conduction

$$P = 5.0\ \text{W}$$

energy per second

Answer

5.0 W

Which heat-transfer mode?

A metal spoon heats along its length in hot soup. Which mode of heat transfer is this?

$$\text{contact?} = \text{yes} - \text{atom to atom} \qquad \text{check the path}$$

$$\text{mode} = \text{conduction}$$

Answer

conduction

Which heat-transfer mode?

Warm air rises off a radiator and circulates the room. Which mode of heat transfer is this?

$$\text{contact?} = \text{no} \qquad \text{check the path}$$

$$\text{mode} = \text{convection}$$

Answer

convection

Which heat-transfer mode?

H4

You feel the Sun's warmth across empty space. Which mode of heat transfer is this?

$$\text{contact?} = \text{no} \qquad \text{check the path}$$

$$\text{mode} = \text{radiation}$$

Answer

radiation

Which heat-transfer mode?

A campfire warms your face without touching you. Which mode of heat transfer is this?

$$\text{contact?} = \text{no} \qquad \text{check the path}$$

$$\text{mode} = \text{radiation}$$

Answer

radiation

Ideal gas: solve for P

$n = 2.0$ *mol of gas in* $V = 0.050$ m^3 *at* $T = 300$ K. *Find the pressure.*

$$P = \frac{nRT}{V} = \frac{2.0 \cdot 8.31 \cdot 300}{0.050} \qquad \text{ideal gas}$$

$$P = 9.97 \times 10^4 \text{ Pa}$$

Answer

9.97×10^4 Pa

Ideal gas: solve for P

$n = 1.0$ *mol of gas in* $V = 0.025\ m^3$ *at* $T = 350\ K$. *Find the pressure.*

$$P = \frac{nRT}{V} = \frac{1.0 \cdot 8.31 \cdot 350}{0.025} \qquad \text{ideal gas}$$

$$P = 1.16 \times 10^5\ \text{Pa}$$

Answer

1.16×10^5 Pa

Ideal gas: solve for V

$n = 3.0$ *mol at* $P = 1.00 \times 10^5$ *Pa,* $T = 300$ *K. Find the volume.*

$$V = \frac{nRT}{P} = \frac{3.0 \cdot 8.31 \cdot 300}{1.00 \times 10^5} \qquad \text{ideal gas}$$

$$V = 7.48 \times 10^{-2}\ \text{m}^3$$

Answer

$7.48 \times 10^{-2}\ \text{m}^3$

Ideal gas: solve for T

$P = 1.20 \times 10^5$ *Pa*, $V = 0.040$ m^3, $n = 2.0$ *mol. Find the temperature.*

$$T = \frac{PV}{nR} = \frac{1.20 \times 10^5 \cdot 0.040}{2.0 \cdot 8.31} \qquad \text{ideal gas}$$

$$T = 289 \text{ K}$$

Answer

289 K

Ideal gas: solve for n

$P = 2.00 \times 10^5$ *Pa*, $V = 0.050$ m^3, $T = 400$ *K. How many moles?*

$$n = \frac{PV}{RT} = \frac{2.00 \times 10^5 \cdot 0.050}{8.31 \cdot 400} \qquad \text{ideal gas}$$

$$n = 3.01 \text{ mol}$$

Answer

3.01 mol

Combined gas law

A gas at $P_1 = 1.00 \times 10^5$ Pa, $V_1 = 0.020$ m^3, $T_1 = 300$ K changes to $P_2 = 2.00 \times 10^5$ Pa, $T_2 = 400$ K. Find V_2.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \qquad n \text{ fixed}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = 0.0133 \text{ m}^3$$

Answer

0.0133 m^3

Combined gas law

A gas at $P_1 = 1.50 \times 10^5$ Pa, $V_1 = 0.030$ m^3, $T_1 = 350$ K changes to $P_2 = 1.00 \times 10^5$ Pa, $T_2 = 300$ K. Find V_2.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \qquad n \text{ fixed}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = 0.0386 \text{ m}^3$$

Answer

0.0386 m^3

Combined gas law

A gas at $P_1 = 1.00 \times 10^5$ Pa, $V_1 = 0.050$ m^3, $T_1 = 250$ K changes to $P_2 = 1.00 \times 10^5$ Pa, $T_2 = 500$ K. Find V_2.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \qquad n \text{ fixed}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = 0.1000 \text{ m}^3$$

Answer

0.1000 m^3

rms speed, nitrogen

Find the rms speed of nitrogen molecules ($M = 0.028$ kg/mol) at $T = 300$ K.

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \cdot 8.31 \cdot 300}{0.028}} \qquad \text{kinetic theory}$$

$$v_{\text{rms}} = 517 \text{ m/s} \qquad \text{lighter} = \text{faster}$$

Answer

517 m/s

rms speed, oxygen

Find the rms speed of oxygen molecules ($M = 0.032$ kg/mol) at $T = 300$ K.

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \cdot 8.31 \cdot 300}{0.032}} \qquad \text{kinetic theory}$$

$$v_{\text{rms}} = 483 \text{ m/s} \qquad \text{lighter} = \text{faster}$$

Answer

483 m/s

rms speed, hydrogen

Find the rms speed of hydrogen molecules ($M = 0.002$ kg/mol) at $T = 300$ K.

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \cdot 8.31 \cdot 300}{0.002}} \qquad \text{kinetic theory}$$

$$v_{\text{rms}} = 1934 \text{ m/s} \qquad \text{lighter = faster}$$

Answer

1934 m/s

rms speed, helium

Find the rms speed of helium molecules ($M = 0.004$ kg/mol) at $T = 300$ K.

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \cdot 8.31 \cdot 300}{0.004}} \qquad \text{kinetic theory}$$

$$v_{\text{rms}} = 1367 \text{ m/s} \qquad \text{lighter = faster}$$

Answer

1367 m/s

rms speed, carbon dioxide

Find the rms speed of carbon dioxide molecules ($M = 0.044$ kg/mol) at $T = 350$ K.

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \cdot 8.31 \cdot 350}{0.044}} \qquad \text{kinetic theory}$$

$$v_{\text{rms}} = 445 \text{ m/s} \qquad \text{lighter} = \text{faster}$$

Answer

445 m/s

rms speed, nitrogen

Find the rms speed of nitrogen molecules ($M = 0.028$ kg/mol) at $T = 500$ K.

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \cdot 8.31 \cdot 500}{0.028}} \qquad \text{kinetic theory}$$

$$v_{\text{rms}} = 667 \text{ m/s} \qquad \text{lighter} = \text{faster}$$

Answer

667 m/s

rms speed, argon

Find the rms speed of argon molecules ($M = 0.040$ kg/mol) at $T = 300$ K.

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \cdot 8.31 \cdot 300}{0.040}} \qquad \text{kinetic theory}$$

$$v_{\text{rms}} = 432 \text{ m/s} \qquad \text{lighter} = \text{faster}$$

Answer

432 m/s

First law, Q=500, W=200

A gas absorbs $Q = 500$ J of heat and does $W = 200$ J of work. Find the change in internal energy.

$$\Delta U = Q - W = 500 - (200) \quad \text{first law}$$

$$\Delta U = 300 \text{ J} \quad \text{rises}$$

Answer

300 J

First law, Q=800, W=300

A gas absorbs $Q = 800$ J of heat and does $W = 300$ J of work. Find the change in internal energy.

$$\Delta U = Q - W = 800 - (300) \quad \text{first law}$$

$$\Delta U = 500 \text{ J} \quad \text{rises}$$

Answer

500 J

First law, Q=0, W=150

A gas absorbs $Q = 0$ J of heat and does $W = 150$ J of work. Find the change in internal energy.

$$\Delta U = Q - W = 0 - (150) \quad \text{first law}$$

$$\Delta U = -150 \text{ J} \quad \text{falls}$$

Answer

-150 J

First law, Q=400, W=-100

A gas absorbs $Q = 400$ J of heat and does $W = -100$ J of work. Find the change in internal energy.

$$\Delta U = Q - W = 400 - (-100) \quad \text{first law}$$

$$\Delta U = 500 \text{ J} \quad \text{rises}$$

Answer

500 J

First law, Q=-300, W=200

A gas absorbs $Q = -300$ J of heat and does $W = 200$ J of work. Find the change in internal energy.

$$\Delta U = Q - W = -300 - (200) \quad \text{first law}$$

$$\Delta U = -500 \text{ J} \quad \text{falls}$$

Answer

-500 J

First law, Q=600, W=600

A gas absorbs $Q = 600$ J of heat and does $W = 600$ J of work. Find the change in internal energy.

$$\Delta U = Q - W = 600 - (600) \quad \text{first law}$$

$$\Delta U = 0 \text{ J} \quad \text{unchanged}$$

Answer

0 J

First law, Q=700, W=250

A gas absorbs $Q = 700$ J of heat and does $W = 250$ J of work. Find the change in internal energy.

$$\Delta U = Q - W = 700 - (250) \quad \text{first law}$$

$$\Delta U = 450 \text{ J} \quad \text{rises}$$

Answer

450 J

Monatomic internal energy

By how much does the internal energy of 2.0 *mol of a monatomic gas change when* T *rises* 50 *K?*

$$\Delta U = \tfrac{3}{2} nR\Delta T = \tfrac{3}{2}(2.0)(8.31)(50) \qquad U = \tfrac{3}{2}nRT$$

$$\Delta U = 1246 \text{ J}$$

Answer

1246 J

Monatomic internal energy

By how much does the internal energy of 1.0 *mol of a monatomic gas change when* T *rises* 100 *K?*

$$\Delta U = \tfrac{3}{2} nR\Delta T = \tfrac{3}{2}(1.0)(8.31)(100) \qquad U = \tfrac{3}{2}nRT$$

$$\Delta U = 1246 \text{ J}$$

Answer

1246 J

Monatomic internal energy

By how much does the internal energy of 3.0 *mol of a monatomic gas change when* T *rises* 30 *K?*

$$\Delta U = \tfrac{3}{2} nR\Delta T = \tfrac{3}{2}(3.0)(8.31)(30) \qquad U = \tfrac{3}{2} nRT$$

$$\Delta U = 1122 \text{ J}$$

Answer

1122 J

Engine efficiency, Qh=800

An engine takes in $Q_h = 800$ J and exhausts $Q_c = 600$ J per cycle. Efficiency and work?

$$e = 1 - \frac{600}{800} = 0.250 \qquad e = W/Q_h$$

$$W = 800 - 600 = 200 \text{ J} \qquad \text{net work out}$$

Answer

25.0%, $W = 200$ J

Engine efficiency, Qh=1000

An engine takes in $Q_h = 1000$ J and exhausts $Q_c = 400$ J per cycle. Efficiency and work?

$$e = 1 - \frac{400}{1000} = 0.600 \qquad e = W/Q_h$$

$$W = 1000 - 400 = 600 \text{ J} \qquad \text{net work out}$$

Answer

60.0%, $W = 600$ J

Engine efficiency, Qh=500

An engine takes in $Q_h = 500$ J and exhausts $Q_c = 350$ J per cycle. Efficiency and work?

$$e = 1 - \frac{350}{500} = 0.300 \qquad e = W/Q_h$$

$$W = 500 - 350 = 150 \text{ J} \qquad \text{net work out}$$

Answer

30.0%, $W = 150$ J

Engine efficiency, Qh=1200

An engine takes in $Q_h = 1200$ J and exhausts $Q_c = 300$ J per cycle. Efficiency and work?

$$e = 1 - \frac{300}{1200} = 0.750 \qquad e = W/Q_h$$

$$W = 1200 - 300 = 900 \text{ J} \qquad \text{net work out}$$

Answer

$75.0\%,\ W = 900$ J

Engine efficiency, Qh=900

An engine takes in $Q_h = 900$ J and exhausts $Q_c = 450$ J per cycle. Efficiency and work?

$$e = 1 - \frac{450}{900} = 0.500 \qquad e = W/Q_h$$

$$W = 900 - 450 = 450 \text{ J} \qquad \text{net work out}$$

Answer

50.0%, $W = 450$ J

Carnot limit, 600/300 K

What is the maximum (Carnot) efficiency of an engine between $T_h = 600\ K$ and $T_c = 300\ K$?

$$e_{max} = 1 - \frac{300}{600} = 0.500$$ temperatures in kelvin

$$e_{max} = 50.0\%$$ no engine beats this

Answer

50.0%

Carnot limit, 500/300 K

What is the maximum (Carnot) efficiency of an engine between $T_h = 500\ K$ and $T_c = 300\ K$?

$$e_{max} = 1 - \frac{300}{500} = 0.400$$ temperatures in kelvin

$$e_{max} = 40.0\%$$ no engine beats this

Answer

40.0%

Carnot limit, 800/400 K

What is the maximum (Carnot) efficiency of an engine between $T_h = 800\ K$ and $T_c = 400\ K$?

$$e_{max} = 1 - \frac{400}{800} = 0.500$$ temperatures in kelvin

$$e_{max} = 50.0\%$$ no engine beats this

Answer

50.0%

Carnot limit, 400/300 K

What is the maximum (Carnot) efficiency of an engine between $T_h = 400\ K$ and $T_c = 300\ K$?

$$e_{max} = 1 - \frac{300}{400} = 0.250$$ temperatures in kelvin

$$e_{max} = 25.0\%$$ no engine beats this

Answer

25.0%

Carnot limit, 1000/250 K

What is the maximum (Carnot) efficiency of an engine between $T_h = 1000\ K$ and $T_c = 250\ K$?

$$e_{max} = 1 - \frac{250}{1000} = 0.750$$ temperatures in kelvin

$$e_{max} = 75.0\%$$ no engine beats this

Answer

75.0%

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Coulomb, $2,3\,\mu$C at 0.10 m

Two charges $q_1 = 2\ \mu C$ and $q_2 = 3\ \mu C$ sit $r = 0.10\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 (2.00 \times 10^{-6})(3.00 \times 10^{-6})}{(0.10)^2}$$

Coulomb's law

$$F = 5.394\ \text{N}$$

along the line

Answer

5.394 N

Coulomb, $1,1\,\mu$C at 0.05 m

Two charges $q_1 = 1\ \mu C$ and $q_2 = 1\ \mu C$ sit $r = 0.05\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 (1.00 \times 10^{-6})(1.00 \times 10^{-6})}{(0.05)^2}$$

Coulomb's law

$$F = 3.596\ \text{N}$$

along the line

Answer

3.596 N

Coulomb, $5,2\,\mu$C at 0.20 m

Two charges $q_1 = 5\ \mu C$ and $q_2 = 2\ \mu C$ sit $r = 0.20\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 (5.00 \times 10^{-6})(2.00 \times 10^{-6})}{(0.20)^2}$$

Coulomb's law

$$F = 2.247\ \text{N}$$

along the line

Answer

2.247 N

Coulomb, $4,4\,\mu$C at 0.10 m

Two charges $q_1 = 4\ \mu C$ and $q_2 = 4\ \mu C$ sit $r = 0.10\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 (4.00 \times 10^{-6})(4.00 \times 10^{-6})}{(0.10)^2}$$

Coulomb's law

$$F = 14.384\ \text{N}$$

along the line

Answer

14.384 N

Coulomb, $3,6\,\mu$C at 0.30 m

Two charges $q_1 = 3\ \mu C$ and $q_2 = 6\ \mu C$ sit $r = 0.30\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 (3.00 \times 10^{-6})(6.00 \times 10^{-6})}{(0.30)^2}$$

Coulomb's law

$$F = 1.798\ \text{N}$$

along the line

Answer

1.798 N

Coulomb, $2,2\,\mu$C at 0.02 m

Two charges $q_1 = 2\ \mu C$ and $q_2 = 2\ \mu C$ sit $r = 0.02\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 (2.00 \times 10^{-6})(2.00 \times 10^{-6})}{(0.02)^2}$$

Coulomb's law

$$F = 89.900\ \text{N}$$

along the line

Answer

89.900 N

Coulomb, $1,5\,\mu$C at 0.15 m

Two charges $q_1 = 1\ \mu C$ and $q_2 = 5\ \mu C$ sit $r = 0.15\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 (1.00 \times 10^{-6})(5.00 \times 10^{-6})}{(0.15)^2}$$

Coulomb's law

$$F = 1.998\ \text{N}$$

along the line

Answer

1.998 N

Coulomb, $10,1\,\mu$C at 0.25 m

Two charges $q_1 = 10\ \mu C$ and $q_2 = 1\ \mu C$ sit $r = 0.25\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9(1.00 \times 10^{-5})(1.00 \times 10^{-6})}{(0.25)^2}$$

Coulomb's law

$$F = 1.438\ \text{N}$$

along the line

Answer

1.438 N

Coulomb, $6,3\,\mu$C at 0.20 m

Two charges $q_1 = 6\ \mu C$ and $q_2 = 3\ \mu C$ sit $r = 0.20\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 (6.00 \times 10^{-6})(3.00 \times 10^{-6})}{(0.20)^2}$$

Coulomb's law

$$F = 4.045\ \text{N}$$

along the line

Answer

4.045 N

Coulomb, $8,2\,\mu$C at 0.40 m

Two charges $q_1 = 8\ \mu C$ and $q_2 = 2\ \mu C$ sit $r = 0.40\ m$ apart. Force between them?

$$F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 (8.00 \times 10^{-6})(2.00 \times 10^{-6})}{(0.40)^2}$$

Coulomb's law

$$F = 0.899\ \text{N}$$

along the line

Answer

0.899 N

Separation for 0.9 N

Q2

Two 2 μC charges repel with $F = 0.9$ N. How far apart are they?

$$r = \sqrt{\frac{kq_1q_2}{F}} = \sqrt{\frac{8.99\times10^{9}(2.00\times10^{-6})(2.00\times10^{-6})}{0.9}}$$

solve Coulomb for r

$$r = 0.200 \text{ m}$$

Answer

0.200 m

Separation for 1.0 N

Q2

Two 3 μC charges repel with $F = 1.0$ N. How far apart are they?

$$r = \sqrt{\frac{kq_1q_2}{F}} = \sqrt{\frac{8.99\times10^{9}(3.00\times10^{-6})(3.00\times10^{-6})}{1.0}}$$

solve Coulomb for r

$$r = 0.284 \text{ m}$$

Answer

0.284 m

Field from force, 0.050 N

A 2 μC charge feels $F = 0.050$ N. What is the electric field there?

$$E = \frac{F}{q} = \frac{0.050}{2.00 \times 10^{-6}} \qquad \text{field = force per charge}$$

$$E = 2.50 \times 10^{4}\ \text{N/C}$$

Answer

2.50×10^{4} N/C

Field from force, 0.100 N

A 5 μC charge feels $F = 0.100$ N. What is the electric field there?

$$E = \frac{F}{q} = \frac{0.100}{5.00 \times 10^{-6}}$$

field = force per charge

$$E = 2.00 \times 10^{4}\ \text{N/C}$$

Answer

2.00×10^{4} N/C

Field from force, 0.020 N

A 1 μC charge feels $F = 0.020$ N. What is the electric field there?

$$E = \frac{F}{q} = \frac{0.020}{1.00 \times 10^{-6}} \qquad \text{field = force per charge}$$

$$E = 2.00 \times 10^{4}\ \text{N/C}$$

Answer

2.00×10^{4} N/C

Field from force, 0.300 N

A 3 μC charge feels $F = 0.300$ N. What is the electric field there?

$$E = \frac{F}{q} = \frac{0.300}{3.00 \times 10^{-6}}$$

field = force per charge

$$E = 1.00 \times 10^{5}\ \text{N/C}$$

Answer

1.00×10^{5} N/C

Field from force, 0.006 N

A 2 μC charge feels $F = 0.006$ N. What is the electric field there?

$$E = \frac{F}{q} = \frac{0.006}{2.00 \times 10^{-6}}$$

field = force per charge

$$E = 3.00 \times 10^{3} \text{ N/C}$$

Answer

3.00×10^{3} N/C

Field-line reasoning

Q4

Where do electric field lines begin and end?

rule $=$ start on $+$, end on $-$ never cross

Answer

start on $+$, end on $-$

Field-line reasoning

Q4

Field lines are drawn denser in one region. What does that mean?

rule = stronger field crowding = strength

Answer

stronger field

Field-line reasoning

Q4

Which way does the field point along a field line?

rule = tangent, from + to −

force on a + test charge

Answer

tangent, from + to −

Conductor in equilibrium

Q5

What is the electric field inside a conductor in equilibrium?

rule $=$ $E = 0$ charges rearrange to cancel it

Answer

$$E = 0$$

Conductor in equilibrium

Q5

Where does excess charge sit on a solid conductor?

rule = on the surface mutual repulsion pushes it out

Answer

on the surface

Conductor in equilibrium

Q5

How do field lines meet a conductor's surface in equilibrium?

rule $=$ $\perp$ (perpendicular) — no component along the surface

Answer

$\perp$ (perpendicular)

Flux, E=500, 0°

A uniform field $E = 500$ N/C crosses area $A = 0.20$ m^2 at $0°$ to the normal. Flux?

$$\Phi = EA\cos\theta = 500 \cdot 0.20 \cdot \cos 0° \qquad \text{field lines through } A$$

$$\Phi = 100.0 \text{ N} \cdot \text{m}^2/\text{C}$$

Answer

100.0 N · m^2/C

Flux, E=400, 60°

A uniform field $E = 400$ N/C crosses area $A = 0.50$ m^2 at $60°$ to the normal. Flux?

$$\Phi = EA\cos\theta = 400 \cdot 0.50 \cdot \cos 60° \qquad \text{field lines through } A$$

$$\Phi = 100.0 \text{ N} \cdot \text{m}^2/\text{C}$$

Answer

100.0 N · m^2/C

Flux, E=1000, 30°

A uniform field $E = 1000$ N/C crosses area $A = 0.10$ m^2 at $30°$ to the normal. Flux?

$$\Phi = EA\cos\theta = 1000 \cdot 0.10 \cdot \cos 30° \qquad \text{field lines through } A$$

$$\Phi = 86.6 \text{ N} \cdot \text{m}^2/\text{C}$$

Answer

86.6 N · m^2/C

Flux, E=600, 0°

A uniform field $E = 600$ N/C crosses area $A = 0.25$ m^2 at $0°$ to the normal. Flux?

$$\Phi = EA\cos\theta = 600 \cdot 0.25 \cdot \cos 0° \qquad \text{field lines through } A$$

$$\Phi = 150.0 \text{ N} \cdot \text{m}^2/\text{C}$$

Answer

150.0 N · m^2/C

Flux, E=800, 90°

A uniform field $E = 800$ N/C crosses area $A = 0.20$ m^2 at $90°$ to the normal. Flux?

$$\Phi = EA\cos\theta = 800 \cdot 0.20 \cdot \cos 90° \qquad \text{field lines through } A$$

$$\Phi = 0.0 \text{ N} \cdot \text{m}^2/\text{C}$$

Answer

0.0 N $\cdot$ m^2/C

Point-charge field, $5\mu C$

Find the electric field 0.20 m from a point charge $Q = 5\ \mu C$.

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 (5.00 \times 10^{-6})}{(0.20)^2}$$ point-charge field

$$E = 1.12 \times 10^6 \text{ N/C}$$ points radially out

Answer

1.12×10^6 N/C

Point-charge field, $2\mu C$

Find the electric field $0.10\ m$ *from a point charge* $Q = 2\ \mu C$.

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 (2.00 \times 10^{-6})}{(0.10)^2} \qquad \text{point-charge field}$$

$$E = 1.80 \times 10^6\ \text{N/C} \qquad \text{points radially out}$$

Answer

$1.80 \times 10^6\ \text{N/C}$

Point-charge field, $10\mu C$

Q7

Find the electric field $0.50\ m$ *from a point charge* $Q = 10\ \mu C$.

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 (1.00 \times 10^{-5})}{(0.50)^2} \qquad \text{point-charge field}$$

$$E = 3.60 \times 10^5\ \text{N/C} \qquad \text{points radially out}$$

Answer

$3.60 \times 10^5\ \text{N/C}$

Point-charge field, $1\mu C$

Find the electric field $0.05\ m$ *from a point charge* $Q = 1\ \mu C$.

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 (1.00 \times 10^{-6})}{(0.05)^2}$$ point-charge field

$$E = 3.60 \times 10^6\ \text{N/C}$$ points radially out

Answer

$3.60 \times 10^6\ \text{N/C}$

Point-charge field, $3\mu C$

Find the electric field $0.30\ m$ *from a point charge* $Q = 3\ \mu C$.

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 (3.00 \times 10^{-6})}{(0.30)^2}$$ point-charge field

$$E = 3.00 \times 10^5\ \text{N/C}$$ points radially out

Answer

3.00×10^5 N/C

Point-charge field, $8\mu C$

Q7

Find the electric field 0.40 m from a point charge $Q = 8\ \mu C$.

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 (8.00 \times 10^{-6})}{(0.40)^2}$$ point-charge field

$$E = 4.49 \times 10^5\ \text{N/C}$$ points radially out

Answer

4.49×10^5 N/C

Point-charge field, $4\mu C$

Find the electric field 0.20 m from a point charge $Q = 4\ \mu C$.

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 (4.00 \times 10^{-6})}{(0.20)^2} \qquad \text{point-charge field}$$

$$E = 8.99 \times 10^5\ \text{N/C} \qquad \text{points radially out}$$

Answer

8.99×10^5 N/C

Point-charge field, 6μC

Find the electric field 0.60 m from a point charge $Q = 6\ \mu C$.

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 (6.00 \times 10^{-6})}{(0.60)^2}$$ point-charge field

$$E = 1.50 \times 10^5\ \text{N/C}$$ points radially out

Answer

1.50×10^5 N/C

Force & accel, $3\mu C$

Q8

A 3 μC charge of mass 1.00×10^{-3} kg sits in $E = 2000$ N/C. Find the force and acceleration.

$$F = qE = 3.00 \times 10^{-6}(2000) = 6.00 \times 10^{-3} \text{ N}$$ force on a charge

$$a = \frac{F}{m} = 6.00 \times 10^{0} \text{ m/s}^2$$ Newton's second law

Answer

$$F = 6.00 \times 10^{-3} \text{ N}, \; a = 6.00 \times 10^{0} \text{ m/s}^2$$

Force & accel, $2\mu C$

A 2 μC charge of mass 2.00×10^{-3} kg sits in $E = 5000$ N/C. Find the force and acceleration.

$$F = qE = 2.00 \times 10^{-6}(5000) = 1.00 \times 10^{-2} \text{ N}$$ force on a charge

$$a = \frac{F}{m} = 5.00 \times 10^{0} \text{ m/s}^2$$ Newton's second law

Answer

$$F = 1.00 \times 10^{-2} \text{ N}, \; a = 5.00 \times 10^{0} \text{ m/s}^2$$

Force & accel, 5μC

Q8

A 5 μC charge of mass 5.00×10^{-4} kg sits in $E = 1000$ N/C. Find the force and acceleration.

$$F = qE = 5.00 \times 10^{-6}(1000) = 5.00 \times 10^{-3}\ \text{N}$$ force on a charge

$$a = \frac{F}{m} = 10.00 \times 10^{0}\ \text{m/s}^2$$ Newton's second law

Answer

$$F = 5.00 \times 10^{-3}\ \text{N},\ a = 10.00 \times 10^{0}\ \text{m/s}^2$$

Force & accel, 1μC

A 1 μC charge of mass 1.00×10^{-3} kg sits in $E = 4000$ N/C. Find the force and acceleration.

$$F = qE = 1.00 \times 10^{-6}(4000) = 4.00 \times 10^{-3}\ \text{N}$$ force on a charge

$$a = \frac{F}{m} = 4.00 \times 10^{0}\ \text{m/s}^2$$ Newton's second law

Answer

$$F = 4.00 \times 10^{-3}\ \text{N},\ a = 4.00 \times 10^{0}\ \text{m/s}^2$$

Force & accel, $4\mu C$

Q8

A 4 μC charge of mass 2.00×10^{-3} kg sits in $E = 2500$ N/C. Find the force and acceleration.

$$F = qE = 4.00 \times 10^{-6}(2500) = 1.00 \times 10^{-2} \text{ N}$$ force on a charge

$$a = \frac{F}{m} = 5.00 \times 10^{0} \text{ m/s}^2$$ Newton's second law

Answer

$$F = 1.00 \times 10^{-2} \text{ N}, \; a = 5.00 \times 10^{0} \text{ m/s}^2$$

Force & accel, 2μC

Q8

A 2 μC charge of mass 1.00×10^{-3} kg sits in $E = 3000$ N/C. Find the force and acceleration.

$$F = qE = 2.00 \times 10^{-6}(3000) = 6.00 \times 10^{-3}\ \text{N}$$ force on a charge

$$a = \frac{F}{m} = 6.00 \times 10^{0}\ \text{m/s}^2$$ Newton's second law

Answer

$$F = 6.00 \times 10^{-3}\ \text{N},\ a = 6.00 \times 10^{0}\ \text{m/s}^2$$

Potential energy, 2μC at 100 V

How much electric potential energy has a 2 μC charge at a point where $V = 100$ V?

$$PE = qV = 2.00 \times 10^{-6}(100) \qquad \text{energy per charge} \times \text{charge}$$

$$PE = 2.00 \times 10^{-4} \text{ J}$$

Answer

2.00×10^{-4} J

Potential energy, 5μC at 50 V

I1

How much electric potential energy has a 5 μC charge at a point where $V = 50$ V?

$$PE = qV = 5.00 \times 10^{-6}(50)$$ energy per charge × charge

$$PE = 2.50 \times 10^{-4} \text{ J}$$

Answer

2.50×10^{-4} J

Potential energy, 1μC at 200 V

How much electric potential energy has a 1 μC charge at a point where $V = 200$ V?

$$PE = qV = 1.00 \times 10^{-6}(200) \qquad \text{energy per charge} \times \text{charge}$$

$$PE = 2.00 \times 10^{-4} \text{ J}$$

Answer

2.00×10^{-4} J

Potential energy, 3μC at 120 V

How much electric potential energy has a 3 μC charge at a point where $V = 120$ V?

$$PE = qV = 3.00 \times 10^{-6}(120) \qquad \text{energy per charge} \times \text{charge}$$

$$PE = 3.60 \times 10^{-4} \text{ J}$$

Answer

3.60×10^{-4} J

Work across 50 V

I1

How much work moves a 2 μC charge through a potential difference of 50 V?

$$W = q\Delta V = 2.00 \times 10^{-6}(50) \qquad \text{work-potential relation}$$

$$W = 1.00 \times 10^{-4}\ \text{J}$$

Answer

1.00×10^{-4} J

Work across 25 V

How much work moves a 4 μC charge through a potential difference of 25 V?

$$W = q\Delta V = 4.00 \times 10^{-6}(25) \qquad \text{work-potential relation}$$

$$W = 1.00 \times 10^{-4}\ \text{J}$$

Answer

1.00×10^{-4} J

Uniform field, 120 V / 0.020 m

Two parallel plates 120 *V apart are separated by* $d = 0.020$ *m. Field between them?*

$$E = \frac{V}{d} = \frac{120}{0.020}$$

uniform-field relation

$$E = 6.00 \times 10^3 \text{ V/m}$$

Answer

6.00×10^3 V/m

Uniform field, 100 V / 0.050 m

Two parallel plates 100 *V apart are separated by* $d = 0.050$ *m. Field between them?*

$$E = \frac{V}{d} = \frac{100}{0.050}$$

uniform-field relation

$$E = 2.00 \times 10^3 \text{ V/m}$$

Answer

2.00×10^3 V/m

Uniform field, 240 V / 0.030 m

Two parallel plates 240 V apart are separated by $d = 0.030$ m. Field between them?

$$E = \frac{V}{d} = \frac{240}{0.030}$$

uniform-field relation

$$E = 8.00 \times 10^3 \text{ V/m}$$

Answer

8.00×10^3 V/m

Uniform field, 60 V / 0.100 m

Two parallel plates 60 V apart are separated by $d = 0.100$ m. Field between them?

$$E = \frac{V}{d} = \frac{60}{0.100}$$

uniform-field relation

$$E = 6.00 \times 10^{2}\ \text{V/m}$$

Answer

$6.00 \times 10^{2}\ \text{V/m}$

Uniform field, 9 V / 0.003 m

Two parallel plates 9 V apart are separated by $d = 0.003$ m. Field between them?

$$E = \frac{V}{d} = \frac{9}{0.003}$$

uniform-field relation

$$E = 3.00 \times 10^3 \text{ V/m}$$

Answer

3.00×10^3 V/m

Capacitance, 60μC at 12 V

A capacitor holds $Q = 60\ \mu C$ at $V = 12\ V$. Find its capacitance.

$$C = \frac{Q}{V} = \frac{6.00 \times 10^{-5}}{12} \qquad \text{definition of } C$$

$$C = 5.00 \times 10^{-6}\ \text{F}$$

Answer

5.00×10^{-6} F

Capacitance, 100μC at 25 V

A capacitor holds $Q = 100\ \mu C$ at $V = 25\ V$. Find its capacitance.

$$C = \frac{Q}{V} = \frac{1.00 \times 10^{-4}}{25} \qquad \text{definition of } C$$

$$C = 4.00 \times 10^{-6}\ \text{F}$$

Answer

4.00×10^{-6} F

Capacitance, 48μC at 6 V

A capacitor holds $Q = 48\ \mu C$ at $V = 6\ V$. Find its capacitance.

$$C = \frac{Q}{V} = \frac{4.80 \times 10^{-5}}{6} \qquad \text{definition of } C$$

$$C = 8.00 \times 10^{-6}\ \text{F}$$

Answer

8.00×10^{-6} F

Charge stored, 5μF at 12 V

How much charge does a 5 μF capacitor hold at $V = 12$ V?

$$Q = CV = 5.00 \times 10^{-6}(12) \qquad \text{rearrange } C = Q/V$$
$$Q = 6.00 \times 10^{-5} \text{ C}$$

Answer

6.00×10^{-5} C

Charge stored, 10μF at 9 V

How much charge does a 10 μF capacitor hold at $V = 9$ V?

$$Q = CV = 1.00 \times 10^{-5}(9) \qquad \text{rearrange } C = Q/V$$
$$Q = 9.00 \times 10^{-5} \text{ C}$$

Answer

9.00×10^{-5} C

Charge stored, 2μF at 50 V

How much charge does a 2 μF capacitor hold at $V = 50$ V?

$$Q = CV = 2.00 \times 10^{-6}(50) \qquad \text{rearrange } C = Q/V$$
$$Q = 1.00 \times 10^{-4} \text{ C}$$

Answer

1.00×10^{-4} C

Energy stored, 5μF at 12 V

How much energy is stored in a $5\ \mu F$ *capacitor charged to* $12\ V$*?*

$$U = \tfrac{1}{2}CV^2 = \tfrac{1}{2}(5.00 \times 10^{-6})(12)^2 \qquad \text{energy in a capacitor}$$

$$U = 3.60 \times 10^{-4}\ \text{J}$$

Answer

3.60×10^{-4} J

Energy stored, 20μF at 6 V

How much energy is stored in a 20 μF capacitor charged to 6 V?

$$U = \tfrac{1}{2}CV^2 = \tfrac{1}{2}(2.00 \times 10^{-5})(6)^2 \qquad \text{energy in a capacitor}$$

$$U = 3.60 \times 10^{-4}\ \text{J}$$

Answer

3.60×10^{-4} J

Energy stored, 100μF at 9 V

How much energy is stored in a 100 μF capacitor charged to 9 V?

$$U = \tfrac{1}{2}CV^2 = \tfrac{1}{2}(1.00 \times 10^{-4})(9)^2 \qquad \text{energy in a capacitor}$$

$$U = 4.05 \times 10^{-3}\ \text{J}$$

Answer

4.05×10^{-3} J

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Current, 6 C in 2 s

A charge of 6 C flows past a point in 2 s. Find the current.

$$I = \frac{Q}{t} = \frac{6}{2}$$ rate of charge flow

$$I = 3.00\ \text{A}$$

Answer

3.00 A

Current, 12 C in 4 s

A charge of 12 C flows past a point in 4 s. Find the current.

$$I = \frac{Q}{t} = \frac{12}{4}$$ rate of charge flow

$$I = 3.00\ \text{A}$$

Answer

3.00 A

Current, 9 C in 3 s

A charge of 9 C flows past a point in 3 s. Find the current.

$$I = \frac{Q}{t} = \frac{9}{3} \qquad \text{rate of charge flow}$$

$$I = 3.00\ \text{A}$$

Answer

3.00 A

Current, 2 C in 5 s

I4

A charge of 2 C flows past a point in 5 s. Find the current.

$$I = \frac{Q}{t} = \frac{2}{5}$$ rate of charge flow

$$I = 0.40 \text{ A}$$

Answer

0.40 A

Current, 20 C in 10 s

A charge of 20 C flows past a point in 10 s. Find the current.

$$I = \frac{Q}{t} = \frac{20}{10}$$ rate of charge flow

$$I = 2.00 \text{ A}$$

Answer

2.00 A

Charge, 3.0 A for 5 s

How much charge flows when 3.0 *A runs for* 5 *s?*

$$Q = It = 3.0(5) \qquad \text{rearrange } I = Q/t$$
$$Q = 15.0 \text{ C}$$

Answer

15.0 C

Charge, 0.5 A for 20 s

How much charge flows when 0.5 *A runs for* 20 *s?*

$$Q = It = 0.5(20) \qquad \text{rearrange } I = Q/t$$

$$Q = 10.0 \text{ C}$$

Answer

10.0 C

Charge, 2.0 A for 8 s

I4

How much charge flows when 2.0 A runs for 8 s?

$$Q = It = 2.0(8) \qquad \text{rearrange } I = Q/t$$
$$Q = 16.0 \text{ C}$$

Answer
16.0 C

Time for 30 C at 2 A

I4

How long does it take 2 A to deliver 30 C?

$$t = \frac{Q}{I} = \frac{30}{2} \qquad \text{rearrange } I = Q/t$$

$$t = 15.0 \text{ s}$$

Answer

15.0 s

Time for 45 C at 3 A

I4

How long does it take 3 A to deliver 45 C?

$$t = \frac{Q}{I} = \frac{45}{3} \qquad \text{rearrange } I = Q/t$$

$$t = 15.0 \text{ s}$$

Answer

15.0 s

Electrons per second at 1.0 A

How many electrons per second make up a 1.0 A current ($e = 1.6 \times 10^{-19}$)?

$$n = \frac{I}{e} = \frac{1.0}{1.6 \times 10^{-19}} \qquad \text{each electron carries } e$$

$$n = 6.25 \times 10^{18} \text{ /s}$$

Answer

6.25×10^{18} electrons/s

Electrons per second at 2.0 A

How many electrons per second make up a 2.0 A current ($e = 1.6 \times 10^{-19}$)?

$$n = \frac{I}{e} = \frac{2.0}{1.6 \times 10^{-19}} \qquad \text{each electron carries } e$$

$$n = 1.25 \times 10^{19} \text{ /s}$$

Answer

1.25×10^{19} electrons/s

Electrons per second at 0.5 A

How many electrons per second make up a 0.5 *A current (*$e = 1.6 \times 10^{-19}$*)?*

$$n = \frac{I}{e} = \frac{0.5}{1.6 \times 10^{-19}} \qquad \text{each electron carries } e$$

$$n = 3.12 \times 10^{18} \text{ /s}$$

Answer

3.12×10^{18} electrons/s

Ohm: V from 2.00 A, 5 Ω

Find the voltage across a 5 Ω *resistor carrying* 2.00 *A.*

$$V = IR = 2.00(5) \qquad \text{Ohm's law}$$
$$V = 10.0\ \text{V}$$

Answer
10.0 V

Ohm: V from 0.50 A, 100 Ω

Find the voltage across a 100 Ω *resistor carrying* 0.50 *A.*

$$V = IR = 0.50(100) \qquad \text{Ohm's law}$$
$$V = 50.0\ \text{V}$$

Answer
50.0 V

Ohm: V from 3.00 A, 4 Ω

Find the voltage across a 4 Ω *resistor carrying* 3.00 *A.*

$$V = IR = 3.00(4) \qquad \text{Ohm's law}$$
$$V = 12.0\ \text{V}$$

Answer
12.0 V

Ohm: V from 0.25 A, 220 Ω

Find the voltage across a 220 Ω *resistor carrying* 0.25 *A.*

$$V = IR = 0.25(220) \qquad \text{Ohm's law}$$
$$V = 55.0\ \text{V}$$

Answer
55.0 V

Ohm: V from 1.50 A, 8 Ω

I5

Find the voltage across a 8 Ω *resistor carrying* 1.50 *A.*

$$V = IR = 1.50(8) \qquad \text{Ohm's law}$$
$$V = 12.0\ \text{V}$$

Answer
12.0 V

Ohm: I from 12 V, 4 Ω

What current flows when 12 V is across a 4 Ω resistor?

$$I = \frac{V}{R} = \frac{12}{4}$$ Ohm's law rearranged

$$I = 3.00\ \text{A}$$

Answer

3.00 A

Ohm: I from 9 V, 3 Ω

What current flows when 9 V is across a 3 Ω resistor?

$$I = \frac{V}{R} = \frac{9}{3}$$

Ohm's law rearranged

$$I = 3.00\ \text{A}$$

Answer

3.00 A

Ohm: I from 120 V, 60 Ω

What current flows when 120 V is across a 60 Ω resistor?

$$I = \frac{V}{R} = \frac{120}{60}$$

Ohm's law rearranged

$$I = 2.00\ \text{A}$$

Answer

2.00 A

Ohm: I from 6 V, 12 Ω

What current flows when 6 V is across a 12 Ω resistor?

$$I = \frac{V}{R} = \frac{6}{12}$$ Ohm's law rearranged

$$I = 0.50\ \text{A}$$

Answer

0.50 A

Ohm: R from 12 V, 3.0 A

A resistor drops 12 *V while carrying* 3.0 *A. Find its resistance.*

$$R = \frac{V}{I} = \frac{12}{3.0}$$

Ohm's law rearranged

$$R = 4.0\ \Omega$$

Answer

4.0 Ω

Ohm: R from 24 V, 2.0 A

A resistor drops 24 V while carrying 2.0 A. Find its resistance.

$$R = \frac{V}{I} = \frac{24}{2.0}$$

Ohm's law rearranged

$$R = 12.0\ \Omega$$

Answer

12.0 Ω

Ohm: R from 9 V, 0.5 A

A resistor drops 9 *V while carrying* 0.5 *A. Find its resistance.*

$$R = \frac{V}{I} = \frac{9}{0.5}$$

Ohm's law rearranged

$$R = 18.0\ \Omega$$

Answer

18.0 Ω

Power, 2.0 A at 12 V

Find the power delivered when 2.0 *A flows at* 12 *V.*

$$P = IV = 2.0(12) \qquad \text{power} = \text{current} \times \text{voltage}$$

$$P = 24.0\ \text{W}$$

Answer
24.0 W

Power, 0.5 A at 120 V

Find the power delivered when 0.5 *A flows at* 120 *V.*

$$P = IV = 0.5(120) \qquad \text{power} = \text{current} \times \text{voltage}$$

$$P = 60.0 \text{ W}$$

Answer

60.0 W

Power, 3.0 A at 9 V

I6

Find the power delivered when 3.0 *A flows at* 9 *V.*

$$P = IV = 3.0(9) \qquad \text{power} = \text{current} \times \text{voltage}$$

$$P = 27.0\ \text{W}$$

Answer
27.0 W

Power, 1.5 A at 6 V

Find the power delivered when 1.5 *A flows at* 6 *V.*

$$P = IV = 1.5(6) \qquad \text{power} = \text{current} \times \text{voltage}$$

$$P = 9.0\ \text{W}$$

Answer

9.0 W

Power, I^2R: 2.0 A, 5 Ω

How much power dissipates in a 5 Ω resistor carrying 2.0 A?

$$P = I^2R = (2.0)^2(5) \qquad \text{power in a resistor}$$

$$P = 20.0 \text{ W}$$

Answer
20.0 W

Power, I^2R: 3.0 A, 4 Ω

How much power dissipates in a 4 Ω resistor carrying 3.0 A?

$$P = I^2R = (3.0)^2(4) \qquad \text{power in a resistor}$$

$$P = 36.0 \text{ W}$$

Answer
36.0 W

Power, I^2R: 0.5 A, 100 Ω

How much power dissipates in a 100 Ω *resistor carrying* 0.5 *A?*

$$P = I^2R = (0.5)^2(100) \qquad \text{power in a resistor}$$

$$P = 25.0 \text{ W}$$

Answer
25.0 W

Power, V^2/R: 12 V, 6 Ω

Find the power dissipated by a 6 Ω resistor across 12 V.

$$P = \frac{V^2}{R} = \frac{(12)^2}{6} \qquad \text{power from voltage}$$

$$P = 24.0 \text{ W}$$

Answer

24.0 W

Power, V^2/R: 120 V, 240 Ω

Find the power dissipated by a 240 Ω *resistor across* 120 *V.*

$$P = \frac{V^2}{R} = \frac{(120)^2}{240} \qquad \text{power from voltage}$$

$$P = 60.0 \text{ W}$$

Answer

60.0 W

Power, V^2/R: 9 V, 3 Ω

Find the power dissipated by a 3 Ω resistor across 9 V.

$$P = \frac{V^2}{R} = \frac{(9)^2}{3} \qquad \text{power from voltage}$$

$$P = 27.0 \text{ W}$$

Answer

27.0 W

Energy, 60 W for 3600 s

How much energy does a 60 W device use in 3600 s?

$$E = Pt = 60(3600) \qquad \text{energy} = \text{power} \times \text{time}$$

$$E = 2.16 \times 10^5 \text{ J}$$

Answer

2.16×10^5 J

Energy, 100 W for 60 s

How much energy does a 100 W device use in 60 s?

$$E = Pt = 100(60) \qquad \text{energy} = \text{power} \times \text{time}$$

$$E = 6.00 \times 10^3 \text{ J}$$

Answer

6.00×10^3 J

Energy, 1500 W for 120 s

How much energy does a 1500 W device use in 120 s?

$$E = Pt = 1500(120) \qquad \text{energy} = \text{power} \times \text{time}$$

$$E = 1.80 \times 10^5 \text{ J}$$

Answer

1.80×10^5 J

Series 4+6 Ω

Two resistors, 4 Ω and 6 Ω, are in series. Total resistance?

$$R_s = R_1 + R_2 = 4 + 6 \qquad \text{series resistors add}$$
$$R_s = 10\ \Omega$$

Answer

10 Ω

Series 10+20 Ω

Two resistors, 10 Ω and 20 Ω, are in series. Total resistance?

$$R_s = R_1 + R_2 = 10 + 20 \qquad \text{series resistors add}$$
$$R_s = 30\ \Omega$$

Answer

30 Ω

Series 3+5 Ω

Two resistors, 3 Ω and 5 Ω, are in series. Total resistance?

$$R_s = R_1 + R_2 = 3 + 5 \qquad \text{series resistors add}$$
$$R_s = 8\ \Omega$$

Answer

8 Ω

Series 100+220 Ω

Two resistors, 100 Ω and 220 Ω, are in series. Total resistance?

$$R_s = R_1 + R_2 = 100 + 220 \qquad \text{series resistors add}$$

$$R_s = 320\ \Omega$$

Answer

320 Ω

Series 2+3+5 Ω

Three resistors 2, 3, *and* 5 Ω *are in series. Total?*

$$R_s = 2 + 3 + 5 \qquad \text{add them all}$$

$$R_s = 10\ \Omega$$

Answer

10 Ω

Series 10+10+10 Ω

Three resistors 10, 10, *and* 10 Ω *are in series. Total?*

$$R_s = 10 + 10 + 10 \qquad \text{add them all}$$
$$R_s = 30\ \Omega$$

Answer
30 Ω

Parallel $6 \| 3\ \Omega$

Two resistors 6 Ω and 3 Ω are in parallel. Equivalent resistance?

$$R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{18}{9} \qquad \text{product over sum}$$

$$R_p = 2.00\ \Omega \qquad \text{less than either}$$

Answer

2.00 Ω

Parallel $4 \| 4\ \Omega$

Two resistors 4 Ω and 4 Ω are in parallel. Equivalent resistance?

$$R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{16}{8} \qquad \text{product over sum}$$

$$R_p = 2.00\ \Omega \qquad \text{less than either}$$

Answer

2.00 Ω

Parallel $12 \| 6\ \Omega$

Two resistors $12\ \Omega$ *and* $6\ \Omega$ *are in parallel. Equivalent resistance?*

$$R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{72}{18} \qquad \text{product over sum}$$

$$R_p = 4.00\ \Omega \qquad \text{less than either}$$

Answer

$4.00\ \Omega$

Parallel 20‖5 Ω

Two resistors 20 Ω *and* 5 Ω *are in parallel. Equivalent resistance?*

$$R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{100}{25} \qquad \text{product over sum}$$

$$R_p = 4.00\ \Omega \qquad \text{less than either}$$

Answer

4.00 Ω

3 equal 12 Ω in parallel

How much is 3 identical 12 Ω resistors in parallel?

$$R_p = \frac{R}{n} = \frac{12}{3} \qquad n \text{ equal resistors}$$

$$R_p = 4.00\ \Omega$$

Answer

4.00 Ω

4 equal 20 Ω in parallel

How much is 4 identical 20 Ω resistors in parallel?

$$R_p = \frac{R}{n} = \frac{20}{4} \qquad n \text{ equal resistors}$$

$$R_p = 5.00\ \Omega$$

Answer

5.00 Ω

2 equal 6 Ω in parallel

How much is 2 identical 6 Ω resistors in parallel?

$$R_p = \frac{R}{n} = \frac{6}{2} \qquad n \text{ equal resistors}$$

$$R_p = 3.00\ \Omega$$

Answer

3.00 Ω

Combo: $(6 \| 3) + 4\ \Omega$

A 6 Ω and 3 Ω in parallel, then 4 Ω in series. Total resistance?

$$R_p = \frac{18}{9} = 2.00\ \Omega \qquad \text{parallel pair first}$$

$$R_{\text{tot}} = 2.00 + 4 = 6.00\ \Omega \qquad \text{add series part}$$

Answer

6.00 Ω

Combo: (4‖4)+10 Ω

A 4 Ω and 4 Ω in parallel, then 10 Ω in series. Total resistance?

$$R_p = \frac{16}{8} = 2.00\ \Omega \qquad \text{parallel pair first}$$

$$R_{\text{tot}} = 2.00 + 10 = 12.00\ \Omega \qquad \text{add series part}$$

Answer

12.00 Ω

Junction rule

Currents $5\ A, 3\ A$ *enter a junction and* $2\ A$ *leave on known branches. Find the remaining branch current.*

$$\sum I_{\text{in}} = \sum I_{\text{out}} \qquad \text{charge conserved}$$

$$I = 8 - 2 = 6.0\ \text{A} \qquad \text{the missing branch}$$

Answer

6.0 A

Junction rule

Currents 4 A enter a junction and 1 A, 1 A leave on known branches. Find the remaining branch current.

$$\sum I_{\text{in}} = \sum I_{\text{out}} \qquad \text{charge conserved}$$

$$I = 4 - 2 = 2.0\ \text{A} \qquad \text{the missing branch}$$

Answer

2.0 A

Junction rule

Currents 6 A, 2 A enter a junction and 3 A leave on known branches. Find the remaining branch current.

$$\sum I_{\text{in}} = \sum I_{\text{out}} \qquad \text{charge conserved}$$

$$I = 8 - 3 = 5.0\ \text{A} \qquad \text{the missing branch}$$

Answer

5.0 A

Junction rule

Currents 10 *A enter a junction and* 4 *A*, 2 *A leave on known branches. Find the remaining branch current.*

$$\sum I_{\text{in}} = \sum I_{\text{out}} \qquad \text{charge conserved}$$

$$I = 10 - 6 = 4.0\ \text{A} \qquad \text{the missing branch}$$

Answer

4.0 A

Loop rule, 12 V

A 12 V battery drives 4 Ω and 2 Ω in series. Find I and each voltage drop.

$$I = \frac{\varepsilon}{R_1 + R_2} = \frac{12}{6} = 2.00\ \text{A} \qquad \text{loop rule}$$

$$V_1, V_2 = 8.0\ \text{V},\ 4.0\ \text{V} \qquad \text{drops sum to } \varepsilon$$

Answer

$$I = 2.00\ \text{A},\ V_1 = 8.0\ \text{V},\ V_2 = 4.0\ \text{V}$$

Loop rule, 9 V

A 9 V battery drives 3 Ω and 6 Ω in series. Find I and each voltage drop.

$$I = \frac{\varepsilon}{R_1 + R_2} = \frac{9}{9} = 1.00\ \text{A} \qquad \text{loop rule}$$

$$V_1, V_2 = 3.0\ \text{V},\ 6.0\ \text{V} \qquad \text{drops sum to } \varepsilon$$

Answer

$$I = 1.00\ \text{A},\ V_1 = 3.0\ \text{V},\ V_2 = 6.0\ \text{V}$$

Loop rule, 24 V

A 24 V battery drives 8 Ω and 4 Ω in series. Find I and each voltage drop.

$$I = \frac{\varepsilon}{R_1 + R_2} = \frac{24}{12} = 2.00\ \text{A} \qquad \text{loop rule}$$

$$V_1, V_2 = 16.0\ \text{V},\ 8.0\ \text{V} \qquad \text{drops sum to } \varepsilon$$

Answer

$$I = 2.00\ \text{A},\ V_1 = 16.0\ \text{V},\ V_2 = 8.0\ \text{V}$$

Loop rule, 6 V

A 6 V battery drives 1 Ω and 2 Ω in series. Find I and each voltage drop.

$$I = \frac{\varepsilon}{R_1 + R_2} = \frac{6}{3} = 2.00\ \text{A} \qquad \text{loop rule}$$

$$V_1, V_2 = 2.0\ \text{V},\ 4.0\ \text{V} \qquad \text{drops sum to } \varepsilon$$

Answer

$$I = 2.00\ \text{A},\ V_1 = 2.0\ \text{V},\ V_2 = 4.0\ \text{V}$$

Dielectric, $\kappa = 3$

A dielectric of constant $\kappa = 3$ fills a 2 μF capacitor. New capacitance?

$$C = \kappa C_0 = 3(2) \quad \text{dielectric law}$$

$$C = 6\ \mu\text{F} \quad \text{always larger}$$

Answer

6 μF

Dielectric, $\kappa = 4$

A dielectric of constant $\kappa = 4$ fills a 5 μF capacitor. New capacitance?

$$C = \kappa C_0 = 4(5) \qquad \text{dielectric law}$$

$$C = 20\ \mu\text{F} \qquad \text{always larger}$$

Answer

20 μF

Dielectric, $\kappa = 2$

A dielectric of constant $\kappa = 2$ fills a 10 μF capacitor. New capacitance?

$$C = \kappa C_0 = 2(10) \qquad \text{dielectric law}$$

$$C = 20\ \mu\text{F} \qquad \text{always larger}$$

Answer

20 μF

Dielectric, $\kappa = 5$

A dielectric of constant $\kappa = 5$ fills a 1 μF capacitor. New capacitance?

$$C = \kappa C_0 = 5(1) \quad \text{dielectric law}$$

$$C = 5\ \mu\text{F} \quad \text{always larger}$$

Answer

5 μF

Charge with $\kappa = 3$ at 12 V

A 2 μF capacitor with a $\kappa = 3$ dielectric is held at 12 V. Charge stored?

$$C = \kappa C_0 = 6\ \mu\text{F} \qquad \text{dielectric raises } C$$

$$Q = CV = 7.20 \times 10^{-5}\ \text{C} \qquad \text{at fixed voltage}$$

Answer

7.20×10^{-5} C

Charge with $\kappa = 4$ at 9 V

A 5 μF capacitor with a $\kappa = 4$ dielectric is held at 9 V. Charge stored?

$$C = \kappa C_0 = 20\ \mu\text{F} \qquad \text{dielectric raises } C$$

$$Q = CV = 1.80 \times 10^{-4}\ \text{C} \qquad \text{at fixed voltage}$$

Answer

1.80×10^{-4} C

Charge with $\kappa = 2$ at 6 V

A 10 μF capacitor with a $\kappa = 2$ dielectric is held at 6 V. Charge stored?

$$C = \kappa C_0 = 20\ \mu\text{F} \qquad \text{dielectric raises } C$$

$$Q = CV = 1.20 \times 10^{-4}\ \text{C} \qquad \text{at fixed voltage}$$

Answer

1.20×10^{-4} C

Energy with $\kappa = 3$

A 2 μF capacitor with a $\kappa = 3$ dielectric is charged to 12 V. Energy stored?

$$C = \kappa C_0 = 6\ \mu\text{F} \qquad \text{dielectric raises } C$$

$$U = \tfrac{1}{2}CV^2 = 4.32 \times 10^{-4}\ \text{J} \qquad \text{at fixed voltage}$$

Answer

4.32×10^{-4} J

Energy with $\kappa = 2$

A 5 μF capacitor with a $\kappa = 2$ dielectric is charged to 10 V. Energy stored?

$$C = \kappa C_0 = 10\ \mu\text{F} \qquad \text{dielectric raises } C$$

$$U = \tfrac{1}{2}CV^2 = 5.00 \times 10^{-4}\ \text{J} \qquad \text{at fixed voltage}$$

Answer

5.00×10^{-4} J

Energy with $\kappa = 4$

A 1 μF capacitor with a $\kappa = 4$ dielectric is charged to 20 V. Energy stored?

$$C = \kappa C_0 = 4\ \mu\text{F} \qquad \text{dielectric raises } C$$

$$U = \tfrac{1}{2}CV^2 = 8.00 \times 10^{-4}\ \text{J} \qquad \text{at fixed voltage}$$

Answer

8.00×10^{-4} J

Loop, 3 resistors, 18 V

A 18 V battery drives 2, 3, 4 Ω in series. Find the current.

$$R_{\text{tot}} = 2 + 3 + 4 = 9\ \Omega \qquad \text{series total}$$

$$I = \frac{\varepsilon}{R} = \frac{18}{9} = 2.00\ \text{A} \qquad \text{loop rule}$$

Answer

2.00 A

Loop, 3 resistors, 12 V

A 12 V battery drives 1, 2, 3 Ω in series. Find the current.

$$R_{\text{tot}} = 1 + 2 + 3 = 6\ \Omega \qquad \text{series total}$$

$$I = \frac{\varepsilon}{R} = \frac{12}{6} = 2.00\ \text{A} \qquad \text{loop rule}$$

Answer

2.00 A

Isolated cap, $\kappa = 3$

An isolated (fixed-charge) capacitor at 12 V gets a $\kappa = 3$ dielectric. New voltage?

$$C = \kappa C_0 \qquad \text{capacitance rises}$$

$$V = \frac{V_0}{\kappa} = \frac{12}{3} = 4.0\ \text{V} \qquad \text{fixed } Q\text{: } V \text{ drops}$$

Answer

4.0 V

Isolated cap, $\kappa = 4$

An isolated (fixed-charge) capacitor at 20 V gets a $\kappa = 4$ dielectric. New voltage?

$$C = \kappa C_0 \qquad \text{capacitance rises}$$

$$V = \frac{V_0}{\kappa} = \frac{20}{4} = 5.0\ \text{V} \qquad \text{fixed } Q\text{: } V \text{ drops}$$

Answer

5.0 V

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Magnetic poles

B1

Two north poles are brought close together. Do they attract or repel?

rule = repel like repel, unlike attract

Answer

repel

Magnetic poles

B1

A north pole faces a south pole. Attract or repel?

rule = attract like repel, unlike attract

Answer

attract

Magnetic poles

Can a single magnetic pole (a monopole) be isolated by cutting a magnet?

rule = no — always N&S pairs like repel, unlike attract

Answer

no — always N&S pairs

Force on charge, 90°

A 0.005 C charge moves at 200 m/s through $B = 0.30$ T at 90° to the field. Force?

$$F = qvB\sin\theta = 0.005(200)(0.30)\sin 90^\circ \qquad \text{magnetic force}$$

$$F = 0.300 \text{ N} \qquad \text{sideways}$$

Answer

0.300 N

Force on charge, 90°

B2

A 0.010 C charge moves at 400 m/s through $B = 0.50$ T at 90° to the field. Force?

$$F = qvB\sin\theta = 0.010(400)(0.50)\sin 90^\circ \quad \text{magnetic force}$$

$$F = 2.000\ \text{N} \quad \text{sideways}$$

Answer

2.000 N

Force on charge, 30°

A 0.002 C charge moves at 500 m/s through $B = 0.20$ T at 30° to the field. Force?

$$F = qvB\sin\theta = 0.002(500)(0.20)\sin 30^\circ \quad \text{magnetic force}$$

$$F = 0.100 \text{ N} \quad \text{sideways}$$

Answer

0.100 N

Force on charge, 60°

A 0.008 C charge moves at 250 m/s through $B = 0.40$ T at 60° to the field. Force?

$$F = qvB\sin\theta = 0.008(250)(0.40)\sin 60^\circ \quad \text{magnetic force}$$

$$F = 0.693 \text{ N} \quad \text{sideways}$$

Answer

0.693 N

Force on charge, 90°

B2

A 0.003 C charge moves at 300 m/s through $B = 0.60$ T at 90° to the field. Force?

$$F = qvB\sin\theta = 0.003(300)(0.60)\sin 90^\circ \qquad \text{magnetic force}$$

$$F = 0.540 \text{ N} \qquad \text{sideways}$$

Answer

0.540 N

Force on charge, 45°

A 0.006 C charge moves at 150 m/s through $B = 0.50$ T at 45° to the field. Force?

$$F = qvB\sin\theta = 0.006(150)(0.50)\sin 45^\circ \quad \text{magnetic force}$$

$$F = 0.318 \text{ N} \quad \text{sideways}$$

Answer

0.318 N

Force on charge, 90°

A 0.004 C charge moves at 350 m/s through $B = 0.25$ T at 90° to the field. Force?

$$F = qvB\sin\theta = 0.004(350)(0.25)\sin 90^\circ \quad \text{magnetic force}$$

$$F = 0.350 \text{ N} \quad \text{sideways}$$

Answer

0.350 N

Force on charge, 90°

A 0.010 C charge moves at 100 m/s through $B = 0.80$ T at 90° to the field. Force?

$$F = qvB\sin\theta = 0.010(100)(0.80)\sin 90^\circ \quad \text{magnetic force}$$

$$F = 0.800 \text{ N} \quad \text{sideways}$$

Answer

0.800 N

Force on charge, 30°

A 0.002 C charge moves at 600 m/s through $B = 0.50$ T at 30° to the field. Force?

$$F = qvB\sin\theta = 0.002(600)(0.50)\sin 30^\circ \quad \text{magnetic force}$$

$$F = 0.300 \text{ N} \quad \text{sideways}$$

Answer

0.300 N

Force on charge, 90°

A 0.005 C charge moves at 400 m/s through $B = 0.30$ T at 90° to the field. Force?

$$F = qvB\sin\theta = 0.005(400)(0.30)\sin 90^\circ \qquad \text{magnetic force}$$

$$F = 0.600 \text{ N} \qquad \text{sideways}$$

Answer

0.600 N

Force on wire, 90°

A wire carrying 5 *A, length* 2.00 *m, sits in* $B = 0.40$ *T at* 90°. *Force on it?*

$$F = BIL\sin\theta = 0.40(5)(2.00)\sin 90^\circ$$ force on a current

$$F = 4.000 \text{ N}$$

Answer

4.000 N

Force on wire, 90°

A wire carrying 10 *A, length* 0.50 *m, sits in* $B = 0.20$ *T at* 90°. *Force on it?*

$$F = BIL\sin\theta = 0.20(10)(0.50)\sin 90^\circ$$ force on a current

$$F = 1.000 \text{ N}$$

Answer

1.000 N

Force on wire, 30°

A wire carrying 3 *A, length* 1.00 *m, sits in* $B = 0.60$ *T at* 30°. *Force on it?*

$$F = BIL\sin\theta = 0.60(3)(1.00)\sin 30^\circ$$ force on a current

$$F = 0.900 \text{ N}$$

Answer

0.900 N

Force on wire, 60°

A wire carrying 8 *A, length* 0.25 *m, sits in* $B = 0.50$ *T at* 60°. *Force on it?*

$$F = BIL\sin\theta = 0.50(8)(0.25)\sin 60^\circ$$ force on a current

$$F = 0.866 \text{ N}$$

Answer

0.866 N

Force on wire, 90°

A wire carrying 4 *A, length* 2.00 *m, sits in* $B = 0.30$ *T at* 90°. *Force on it?*

$$F = BIL\sin\theta = 0.30(4)(2.00)\sin 90^\circ$$ force on a current

$$F = 2.400 \text{ N}$$

Answer

2.400 N

Force on wire, 90°

A wire carrying 2 *A, length* 1.50 *m, sits in* $B = 0.80$ *T at* 90°. *Force on it?*

$$F = BIL\sin\theta = 0.80(2)(1.50)\sin 90^\circ$$ force on a current

$$F = 2.400 \text{ N}$$

Answer

2.400 N

Force on wire, 45°

A wire carrying 6 *A, length* 0.40 *m, sits in* $B = 0.25$ *T at* 45°. *Force on it?*

$$F = BIL\sin\theta = 0.25(6)(0.40)\sin 45^\circ$$ force on a current

$$F = 0.424 \text{ N}$$

Answer

0.424 N

Wire field, 10 A at 0.050 m

Find the magnetic field 0.050 *m from a long straight wire carrying* 10 *A* ($\mu_0/2\pi = 2 \times 10^{-7}$).

$$B = \frac{\mu_0 I}{2\pi r} = \frac{2 \times 10^{-7}(10)}{0.050}$$

field circles the wire

$$B = 4.00 \times 10^{-5}\ \text{T}$$

Answer

4.00×10^{-5} T

Wire field, 5 A at 0.020 m

Find the magnetic field 0.020 *m from a long straight wire carrying* 5 *A* ($\mu_0/2\pi = 2 \times 10^{-7}$).

$$B = \frac{\mu_0 I}{2\pi r} = \frac{2 \times 10^{-7}(5)}{0.020}$$

field circles the wire

$$B = 5.00 \times 10^{-5}\ \text{T}$$

Answer

5.00×10^{-5} T

Wire field, 20 A at 0.100 m

Find the magnetic field 0.100 *m from a long straight wire carrying* 20 *A* ($\mu_0/2\pi = 2 \times 10^{-7}$).

$$B = \frac{\mu_0 I}{2\pi r} = \frac{2 \times 10^{-7}(20)}{0.100}$$

field circles the wire

$$B = 4.00 \times 10^{-5}\ \text{T}$$

Answer

4.00×10^{-5} T

Wire field, 2 A at 0.010 m

Find the magnetic field 0.010 *m from a long straight wire carrying* 2 *A* ($\mu_0/2\pi = 2 \times 10^{-7}$).

$$B = \frac{\mu_0 I}{2\pi r} = \frac{2 \times 10^{-7}(2)}{0.010}$$

field circles the wire

$$B = 4.00 \times 10^{-5}\ \text{T}$$

Answer

4.00×10^{-5} T

Wire field, 15 A at 0.300 m

Find the magnetic field 0.300 *m from a long straight wire carrying* 15 *A* ($\mu_0/2\pi = 2 \times 10^{-7}$).

$$B = \frac{\mu_0 I}{2\pi r} = \frac{2 \times 10^{-7}(15)}{0.300}$$

field circles the wire

$$B = 1.00 \times 10^{-5}\ \text{T}$$

Answer

1.00×10^{-5} T

Wire field, 8 A at 0.040 m

Find the magnetic field 0.040 *m from a long straight wire carrying* 8 *A* ($\mu_0/2\pi = 2 \times 10^{-7}$).

$$B = \frac{\mu_0 I}{2\pi r} = \frac{2 \times 10^{-7}(8)}{0.040}$$ field circles the wire

$$B = 4.00 \times 10^{-5}\ \text{T}$$

Answer

4.00×10^{-5} T

Wire field, 100 A at 0.500 m

Find the magnetic field 0.500 *m from a long straight wire carrying* 100 *A* ($\mu_0/2\pi = 2 \times 10^{-7}$).

$$B = \frac{\mu_0 I}{2\pi r} = \frac{2 \times 10^{-7}(100)}{0.500}$$

field circles the wire

$$B = 4.00 \times 10^{-5}\ \text{T}$$

Answer

4.00×10^{-5} T

Solenoid, 1000/m at 2 A

A solenoid with 1000 *turns/m carries* 2 *A. Field inside* ($\mu_0 = 4\pi \times 10^{-7}$)*?*

$$B = \mu_0 n I = (4\pi \times 10^{-7})(1000)(2) \qquad \text{uniform inside}$$

$$B = 2.51 \times 10^{-3}\ \text{T}$$

Answer

2.51×10^{-3} T

Solenoid, 500/m at 3 A

A solenoid with 500 *turns/m carries* 3 *A. Field inside* ($\mu_0 = 4\pi \times 10^{-7}$)*?*

$$B = \mu_0 n I = (4\pi \times 10^{-7})(500)(3) \qquad \text{uniform inside}$$

$$B = 1.88 \times 10^{-3}\ \text{T}$$

Answer

1.88×10^{-3} T

Solenoid, 2000/m at 1 A

A solenoid with 2000 *turns/m carries* 1 *A. Field inside* ($\mu_0 = 4\pi \times 10^{-7}$)*?*

$$B = \mu_0 n I = (4\pi \times 10^{-7})(2000)(1) \qquad \text{uniform inside}$$

$$B = 2.51 \times 10^{-3}\ \text{T}$$

Answer

2.51×10^{-3} T

Solenoid, 800/m at 5 A

B5

A solenoid with 800 turns/m carries 5 A. Field inside ($\mu_0 = 4\pi \times 10^{-7}$)?

$$B = \mu_0 n I = (4\pi \times 10^{-7})(800)(5) \qquad \text{uniform inside}$$

$$B = 5.03 \times 10^{-3}\ \text{T}$$

Answer

5.03×10^{-3} T

Solenoid, 1500/m at 2 A

A solenoid with 1500 *turns/m carries* 2 *A. Field inside* ($\mu_0 = 4\pi \times 10^{-7}$)*?*

$$B = \mu_0 n I = (4\pi \times 10^{-7})(1500)(2) \qquad \text{uniform inside}$$

$$B = 3.77 \times 10^{-3}\ \text{T}$$

Answer

3.77×10^{-3} T

Loop torque, 1 turns

A 1-turn loop of area $0.010\ m^2$ *carries* $2.0\ A$ *in* $B = 0.50\ T$ *at* $90°$. *Torque?*

$$\tau = NBIA\sin\theta = 1(0.50)(2.0)(0.010)\sin 90° \qquad \text{torque on a loop}$$

$$\tau = 1.00 \times 10^{-2}\ \text{N}\cdot\text{m}$$

Answer

$1.00 \times 10^{-2}\ \text{N}\cdot\text{m}$

Loop torque, 100 turns

A 100-turn loop of area 0.020 m^2 carries 0.5 A in $B = 0.20$ T at 90°. Torque?

$$\tau = NBIA\sin\theta = 100(0.20)(0.5)(0.020)\sin 90^\circ \qquad \text{torque on a loop}$$

$$\tau = 2.00 \times 10^{-1}\ \text{N}\cdot\text{m}$$

Answer

2.00×10^{-1} N · m

Loop torque, 50 turns

A 50-turn loop of area 0.005 m^2 carries 1.0 A in $B = 0.40$ T at 30°. Torque?

$$\tau = NBIA\sin\theta = 50(0.40)(1.0)(0.005)\sin 30^\circ \qquad \text{torque on a loop}$$

$$\tau = 5.00 \times 10^{-2}\ \text{N}\cdot\text{m}$$

Answer

5.00×10^{-2} N · m

Loop torque, 200 turns

A 200-turn loop of area 0.010 m^2 carries 2.0 A in $B = 0.10$ T at 90°. Torque?

$$\tau = NBIA\sin\theta = 200(0.10)(2.0)(0.010)\sin 90^\circ \qquad \text{torque on a loop}$$

$$\tau = 4.00 \times 10^{-1}\ \text{N}\cdot\text{m}$$

Answer

4.00×10^{-1} N · m

Loop torque, 10 turns

A 10-turn loop of area 0.008 m^2 carries 3.0 A in $B = 0.60$ T at 60°. Torque?

$$\tau = NBIA\sin\theta = 10(0.60)(3.0)(0.008)\sin 60^\circ$$ torque on a loop

$$\tau = 1.25 \times 10^{-1}\ \text{N}\cdot\text{m}$$

Answer

1.25×10^{-1} N · m

Radius, a proton

Find the radius of a proton's circular path at $v = 1.00 \times 10^{6}$ m/s in $B = 0.50$ T ($m = 1.67 \times 10^{-27}$ kg).

$$r = \frac{mv}{qB} = \frac{1.67 \times 10^{-27}(1.00 \times 10^{6})}{1.60 \times 10^{-19}(0.50)} \qquad qvB = mv^2/r$$

$$r = 2.09 \times 10^{-2} \text{ m}$$

Answer

2.09×10^{-2} m

Radius, a proton

Find the radius of a proton's circular path at $v = 2.00 \times 10^{6}$ m/s in $B = 0.40$ T ($m = 1.67 \times 10^{-27}$ kg).

$$r = \frac{mv}{qB} = \frac{1.67 \times 10^{-27}(2.00 \times 10^{6})}{1.60 \times 10^{-19}(0.40)} \qquad qvB = mv^2/r$$

$$r = 5.22 \times 10^{-2} \text{ m}$$

Answer

5.22×10^{-2} m

Radius, an electron

Find the radius of an electron's circular path at $v = 1.00 \times 10^{6}$ m/s in $B = 0.20$ T ($m = 9.11 \times 10^{-31}$ kg).

$$r = \frac{mv}{qB} = \frac{9.11 \times 10^{-31}(1.00 \times 10^{6})}{1.60 \times 10^{-19}(0.20)} \qquad qvB = mv^2/r$$

$$r = 2.85 \times 10^{-5} \text{ m}$$

Answer

2.85×10^{-5} m

Radius, an electron

Find the radius of an electron's circular path at $v = 5.00 \times 10^{6}$ m/s in $B = 0.50$ T ($m = 9.11 \times 10^{-31}$ kg).

$$r = \frac{mv}{qB} = \frac{9.11 \times 10^{-31}(5.00 \times 10^{6})}{1.60 \times 10^{-19}(0.50)} \qquad qvB = mv^2/r$$

$$r = 5.69 \times 10^{-5} \text{ m}$$

Answer

5.69×10^{-5} m

Radius, a proton

Find the radius of a proton's circular path at $v = 3.00 \times 10^5$ m/s in $B = 0.10$ T ($m = 1.67 \times 10^{-27}$ kg).

$$r = \frac{mv}{qB} = \frac{1.67 \times 10^{-27}(3.00 \times 10^5)}{1.60 \times 10^{-19}(0.10)} \qquad qvB = mv^2/r$$

$$r = 3.13 \times 10^{-2} \text{ m}$$

Answer

3.13×10^{-2} m

Period, a proton

Find the period of a proton's circular motion in $B = 0.50\ T$ ($m = 1.67 \times 10^{-27}\ kg$).

$$T = \frac{2\pi m}{qB} = \frac{2\pi(1.67 \times 10^{-27})}{1.60 \times 10^{-19}(0.50)}$$

independent of speed

$$T = 1.31 \times 10^{-7}\ \text{s}$$

Answer

1.31×10^{-7} s

Period, an electron

Find the period of an electron's circular motion in $B = 0.20\ T$ ($m = 9.11 \times 10^{-31}\ kg$).

$$T = \frac{2\pi m}{qB} = \frac{2\pi(9.11 \times 10^{-31})}{1.60 \times 10^{-19}(0.20)}$$

independent of speed

$$T = 1.79 \times 10^{-10}\ \text{s}$$

Answer

1.79×10^{-10} s

Period, a proton

Find the period of a proton's circular motion in $B = 1.00\ T$ ($m = 1.67 \times 10^{-27}\ kg$).

$$T = \frac{2\pi m}{qB} = \frac{2\pi(1.67 \times 10^{-27})}{1.60 \times 10^{-19}(1.00)}$$

independent of speed

$$T = 6.56 \times 10^{-8}\ \text{s}$$

Answer

6.56×10^{-8} s

Earth's magnetic field

B8

Which geographic direction does a compass needle's north end point?

$$\text{fact} = \text{geographic north}$$

Answer

geographic north

Earth's magnetic field

What produces Earth's magnetic field?

fact = churning molten iron core

Answer

churning molten iron core

Flux, B=0.5 T, 0°

Find the magnetic flux through a 0.20 m^2 loop in $B = 0.50$ T at 0° to the normal.

$$\Phi = BA\cos\theta = 0.50(0.20)\cos 0^\circ$$ field threading the loop

$$\Phi = 1.00 \times 10^{-1}\ \text{Wb}$$

Answer

1.00×10^{-1} Wb

Flux, B=0.3 T, 60°

Find the magnetic flux through a $0.10\ m^2$ *loop in* $B = 0.30\ T$ *at* $60°$ *to the normal.*

$$\Phi = BA\cos\theta = 0.30(0.10)\cos 60° \qquad \text{field threading the loop}$$

$$\Phi = 1.50 \times 10^{-2}\ \text{Wb}$$

Answer

1.50×10^{-2} Wb

Flux, B=0.8 T, 30°

Find the magnetic flux through a $0.05\ m^2$ *loop in* $B = 0.80\ T$ *at* $30°$ *to the normal.*

$$\Phi = BA\cos\theta = 0.80(0.05)\cos 30° \qquad \text{field threading the loop}$$

$$\Phi = 3.46 \times 10^{-2}\ \text{Wb}$$

Answer

3.46×10^{-2} Wb

Flux, B=0.4 T, 0°

Find the magnetic flux through a 0.25 m^2 loop in $B = 0.40$ T at 0° to the normal.

$$\Phi = BA\cos\theta = 0.40(0.25)\cos 0^\circ$$ field threading the loop

$$\Phi = 1.00 \times 10^{-1}\ \text{Wb}$$

Answer

1.00×10^{-1} Wb

Flux, B=0.6 T, 90°

Find the magnetic flux through a $0.02\ m^2$ *loop in* $B = 0.60\ T$ *at* $90°$ *to the normal.*

$$\Phi = BA\cos\theta = 0.60(0.02)\cos 90° \qquad \text{field threading the loop}$$

$$\Phi = 7.35 \times 10^{-19}\ \text{Wb}$$

Answer

7.35×10^{-19} Wb

Flux, B=0.2 T, 45°

Find the magnetic flux through a $0.50\ m^2$ *loop in* $B = 0.20\ T$ *at* $45°$ *to the normal.*

$$\Phi = BA\cos\theta = 0.20(0.50)\cos 45° \qquad \text{field threading the loop}$$

$$\Phi = 7.07 \times 10^{-2}\ \text{Wb}$$

Answer

7.07×10^{-2} Wb

Flux, B=1.0 T, 0°

Find the magnetic flux through a 0.10 m^2 loop in $B = 1.00$ T at 0° to the normal.

$$\Phi = BA\cos\theta = 1.00(0.10)\cos 0° \qquad \text{field threading the loop}$$

$$\Phi = 1.00 \times 10^{-1}\ \text{Wb}$$

Answer

1.00×10^{-1} Wb

Flux, B=0.5 T, 60°

Find the magnetic flux through a $0.08\ m^2$ *loop in* $B = 0.50\ T$ *at* $60°$ *to the normal.*

$$\Phi = BA\cos\theta = 0.50(0.08)\cos 60° \qquad \text{field threading the loop}$$

$$\Phi = 2.00 \times 10^{-2}\ \text{Wb}$$

Answer

2.00×10^{-2} Wb

Faraday, 1 turns

A 1-turn coil of area 0.100 m^2 sits in a field changing by 0.5 T in 0.2 s. Induced EMF?

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = NA\frac{\Delta B}{\Delta t} = 1(0.100)\frac{0.5}{0.2} \qquad \text{Faraday's law}$$

$$\varepsilon = 0.250 \text{ V}$$

Answer

0.250 V

Faraday, 100 turns

A 100-turn coil of area 0.020 m^2 sits in a field changing by 0.3 T in 0.1 s. Induced EMF?

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = NA\frac{\Delta B}{\Delta t} = 100(0.020)\frac{0.3}{0.1} \qquad \text{Faraday's law}$$

$$\varepsilon = 6.000\ \text{V}$$

Answer

6.000 V

Faraday, 50 turns

A 50-turn coil of area 0.050 m^2 sits in a field changing by 0.8 T in 0.4 s. Induced EMF?

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = NA\frac{\Delta B}{\Delta t} = 50(0.050)\frac{0.8}{0.4} \qquad \text{Faraday's law}$$

$$\varepsilon = 5.000\ \text{V}$$

Answer

5.000 V

Faraday, 200 turns

A 200-turn coil of area 0.010 m^2 sits in a field changing by 0.4 T in 0.2 s. Induced EMF?

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = NA\frac{\Delta B}{\Delta t} = 200(0.010)\frac{0.4}{0.2} \qquad \text{Faraday's law}$$

$$\varepsilon = 4.000\ \text{V}$$

Answer

4.000 V

Faraday, 10 turns

A 10-turn coil of area 0.200 m^2 sits in a field changing by 0.6 T in 0.3 s. Induced EMF?

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = NA\frac{\Delta B}{\Delta t} = 10(0.200)\frac{0.6}{0.3} \qquad \text{Faraday's law}$$

$$\varepsilon = 4.000\ \text{V}$$

Answer

4.000 V

Faraday, 500 turns

A 500-turn coil of area 0.005 m^2 sits in a field changing by 1.0 T in 0.5 s. Induced EMF?

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = NA\frac{\Delta B}{\Delta t} = 500(0.005)\frac{1.0}{0.5} \qquad \text{Faraday's law}$$

$$\varepsilon = 5.000\ \text{V}$$

Answer

5.000 V

Faraday, 20 turns

A 20-turn coil of area 0.100 m^2 sits in a field changing by 0.2 T in 0.1 s. Induced EMF?

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = NA\frac{\Delta B}{\Delta t} = 20(0.100)\frac{0.2}{0.1}$$ Faraday's law

$$\varepsilon = 4.000\ \text{V}$$

Answer

4.000 V

Lenz's law

The flux through a loop is increasing. What does the induced current do?

rule = opposes the increase conserve energy

Answer

opposes the increase

Lenz's law

A magnet's north pole approaches a loop. What pole does the loop's near face become?

rule = north (to repel) conserve energy

Answer

north (to repel)

Lenz's law

The flux through a loop is decreasing. The induced current tries to?

rule = maintain the flux conserve energy

Answer

maintain the flux

Lenz's law

Does an induced current ever aid the change that creates it?

rule = no — always opposes conserve energy

Answer

no — always opposes

AC peak EMF, 100 turns

N4

A 100-turn loop of area $0.010\ m^2$ spins at $\omega = 60\ rad/s$ in $B = 0.20\ T$. Peak EMF?

$$\varepsilon_0 = NBA\omega = 100(0.20)(0.010)(60) \quad \text{rotating loop}$$

$$\varepsilon_0 = 12.00\ \text{V} \quad \text{peak value}$$

Answer

12.00 V

AC peak EMF, 50 turns

N4

A 50-turn loop of area 0.020 m^2 spins at $\omega = 100$ rad/s in $B = 0.50$ T. Peak EMF?

$$\varepsilon_0 = NBA\omega = 50(0.50)(0.020)(100) \quad \text{rotating loop}$$

$$\varepsilon_0 = 50.00 \text{ V} \quad \text{peak value}$$

Answer

50.00 V

AC peak EMF, 200 turns

N4

A 200-turn loop of area 0.005 m^2 spins at $\omega = 120$ rad/s in $B = 0.10$ T. Peak EMF?

$$\varepsilon_0 = NBA\omega = 200(0.10)(0.005)(120) \quad \text{rotating loop}$$

$$\varepsilon_0 = 12.00\ \text{V} \quad \text{peak value}$$

Answer

12.00 V

AC peak EMF, 10 turns

N4

A 10-turn loop of area 0.050 m^2 spins at $\omega = 50$ rad/s in $B = 0.40$ T. Peak EMF?

$$\varepsilon_0 = NBA\omega = 10(0.40)(0.050)(50) \quad \text{rotating loop}$$

$$\varepsilon_0 = 10.00\ \text{V} \quad \text{peak value}$$

Answer

10.00 V

Self-induction, L=0.50 H

A 0.50 H coil's current changes by 2.0 A in 0.10 s. Induced EMF?

$$\varepsilon = L\frac{\Delta I}{\Delta t} = 0.50\frac{2.0}{0.10}$$

coil opposes its own change

$$\varepsilon = 10.00\ \text{V}$$

Answer

10.00 V

Self-induction, L=0.02 H

A 0.02 H coil's current changes by 3.0 A in 0.05 s. Induced EMF?

$$\varepsilon = L\frac{\Delta I}{\Delta t} = 0.02\frac{3.0}{0.05}$$ coil opposes its own change

$$\varepsilon = 1.20\ \text{V}$$

Answer

1.20 V

Self-induction, L=0.10 H

N5

A 0.10 H coil's current changes by 0.5 A in 0.20 s. Induced EMF?

$$\varepsilon = L\frac{\Delta I}{\Delta t} = 0.10\frac{0.5}{0.20}$$ coil opposes its own change

$$\varepsilon = 0.25\ \text{V}$$

Answer

0.25 V

Self-induction, L=2.00 H

A 2.00 H coil's current changes by 1.0 A in 0.50 s. Induced EMF?

$$\varepsilon = L\frac{\Delta I}{\Delta t} = 2.00\frac{1.0}{0.50}$$ coil opposes its own change

$$\varepsilon = 4.00\ \text{V}$$

Answer

4.00 V

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Reflection at 12°

A ray hits a mirror 12° from the normal. Reflected angle?

$$\theta_r = \theta_i = 12^\circ \qquad \text{law of reflection}$$

Answer

12°

Reflection at 18°

A ray hits a mirror 18° from the normal. Reflected angle?

$$\theta_r = \theta_i = 18^\circ \qquad \text{law of reflection}$$

Answer

18°

Reflection at 27°

A ray hits a mirror 27° from the normal. Reflected angle?

$$\theta_r = \theta_i = 27^\circ \qquad \text{law of reflection}$$

Answer

27°

Reflection at 34°

01

A ray hits a mirror 34° from the normal. Reflected angle?

$$\theta_r = \theta_i = 34^\circ \qquad \text{law of reflection}$$

Answer

34°

Reflection at 41°

A ray hits a mirror 41° from the normal. Reflected angle?

$$\theta_r = \theta_i = 41^\circ \qquad \text{law of reflection}$$

Answer

41°

Reflection at 53°

01

A ray hits a mirror 53° from the normal. Reflected angle?

$$\theta_r = \theta_i = 53^\circ \qquad \text{law of reflection}$$

Answer

53°

Reflection at 66°

A ray hits a mirror 66° from the normal. Reflected angle?

$$\theta_r = \theta_i = 66^\circ$$ law of reflection

Answer

66°

Reflection at 72°

A ray hits a mirror 72° from the normal. Reflected angle?

$$\theta_r = \theta_i = 72^\circ \qquad \text{law of reflection}$$

Answer

72°

Plane mirror, 1.5 m

You stand 1.5 *m in front of a plane mirror. Where is the image?*

$$d_i = 1.5 \text{ m behind} \quad \text{as far behind as in front}$$

$$\text{type} = \text{virtual, upright} \quad \text{same size}$$

Answer

1.5 m behind

Plane mirror, 2.0 m

You stand 2.0 m in front of a plane mirror. Where is the image?

$$d_i = 2.0 \text{ m behind} \qquad \text{as far behind as in front}$$

$$\text{type} = \text{virtual, upright} \qquad \text{same size}$$

Answer

2.0 m behind

Plane mirror, 3.0 m

You stand 3.0 *m in front of a plane mirror. Where is the image?*

$$d_i = 3.0 \text{ m behind} \qquad \text{as far behind as in front}$$

$$\text{type} = \text{virtual, upright} \qquad \text{same size}$$

Answer

3.0 m behind

Plane mirror, 4.0 m

You stand 4.0 m in front of a plane mirror. Where is the image?

$$d_i = 4.0 \text{ m behind} \quad \text{as far behind as in front}$$

$$\text{type} = \text{virtual, upright} \quad \text{same size}$$

Answer

4.0 m behind

Plane mirror, 5.0 m

You stand 5.0 *m in front of a plane mirror. Where is the image?*

$$d_i = 5.0 \text{ m behind} \qquad \text{as far behind as in front}$$

$$\text{type} = \text{virtual, upright} \qquad \text{same size}$$

Answer

5.0 m behind

Air into water, 20°

Light in air enters water ($n = 1.33$) at 20°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 20^\circ}{1.33} = 0.257 \qquad \text{Snell, into denser}$$

$$\theta_2 = 15^\circ \qquad \text{toward the normal}$$

Answer

15°

Air into water, 30°

Light in air enters water ($n = 1.33$) at 30°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 30^\circ}{1.33} = 0.376 \qquad \text{Snell, into denser}$$

$$\theta_2 = 22^\circ \qquad \text{toward the normal}$$

Answer

22°

Air into water, 40°

Light in air enters water ($n = 1.33$) at 40°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 40^\circ}{1.33} = 0.483 \qquad \text{Snell, into denser}$$

$$\theta_2 = 29^\circ \qquad \text{toward the normal}$$

Answer

29°

Air into water, 50°

Light in air enters water ($n = 1.33$) at 50°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 50^\circ}{1.33} = 0.576 \qquad \text{Snell, into denser}$$

$$\theta_2 = 35^\circ \qquad \text{toward the normal}$$

Answer

35°

Air into glass, 20°

Light in air enters glass ($n = 1.5$) at 20°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 20^\circ}{1.5} = 0.228$$ Snell, into denser

$$\theta_2 = 13^\circ$$ toward the normal

Answer

13°

Air into glass, 30°

Light in air enters glass ($n = 1.5$) at 30°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 30^\circ}{1.5} = 0.333$$ Snell, into denser

$$\theta_2 = 19^\circ$$ toward the normal

Answer

19°

Air into glass, 40°

Light in air enters glass ($n = 1.5$) at 40°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 40^\circ}{1.5} = 0.429$$ Snell, into denser

$$\theta_2 = 25^\circ$$ toward the normal

Answer

25°

Air into glass, 50°

Light in air enters glass ($n = 1.5$) at 50°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 50^\circ}{1.5} = 0.511$$ Snell, into denser

$$\theta_2 = 31^\circ$$ toward the normal

Answer

31°

Air into diamond, 20°

Light in air enters diamond ($n = 2.42$) at 20°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 20^\circ}{2.42} = 0.141 \qquad \text{Snell, into denser}$$

$$\theta_2 = 8^\circ \qquad \text{toward the normal}$$

Answer

8°

Air into diamond, 30°

Light in air enters diamond ($n = 2.42$) at 30°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 30^\circ}{2.42} = 0.207 \qquad \text{Snell, into denser}$$

$$\theta_2 = 12^\circ \qquad \text{toward the normal}$$

Answer

12°

Air into diamond, 40°

O2

Light in air enters diamond ($n = 2.42$) at 40°. Refraction angle?

$$\sin\theta_2 = \frac{\sin 40^\circ}{2.42} = 0.266 \qquad \text{Snell, into denser}$$

$$\theta_2 = 15^\circ \qquad \text{toward the normal}$$

Answer

15°

Air into diamond, 50°

Light in air enters diamond ($n = 2.42$) at $50°$. Refraction angle?

$$\sin\theta_2 = \frac{\sin 50^\circ}{2.42} = 0.317 \qquad \text{Snell, into denser}$$

$$\theta_2 = 18^\circ \qquad \text{toward the normal}$$

Answer

$18°$

Water into air, 20°

Light in water ($n = 1.33$) meets the surface with air at 20°. Refraction angle?

$$\sin\theta_2 = 1.33\sin 20^\circ = 0.455$$ leaving denser

$$\theta_2 = 27^\circ$$ away from the normal

Answer

27°

Water into air, 30°

O2

Light in water ($n = 1.33$) meets the surface with air at 30°. Refraction angle?

$$\sin\theta_2 = 1.33\sin 30^\circ = 0.665$$ leaving denser

$$\theta_2 = 42^\circ$$ away from the normal

Answer

42°

Water into air, 40°

O2

Light in water ($n = 1.33$) meets the surface with air at 40°. Refraction angle?

$$\sin\theta_2 = 1.33\sin 40^\circ = 0.855 \qquad \text{leaving denser}$$

$$\theta_2 = 59^\circ \qquad \text{away from the normal}$$

Answer

59°

Glass into air, 15°

Light in glass ($n = 1.5$) meets the surface with air at 15°. Refraction angle?

$$\sin\theta_2 = 1.50\sin 15^\circ = 0.388 \qquad \text{leaving denser}$$

$$\theta_2 = 23^\circ \qquad \text{away from the normal}$$

Answer

23°

Glass into air, 25°

Light in glass ($n = 1.5$) meets the surface with air at 25°. Refraction angle?

$$\sin\theta_2 = 1.50\sin 25^\circ = 0.634 \qquad \text{leaving denser}$$

$$\theta_2 = 39^\circ \qquad \text{away from the normal}$$

Answer

39°

Glass into air, 35°

Light in glass ($n = 1.5$) meets the surface with air at 35°. Refraction angle?

$$\sin\theta_2 = 1.50\sin 35^\circ = 0.860 \qquad \text{leaving denser}$$

$$\theta_2 = 59^\circ \qquad \text{away from the normal}$$

Answer

59°

Diamond into air, 10°

Light in diamond ($n = 2.42$) meets the surface with air at $10°$. Refraction angle?

$$\sin\theta_2 = 2.42\sin 10° = 0.420 \qquad \text{leaving denser}$$

$$\theta_2 = 25° \qquad \text{away from the normal}$$

Answer

$25°$

Diamond into air, 15°

Light in diamond ($n = 2.42$) meets the surface with air at 15°. Refraction angle?

$$\sin\theta_2 = 2.42\sin 15^\circ = 0.626 \qquad \text{leaving denser}$$

$$\theta_2 = 39^\circ \qquad \text{away from the normal}$$

Answer

39°

Diamond into air, 20°

O2

Light in diamond ($n = 2.42$) meets the surface with air at 20°. Refraction angle?

$$\sin\theta_2 = 2.42\sin 20^\circ = 0.828$$ leaving denser

$$\theta_2 = 56^\circ$$ away from the normal

Answer

56°

Critical angle, $n = 1.33$

Find the critical angle for water to air.

$$\sin\theta_c = \frac{1}{1.33} = 0.752 \qquad \text{low over high index}$$

$$\theta_c = 49^\circ \qquad \text{beyond this: total reflection}$$

Answer

49°

Critical angle, $n = 1.5$

Find the critical angle for glass to air.

$$\sin\theta_c = \frac{1}{1.5} = 0.667 \qquad \text{low over high index}$$

$$\theta_c = 42^\circ \qquad \text{beyond this: total reflection}$$

Answer

42°

Critical angle, $n = 2.42$

Find the critical angle for diamond to air.

$$\sin\theta_c = \frac{1}{2.42} = 0.413 \qquad \text{low over high index}$$

$$\theta_c = 24^\circ \qquad \text{beyond this: total reflection}$$

Answer

24°

Critical angle, $n = 1.4$

Find the critical angle for a medium with $n = 1.40$ to air.

$$\sin\theta_c = \frac{1}{1.4} = 0.714 \qquad \text{low over high index}$$

$$\theta_c = 46^\circ \qquad \text{beyond this: total reflection}$$

Answer

46°

Critical angle, $n = 1.6$

Find the critical angle for a medium with $n = 1.60$ to air.

$$\sin\theta_c = \frac{1}{1.6} = 0.625 \qquad \text{low over high index}$$

$$\theta_c = 39^\circ \qquad \text{beyond this: total reflection}$$

Answer

39°

TIR check: water, 30°

A ray in water ($\theta_c \approx 49°$) meets the air surface at 30°. What happens?

$$30° \;=\; < \;\theta_c = 49°$$

below the critical angle

$$\text{result} \;=\; \text{refracts out}$$

Answer

refracts out

TIR check: water, 55°

A ray in water ($\theta_c \approx 49^\circ$) meets the air surface at 55°. What happens?

$$55^\circ \; => \; \theta_c = 49^\circ$$

beyond the critical angle

$$\text{result} = \text{total internal reflection}$$

Answer

total internal reflection

TIR check: glass, 30°

A ray in glass ($\theta_c \approx 42°$) meets the air surface at 30°. What happens?

$$30° \;=\; < \;\theta_c = 42° \qquad \text{below the critical angle}$$

$$\text{result} \;=\; \text{refracts out}$$

Answer

refracts out

TIR check: glass, 50°

A ray in glass ($\theta_c \approx 42°$) meets the air surface at 50°. What happens?

$$50° \; => \; \theta_c = 42°$$

beyond the critical angle

$$\text{result} = \text{total internal reflection}$$

Answer

total internal reflection

TIR check: diamond, 20°

A ray in diamond ($\theta_c \approx 24°$) meets the air surface at 20°. What happens?

$$20° \;=\; < \;\theta_c = 24° \qquad \text{below the critical angle}$$

$$\text{result} \;=\; \text{refracts out}$$

Answer

refracts out

TIR check: diamond, 40°

A ray in diamond ($\theta_c \approx 24^\circ$) meets the air surface at 40°. What happens?

$$40^\circ \;=\; > \;\; \theta_c = 24^\circ$$

beyond the critical angle

$$\text{result} \;=\; \text{total internal reflection}$$

Answer

total internal reflection

concave mirror, f=10, do=30

A concave mirror, $f = 10$ cm, has an object at $d_o = 30$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{10} - \frac{1}{30} \qquad \text{concave mirror}$$

$$d_i = 15.0 \text{ cm (real)} \qquad \text{positive}$$

$$m = -0.50 \qquad \text{inverted, reduced}$$

Answer

$$d_i = 15.0 \text{ cm}, \quad m = -0.50$$

concave mirror, f=12, do=36

A concave mirror, $f = 12$ cm, has an object at $d_o = 36$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{12} - \frac{1}{36} \qquad \text{concave mirror}$$

$$d_i = 18.0 \text{ cm (real)} \qquad \text{positive}$$

$$m = -0.50 \qquad \text{inverted, reduced}$$

Answer

$$d_i = 18.0 \text{ cm}, \; m = -0.50$$

concave mirror, f=15, do=45

A concave mirror, $f = 15$ cm, has an object at $d_o = 45$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{15} - \frac{1}{45} \qquad \text{concave mirror}$$

$$d_i = 22.5 \text{ cm (real)} \qquad \text{positive}$$

$$m = -0.50 \qquad \text{inverted, reduced}$$

Answer

$$d_i = 22.5 \text{ cm}, \quad m = -0.50$$

concave mirror, f=20, do=60

O4

A concave mirror, $f = 20$ cm, has an object at $d_o = 60$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{20} - \frac{1}{60} \qquad \text{concave mirror}$$

$$d_i = 30.0 \text{ cm (real)} \qquad \text{positive}$$

$$m = -0.50 \qquad \text{inverted, reduced}$$

Answer

$$d_i = 30.0 \text{ cm}, \; m = -0.50$$

concave mirror, f=8, do=24

O4

A concave mirror, $f = 8$ cm, has an object at $d_o = 24$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{8} - \frac{1}{24} \qquad \text{concave mirror}$$

$$d_i = 12.0 \text{ cm (real)} \qquad \text{positive}$$

$$m = -0.50 \qquad \text{inverted, reduced}$$

Answer

$$d_i = 12.0 \text{ cm}, \; m = -0.50$$

concave mirror, f=10, do=15

A concave mirror, $f = 10$ cm, has an object at $d_o = 15$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{10} - \frac{1}{15} \qquad \text{concave mirror}$$

$$d_i = 30.0 \text{ cm (real)} \qquad \text{positive}$$

$$m = -2.00 \qquad \text{inverted, enlarged}$$

Answer

$$d_i = 30.0 \text{ cm}, \; m = -2.00$$

concave mirror, f=15, do=10

O4

A concave mirror, $f = 15$ cm, has an object at $d_o = 10$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{15} - \frac{1}{10} \qquad \text{concave mirror}$$

$$d_i = -30.0 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 3.00 \qquad \text{upright, enlarged}$$

Answer

$$d_i = -30.0 \text{ cm}, \quad m = 3.00$$

concave mirror, f=18, do=12

A concave mirror, $f = 18$ cm, has an object at $d_o = 12$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{18} - \frac{1}{12} \quad \text{concave mirror}$$

$$d_i = -36.0 \text{ cm (virtual)} \quad \text{negative}$$

$$m = 3.00 \quad \text{upright, enlarged}$$

Answer

$$d_i = -36.0 \text{ cm}, \; m = 3.00$$

convex mirror, f=-10, do=20

A convex mirror, $f = -10$ cm, has an object at $d_o = 20$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-10} - \frac{1}{20} \qquad \text{convex mirror}$$

$$d_i = -6.7 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 0.33 \qquad \text{upright, reduced}$$

Answer

$$d_i = -6.7 \text{ cm}, \quad m = 0.33$$

convex mirror, f=-8, do=16

A convex mirror, $f = -8$ cm, has an object at $d_o = 16$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-8} - \frac{1}{16} \quad \text{convex mirror}$$

$$d_i = -5.3 \text{ cm (virtual)} \quad \text{negative}$$

$$m = 0.33 \quad \text{upright, reduced}$$

Answer

$$d_i = -5.3 \text{ cm}, \; m = 0.33$$

convex mirror, f=-12, do=24

A convex mirror, $f = -12$ cm, has an object at $d_o = 24$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-12} - \frac{1}{24} \qquad \text{convex mirror}$$

$$d_i = -8.0 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 0.33 \qquad \text{upright, reduced}$$

Answer

$$d_i = -8.0 \text{ cm}, \quad m = 0.33$$

convex mirror, f=-15, do=30

A convex mirror, $f = -15$ cm, has an object at $d_o = 30$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-15} - \frac{1}{30} \qquad \text{convex mirror}$$

$$d_i = -10.0 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 0.33 \qquad \text{upright, reduced}$$

Answer

$$d_i = -10.0 \text{ cm}, \quad m = 0.33$$

convex mirror, f=-6, do=18

O4

A convex mirror, $f = -6$ cm, has an object at $d_o = 18$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-6} - \frac{1}{18} \qquad \text{convex mirror}$$

$$d_i = -4.5 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 0.25 \qquad \text{upright, reduced}$$

Answer

$$d_i = -4.5 \text{ cm}, \; m = 0.25$$

convex mirror, f=-20, do=10

A convex mirror, $f = -20$ cm, has an object at $d_o = 10$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-20} - \frac{1}{10} \quad \text{convex mirror}$$

$$d_i = -6.7 \text{ cm (virtual)} \quad \text{negative}$$

$$m = 0.67 \quad \text{upright, reduced}$$

Answer

$$d_i = -6.7 \text{ cm}, \; m = 0.67$$

converging lens, f=20, do=30

A converging lens, $f = 20$ cm, has an object at $d_o = 30$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{20} - \frac{1}{30} \qquad \text{converging lens}$$

$$d_i = 60.0 \text{ cm (real)} \qquad \text{positive}$$

$$m = -2.00 \qquad \text{inverted, enlarged}$$

Answer

$$d_i = 60.0 \text{ cm}, \; m = -2.00$$

converging lens, f=10, do=15

A converging lens, $f = 10$ cm, has an object at $d_o = 15$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{10} - \frac{1}{15} \qquad \text{converging lens}$$

$$d_i = 30.0 \text{ cm (real)} \qquad \text{positive}$$

$$m = -2.00 \qquad \text{inverted, enlarged}$$

Answer

$$d_i = 30.0 \text{ cm}, \quad m = -2.00$$

converging lens, f=15, do=45

A converging lens, $f = 15$ cm, has an object at $d_o = 45$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{15} - \frac{1}{45} \qquad \text{converging lens}$$

$$d_i = 22.5 \text{ cm (real)} \qquad \text{positive}$$

$$m = -0.50 \qquad \text{inverted, reduced}$$

Answer

$$d_i = 22.5 \text{ cm}, \quad m = -0.50$$

converging lens, f=25, do=100

A converging lens, $f = 25$ cm, has an object at $d_o = 100$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{25} - \frac{1}{100} \qquad \text{converging lens}$$

$$d_i = 33.3 \text{ cm (real)} \qquad \text{positive}$$

$$m = -0.33 \qquad \text{inverted, reduced}$$

Answer

$$d_i = 33.3 \text{ cm}, \quad m = -0.33$$

converging lens, f=10, do=5

A converging lens, $f = 10$ cm, has an object at $d_o = 5$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{10} - \frac{1}{5} \qquad \text{converging lens}$$

$$d_i = -10.0 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 2.00 \qquad \text{upright, enlarged}$$

Answer

$$d_i = -10.0 \text{ cm}, \quad m = 2.00$$

converging lens, f=15, do=10

A converging lens, $f = 15$ cm, has an object at $d_o = 10$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{15} - \frac{1}{10} \qquad \text{converging lens}$$

$$d_i = -30.0 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 3.00 \qquad \text{upright, enlarged}$$

Answer

$$d_i = -30.0 \text{ cm}, \quad m = 3.00$$

converging lens, f=20, do=60

A converging lens, $f = 20$ cm, has an object at $d_o = 60$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{20} - \frac{1}{60} \qquad \text{converging lens}$$

$$d_i = 30.0 \text{ cm (real)} \qquad \text{positive}$$

$$m = -0.50 \qquad \text{inverted, reduced}$$

Answer

$$d_i = 30.0 \text{ cm}, \quad m = -0.50$$

converging lens, f=12, do=8

A converging lens, $f = 12$ cm, has an object at $d_o = 8$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{12} - \frac{1}{8} \qquad \text{converging lens}$$

$$d_i = -24.0 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 3.00 \qquad \text{upright, enlarged}$$

Answer

$$d_i = -24.0 \text{ cm}, \quad m = 3.00$$

diverging lens, f=-12, do=24

A diverging lens, $f = -12$ cm, has an object at $d_o = 24$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-12} - \frac{1}{24} \quad \text{diverging lens}$$

$$d_i = -8.0 \text{ cm (virtual)} \quad \text{negative}$$

$$m = 0.33 \quad \text{upright, reduced}$$

Answer

$$d_i = -8.0 \text{ cm}, \; m = 0.33$$

diverging lens, f=-10, do=20

A diverging lens, $f = -10$ cm, has an object at $d_o = 20$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-10} - \frac{1}{20} \qquad \text{diverging lens}$$

$$d_i = -6.7 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 0.33 \qquad \text{upright, reduced}$$

Answer

$$d_i = -6.7 \text{ cm}, \quad m = 0.33$$

diverging lens, f=-15, do=30

A diverging lens, $f = -15$ cm, has an object at $d_o = 30$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-15} - \frac{1}{30} \qquad \text{diverging lens}$$

$$d_i = -10.0 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 0.33 \qquad \text{upright, reduced}$$

Answer

$$d_i = -10.0 \text{ cm}, \quad m = 0.33$$

diverging lens, f=-20, do=40

A diverging lens, $f = -20$ cm, has an object at $d_o = 40$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-20} - \frac{1}{40} \qquad \text{diverging lens}$$

$$d_i = -13.3 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 0.33 \qquad \text{upright, reduced}$$

Answer

$$d_i = -13.3 \text{ cm}, \quad m = 0.33$$

diverging lens, f=-8, do=16

A diverging lens, $f = -8$ cm, has an object at $d_o = 16$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-8} - \frac{1}{16} \qquad \text{diverging lens}$$

$$d_i = -5.3 \text{ cm (virtual)} \qquad \text{negative}$$

$$m = 0.33 \qquad \text{upright, reduced}$$

Answer

$$d_i = -5.3 \text{ cm}, \quad m = 0.33$$

diverging lens, f=-12, do=6

A diverging lens, $f = -12$ cm, has an object at $d_o = 6$ cm. Find d_i and m.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-12} - \frac{1}{6} \quad \text{diverging lens}$$

$$d_i = -4.0 \text{ cm (virtual)} \quad \text{negative}$$

$$m = 0.67 \quad \text{upright, reduced}$$

Answer

$$d_i = -4.0 \text{ cm}, \; m = 0.67$$

Magnification, do=50, di=25

An object 8 cm tall has $d_o = 50$ cm and $d_i = 25$ cm. Find m and h_i.

$$m = -\frac{25}{50} = -0.50 \qquad \text{inverted}$$

$$h_i = -0.50 \times 8 = -4.0 \text{ cm} \qquad \text{image height}$$

Answer

$$m = -0.50, \; h_i = -4.0 \text{ cm}$$

Magnification, do=40, di=20

An object 6 cm tall has $d_o = 40$ cm and $d_i = 20$ cm. Find m and h_i.

$$m = -\frac{20}{40} = -0.50 \qquad \text{inverted}$$

$$h_i = -0.50 \times 6 = -3.0 \text{ cm} \qquad \text{image height}$$

Answer

$$m = -0.50, \; h_i = -3.0 \text{ cm}$$

Magnification, do=30, di=60

An object 4 cm tall has $d_o = 30$ cm and $d_i = 60$ cm. Find m and h_i.

$$m = -\frac{60}{30} = -2.00 \quad \text{inverted}$$

$$h_i = -2.00 \times 4 = -8.0 \text{ cm} \quad \text{image height}$$

Answer

$$m = -2.00, \; h_i = -8.0 \text{ cm}$$

Magnification, do=60, di=30

An object 10 *cm tall has* $d_o = 60$ *cm and* $d_i = 30$ *cm. Find* m *and* h_i.

$$m = -\frac{30}{60} = -0.50 \qquad \text{inverted}$$

$$h_i = -0.50 \times 10 = -5.0 \text{ cm} \qquad \text{image height}$$

Answer

$$m = -0.50, \; h_i = -5.0 \text{ cm}$$

Magnification, do=20, di=40

An object 5 cm tall has $d_o = 20$ cm and $d_i = 40$ cm. Find m and h_i.

$$m = -\frac{40}{20} = -2.00 \qquad \text{inverted}$$

$$h_i = -2.00 \times 5 = -10.0 \text{ cm} \qquad \text{image height}$$

Answer

$$m = -2.00, \; h_i = -10.0 \text{ cm}$$

Magnification, do=45, di=15

An object 9 cm tall has $d_o = 45$ cm and $d_i = 15$ cm. Find m and h_i.

$$m = -\frac{15}{45} = -0.33 \qquad \text{inverted}$$

$$h_i = -0.33 \times 9 = -3.0 \text{ cm} \qquad \text{image height}$$

Answer

$$m = -0.33, \; h_i = -3.0 \text{ cm}$$

Double slit, lam=500 nm

$\lambda = 500$ *nm through slits* $d = 0.50$ *mm, screen* $L = 2.0$ *m. Fringe spacing?*

$$\Delta y = \frac{\lambda L}{d} \qquad \text{fringe spacing}$$

$$\Delta y = 2.00\ \text{mm} \qquad \text{on the screen}$$

Answer

$$\Delta y = 2.00\ \text{mm}$$

Double slit, lam=650 nm

$\lambda = 650$ *nm through slits* $d = 0.25$ *mm, screen* $L = 1.5$ *m. Fringe spacing?*

$$\Delta y = \frac{\lambda L}{d} \qquad \text{fringe spacing}$$

$$\Delta y = 3.90 \text{ mm} \qquad \text{on the screen}$$

Answer

$$\Delta y = 3.90 \text{ mm}$$

Double slit, lam=600 nm

$\lambda = 600$ *nm through slits* $d = 0.20$ *mm, screen* $L = 1.0$ *m. Fringe spacing?*

$$\Delta y = \frac{\lambda L}{d} \qquad \text{fringe spacing}$$

$$\Delta y = 3.00 \text{ mm} \qquad \text{on the screen}$$

Answer

$$\Delta y = 3.00 \text{ mm}$$

Double slit, lam=450 nm

$\lambda = 450$ *nm through slits* $d = 0.10$ *mm, screen* $L = 1.5$ *m. Fringe spacing?*

$$\Delta y = \frac{\lambda L}{d} \qquad \text{fringe spacing}$$

$$\Delta y = 6.75\ \text{mm} \qquad \text{on the screen}$$

Answer

$$\Delta y = 6.75\ \text{mm}$$

Double slit, lam=550 nm

$\lambda = 550$ *nm through slits* $d = 0.40$ *mm, screen* $L = 2.0$ *m. Fringe spacing?*

$$\Delta y = \frac{\lambda L}{d} \qquad \text{fringe spacing}$$

$$\Delta y = 2.75 \text{ mm} \qquad \text{on the screen}$$

Answer

$$\Delta y = 2.75 \text{ mm}$$

Double slit, lam=700 nm

$\lambda = 700$ *nm through slits* $d = 0.30$ *mm, screen* $L = 1.2$ *m. Fringe spacing?*

$$\Delta y = \frac{\lambda L}{d} \qquad \text{fringe spacing}$$

$$\Delta y = 2.80 \text{ mm} \qquad \text{on the screen}$$

Answer

$$\Delta y = 2.80 \text{ mm}$$

First bright angle, lam=600 nm

First-order ($m = 1$) bright fringe for $\lambda = 600$ nm, $d = 0.15$ mm. Angle?

$$\sin\theta = \frac{m\lambda}{d} = 0.0040 \qquad m = 1$$

$$\theta = 0.23^\circ \qquad \text{small angle}$$

Answer

$$\theta \approx 0.23^\circ$$

First bright angle, lam=500 nm

First-order ($m = 1$) bright fringe for $\lambda = 500$ nm, $d = 0.10$ mm. Angle?

$$\sin\theta = \frac{m\lambda}{d} = 0.0050 \qquad m = 1$$

$$\theta = 0.29^\circ \qquad \text{small angle}$$

Answer

$$\theta \approx 0.29^\circ$$

First bright angle, lam=650 nm

First-order ($m = 1$) bright fringe for $\lambda = 650$ nm, $d = 0.20$ mm. Angle?

$$\sin\theta = \frac{m\lambda}{d} = 0.0032 \qquad m = 1$$

$$\theta = 0.19^\circ \qquad \text{small angle}$$

Answer

$$\theta \approx 0.19^\circ$$

First bright angle, lam=550 nm

First-order ($m = 1$) bright fringe for $\lambda = 550$ nm, $d = 0.12$ mm. Angle?

$$\sin\theta = \frac{m\lambda}{d} = 0.0046 \qquad m = 1$$

$$\theta = 0.26^\circ \qquad \text{small angle}$$

Answer

$$\theta \approx 0.26^\circ$$

Grating, 600/mm, m=1

A 600-line/mm grating, $\lambda = 500$ nm, order $m = 1$. Diffraction angle?

$$d = \frac{1}{600}\ \text{mm} = 1667\ \text{nm} \qquad \text{spacing}$$

$$\sin\theta = \frac{1\lambda}{d} = 0.300 \qquad \text{grating condition}$$

$$\theta = 17^\circ \qquad \text{sharp bright line}$$

Answer

$$\theta \approx 17^\circ$$

Grating, 500/mm, m=1

A 500-line/mm grating, $\lambda = 600$ nm, order $m = 1$. Diffraction angle?

$$d = \frac{1}{500}\ \text{mm} = 2000\ \text{nm} \qquad \text{spacing}$$

$$\sin\theta = \frac{1\lambda}{d} = 0.300 \qquad \text{grating condition}$$

$$\theta = 17^\circ \qquad \text{sharp bright line}$$

Answer

$$\theta \approx 17^\circ$$

Grating, 300/mm, m=1

A 300-line/mm grating, $\lambda = 500$ nm, order $m = 1$. Diffraction angle?

$$d = \frac{1}{300}\ \text{mm} = 3333\ \text{nm} \qquad \text{spacing}$$

$$\sin\theta = \frac{1\lambda}{d} = 0.150 \qquad \text{grating condition}$$

$$\theta = 9^\circ \qquad \text{sharp bright line}$$

Answer

$\theta \approx 9^\circ$

Grating, 500/mm, m=2

A 500-line/mm grating, $\lambda = 500$ nm, order $m = 2$. Diffraction angle?

$$d = \frac{1}{500}\ \text{mm} = 2000\ \text{nm} \qquad \text{spacing}$$

$$\sin\theta = \frac{2\lambda}{d} = 0.500 \qquad \text{grating condition}$$

$$\theta = 30^\circ \qquad \text{sharp bright line}$$

Answer

$$\theta \approx 30^\circ$$

Grating, 600/mm, m=1

A 600-line/mm grating, $\lambda = 450$ nm, order $m = 1$. Diffraction angle?

$$d = \frac{1}{600}\ \text{mm} = 1667\ \text{nm} \qquad \text{spacing}$$

$$\sin\theta = \frac{1\lambda}{d} = 0.270 \qquad \text{grating condition}$$

$$\theta = 16^\circ \qquad \text{sharp bright line}$$

Answer

$$\theta \approx 16^\circ$$

Grating, 400/mm, m=1

A 400-line/mm grating, $\lambda = 550$ nm, order $m = 1$. Diffraction angle?

$$d = \frac{1}{400}\ \text{mm} = 2500\ \text{nm} \qquad \text{spacing}$$

$$\sin\theta = \frac{1\lambda}{d} = 0.220 \qquad \text{grating condition}$$

$$\theta = 13^\circ \qquad \text{sharp bright line}$$

Answer

$$\theta \approx 13^\circ$$

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Photoelectron KE, E=4.0 eV

A photon of 4.0 eV strikes a metal of work function $\phi = 2.3$ eV. Max KE of the ejected electron?

$$K_{max} = hf - \phi = 4.0 - 2.3 \quad \text{photoelectric equation}$$

$$K_{max} = 1.7 \text{ eV} \quad \text{positive: electron escapes}$$

Answer

1.7 eV

Photoelectron KE, E=3.5 eV

A photon of 3.5 *eV strikes a metal of work function* $\phi = 2.0$ *eV. Max KE of the ejected electron?*

$$K_{\max} = hf - \phi = 3.5 - 2.0 \qquad \text{photoelectric equation}$$

$$K_{\max} = 1.5 \text{ eV} \qquad \text{positive: electron escapes}$$

Answer

1.5 eV

Photoelectron KE, E=5.0 eV

A photon of 5.0 *eV strikes a metal of work function* $\phi = 4.5$ *eV. Max KE of the ejected electron?*

$$K_{\max} = hf - \phi = 5.0 - 4.5 \qquad \text{photoelectric equation}$$

$$K_{\max} = 0.5 \text{ eV} \qquad \text{positive: electron escapes}$$

Answer

0.5 eV

Photoelectron KE, E=6.0 eV

Z1

A photon of 6.0 eV strikes a metal of work function $\phi = 2.9$ eV. Max KE of the ejected electron?

$$K_{max} = hf - \phi = 6.0 - 2.9 \qquad \text{photoelectric equation}$$

$$K_{max} = 3.1 \text{ eV} \qquad \text{positive: electron escapes}$$

Answer

3.1 eV

Photoelectron KE, E=2.5 eV

A photon of 2.5 eV strikes a metal of work function $\phi = 2.1$ eV. Max KE of the ejected electron?

$$K_{max} = hf - \phi = 2.5 - 2.1 \quad \text{photoelectric equation}$$

$$K_{max} = 0.4 \text{ eV} \quad \text{positive: electron escapes}$$

Answer

0.4 eV

Photoelectron KE, E=4.8 eV

A photon of 4.8 *eV strikes a metal of work function* $\phi = 3.6$ *eV. Max KE of the ejected electron?*

$$K_{\max} = hf - \phi = 4.8 - 3.6 \qquad \text{photoelectric equation}$$

$$K_{\max} = 1.2 \text{ eV} \qquad \text{positive: electron escapes}$$

Answer

1.2 eV

Photoelectric, 400 nm

Light of $\lambda = 400$ nm ($E = \frac{1240}{\lambda}$ eV) hits a metal, $\phi = 2.0$ eV. Max KE?

$$E = \frac{1240}{400} = 3.10 \text{ eV} \qquad \text{photon energy}$$

$$K_{\max} = 3.10 - 2.0 = 1.10 \text{ eV} \qquad \text{subtract } \phi$$

Answer

1.10 eV

Photoelectric, 300 nm

Light of $\lambda = 300$ nm ($E = \frac{1240}{\lambda}$ eV) hits a metal, $\phi = 3.0$ eV. Max KE?

$$E = \frac{1240}{300} = 4.13 \text{ eV} \quad \text{photon energy}$$

$$K_{max} = 4.13 - 3.0 = 1.13 \text{ eV} \quad \text{subtract } \phi$$

Answer

1.13 eV

Photoelectric, 250 nm

Light of $\lambda = 250$ nm ($E = \frac{1240}{\lambda}$ eV) hits a metal, $\phi = 2.8$ eV. Max KE?

$$E = \frac{1240}{250} = 4.96 \text{ eV} \qquad \text{photon energy}$$

$$K_{\max} = 4.96 - 2.8 = 2.16 \text{ eV} \qquad \text{subtract } \phi$$

Answer

2.16 eV

Photoelectric, 500 nm

Light of $\lambda = 500$ nm ($E = \frac{1240}{\lambda}$ eV) hits a metal, $\phi = 1.9$ eV. Max KE?

$$E = \frac{1240}{500} = 2.48 \text{ eV} \qquad \text{photon energy}$$

$$K_{\max} = 2.48 - 1.9 = 0.58 \text{ eV} \qquad \text{subtract } \phi$$

Answer

0.58 eV

Photoelectric, 350 nm

Light of $\lambda = 350$ nm ($E = \frac{1240}{\lambda}$ eV) hits a metal, $\phi = 2.5$ eV. Max KE?

$$E = \frac{1240}{350} = 3.54 \text{ eV} \qquad \text{photon energy}$$

$$K_{\max} = 3.54 - 2.5 = 1.04 \text{ eV} \qquad \text{subtract } \phi$$

Answer

1.04 eV

Threshold, phi=2.0 eV

A metal has work function $\phi = 2.0$ eV. Longest wavelength that still ejects an electron?

$$\lambda_0 = \frac{1240}{\phi} = \frac{1240}{2.0} \qquad \text{threshold: } hf = \phi$$

$$\lambda_0 = 620 \text{ nm} \qquad \text{longer} = \text{no emission}$$

Answer

620 nm

Threshold, phi=2.5 eV

A metal has work function $\phi = 2.5$ eV. Longest wavelength that still ejects an electron?

$$\lambda_0 = \frac{1240}{\phi} = \frac{1240}{2.5} \qquad \text{threshold: } hf = \phi$$

$$\lambda_0 = 496 \text{ nm} \qquad \text{longer} = \text{no emission}$$

Answer

496 nm

Threshold, phi=3.1 eV

A metal has work function $\phi = 3.1$ eV. Longest wavelength that still ejects an electron?

$$\lambda_0 = \frac{1240}{\phi} = \frac{1240}{3.1} \qquad \text{threshold: } hf = \phi$$

$$\lambda_0 = 400 \text{ nm} \qquad \text{longer} = \text{no emission}$$

Answer

400 nm

Threshold, phi=4.0 eV

A metal has work function $\phi = 4.0$ eV. Longest wavelength that still ejects an electron?

$$\lambda_0 = \frac{1240}{\phi} = \frac{1240}{4.0} \qquad \text{threshold: } hf = \phi$$

$$\lambda_0 = 310 \text{ nm} \qquad \text{longer} = \text{no emission}$$

Answer

310 nm

Photon energy, 700 nm

Z2

Find the energy of a photon of wavelength $\lambda = 700$ nm.

$$E = \frac{hc}{\lambda} = \frac{1240}{700}\ \text{eV} \qquad hc = 1240\ \text{eV·nm}$$

$$E = 1.77\ \text{eV} \qquad \text{shorter } \lambda = \text{more energy}$$

Answer

1.77 eV

Photon energy, 620 nm

Z2

Find the energy of a photon of wavelength $\lambda = 620$ nm.

$$E = \frac{hc}{\lambda} = \frac{1240}{620}\ \text{eV} \qquad hc = 1240\ \text{eV·nm}$$

$$E = 2.00\ \text{eV} \qquad \text{shorter } \lambda = \text{more energy}$$

Answer

2.00 eV

Photon energy, 550 nm

Z2

Find the energy of a photon of wavelength $\lambda = 550$ nm.

$$E = \frac{hc}{\lambda} = \frac{1240}{550}\ \text{eV} \qquad hc = 1240\ \text{eV·nm}$$

$$E = 2.25\ \text{eV} \qquad \text{shorter } \lambda = \text{more energy}$$

Answer

2.25 eV

Photon energy, 500 nm

Z2

Find the energy of a photon of wavelength $\lambda = 500$ nm.

$$E = \frac{hc}{\lambda} = \frac{1240}{500}\ \text{eV} \qquad hc = 1240\ \text{eV·nm}$$

$$E = 2.48\ \text{eV} \qquad \text{shorter } \lambda = \text{more energy}$$

Answer

2.48 eV

Photon energy, 450 nm

Z2

Find the energy of a photon of wavelength $\lambda = 450$ nm.

$$E = \frac{hc}{\lambda} = \frac{1240}{450}\ \text{eV} \qquad hc = 1240\ \text{eV·nm}$$

$$E = 2.76\ \text{eV} \qquad \text{shorter } \lambda = \text{more energy}$$

Answer

2.76 eV

Photon energy, 400 nm

Z2

Find the energy of a photon of wavelength $\lambda = 400$ nm.

$$E = \frac{hc}{\lambda} = \frac{1240}{400}\ \text{eV} \qquad hc = 1240\ \text{eV·nm}$$

$$E = 3.10\ \text{eV} \qquad \text{shorter } \lambda = \text{more energy}$$

Answer

3.10 eV

Photon energy, 350 nm

Z2

Find the energy of a photon of wavelength $\lambda = 350$ nm.

$$E = \frac{hc}{\lambda} = \frac{1240}{350}\ \text{eV} \qquad hc = 1240\ \text{eV·nm}$$

$$E = 3.54\ \text{eV} \qquad \text{shorter } \lambda = \text{more energy}$$

Answer

3.54 eV

Photon energy, 250 nm

Z2

Find the energy of a photon of wavelength $\lambda = 250$ nm.

$$E = \frac{hc}{\lambda} = \frac{1240}{250}\ \text{eV} \qquad hc = 1240\ \text{eV·nm}$$

$$E = 4.96\ \text{eV} \qquad \text{shorter } \lambda = \text{more energy}$$

Answer

4.96 eV

Frequency, 600 nm

Z2

What is the frequency of light with $\lambda = 600$ nm?

$$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{6.00 \times 10^{-7}} \qquad \text{wave relation}$$

$$f = 5.00 \times 10^{14} \text{ Hz}$$

Answer

5.00×10^{14} Hz

Frequency, 500 nm

What is the frequency of light with $\lambda = 500$ nm?

$$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{5.00 \times 10^{-7}} \qquad \text{wave relation}$$

$$f = 6.00 \times 10^{14} \text{ Hz}$$

Answer

6.00×10^{14} Hz

Frequency, 450 nm

Z2

What is the frequency of light with $\lambda = 450$ nm?

$$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{4.50 \times 10^{-7}} \qquad \text{wave relation}$$

$$f = 6.67 \times 10^{14}\ \text{Hz}$$

Answer

6.67×10^{14} Hz

Frequency, 400 nm

Z2

What is the frequency of light with $\lambda = 400$ nm?

$$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{4.00 \times 10^{-7}} \qquad \text{wave relation}$$

$$f = 7.50 \times 10^{14} \text{ Hz}$$

Answer

7.50×10^{14} Hz

Photon energy in J, 500 nm

Z2

Find the energy in joules of a $\lambda = 500$ nm photon ($h = 6.63 \times 10^{-34}$).

$$E = \frac{hc}{\lambda} \qquad \text{photon energy}$$

$$E = 3.98 \times 10^{-19}\ \text{J} \qquad \text{very small}$$

Answer

3.98×10^{-19} J

Photon energy in J, 400 nm

Z2

Find the energy in joules of a $\lambda = 400$ nm photon ($h = 6.63 \times 10^{-34}$).

$$E = \frac{hc}{\lambda} \qquad \text{photon energy}$$

$$E = 4.97 \times 10^{-19}\ \text{J} \qquad \text{very small}$$

Answer

4.97×10^{-19} J

Photon energy in J, 650 nm

Z2

Find the energy in joules of a $\lambda = 650$ nm photon ($h = 6.63 \times 10^{-34}$).

$$E = \frac{hc}{\lambda} \qquad \text{photon energy}$$

$$E = 3.06 \times 10^{-19}\ \text{J} \qquad \text{very small}$$

Answer

3.06×10^{-19} J

de Broglie, an electron

Find the de Broglie wavelength of an electron moving at $v = 1.00 \times 10^{6}$ m/s ($m = 9.11 \times 10^{-31}$ kg).

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \cdot 1.00 \times 10^{6}}$$

matter wave

$$\lambda = 7.27 \times 10^{-10}\ \text{m}$$

Answer

7.27×10^{-10} m

de Broglie, an electron

Find the de Broglie wavelength of an electron moving at $v = 2.00 \times 10^{6}$ m/s ($m = 9.11 \times 10^{-31}$ kg).

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \cdot 2.00 \times 10^{6}}$$

matter wave

$$\lambda = 3.64 \times 10^{-10}\ \text{m}$$

Answer

3.64×10^{-10} m

de Broglie, an electron

Find the de Broglie wavelength of an electron moving at $v = 5.00 \times 10^{5}$ m/s ($m = 9.11 \times 10^{-31}$ kg).

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \cdot 5.00 \times 10^{5}}$$

matter wave

$$\lambda = 1.45 \times 10^{-9} \text{ m}$$

Answer

1.45×10^{-9} m

de Broglie, a proton

Z3

Find the de Broglie wavelength of a proton moving at $v = 1.00 \times 10^{5}$ m/s ($m = 1.67 \times 10^{-27}$ kg).

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \cdot 1.00 \times 10^{5}}$$

matter wave

$$\lambda = 3.97 \times 10^{-12}\ \text{m}$$

Answer

3.97×10^{-12} m

de Broglie, a proton

Find the de Broglie wavelength of a proton moving at $v = 1.00 \times 10^{6}$ m/s ($m = 1.67 \times 10^{-27}$ kg).

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \cdot 1.00 \times 10^{6}}$$

matter wave

$$\lambda = 3.97 \times 10^{-13}\ \text{m}$$

Answer

3.97×10^{-13} m

de Broglie, a proton

Find the de Broglie wavelength of a proton moving at $v = 3.00 \times 10^{5}$ m/s ($m = 1.67 \times 10^{-27}$ kg).

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \cdot 3.00 \times 10^{5}}$$

matter wave

$$\lambda = 1.32 \times 10^{-12}\ \text{m}$$

Answer

1.32×10^{-12} m

de Broglie, an electron

Z3

Find the de Broglie wavelength of an electron moving at $v = 3.00 \times 10^{6}$ m/s ($m = 9.11 \times 10^{-31}$ kg).

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \cdot 3.00 \times 10^{6}}$$

matter wave

$$\lambda = 2.42 \times 10^{-10}\ \text{m}$$

Answer

2.42×10^{-10} m

de Broglie, a proton

Find the de Broglie wavelength of a proton moving at $v = 5.00 \times 10^{5}$ m/s ($m = 1.67 \times 10^{-27}$ kg).

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \cdot 5.00 \times 10^{5}}$$

matter wave

$$\lambda = 7.94 \times 10^{-13}\ \text{m}$$

Answer

7.94×10^{-13} m

Emission, -13.60 eV→-3.40 eV

Z4

An electron drops from a level at -3.40 eV to -13.60 eV. Photon energy and wavelength?

$$\Delta E = -3.40 - (-13.60) = 10.20 \text{ eV} \quad \text{energy released}$$

$$\lambda = \frac{1240}{10.20} = 122 \text{ nm} \quad \text{emitted photon}$$

Answer

10.20 eV, 122 nm

Emission, -3.40 eV→-1.50 eV

An electron drops from a level at -1.50 eV to -3.40 eV. Photon energy and wavelength?

$$\Delta E = -1.50 - (-3.40) = 1.90 \text{ eV} \quad \text{energy released}$$

$$\lambda = \frac{1240}{1.90} = 653 \text{ nm} \quad \text{emitted photon}$$

Answer

1.90 eV, 653 nm

Emission, -13.60 eV→-1.50 eV

Z4

An electron drops from a level at -1.50 eV to -13.60 eV. Photon energy and wavelength?

$$\Delta E = -1.50 - (-13.60) = 12.10 \text{ eV} \quad \text{energy released}$$

$$\lambda = \frac{1240}{12.10} = 102 \text{ nm} \quad \text{emitted photon}$$

Answer

12.10 eV, 102 nm

Emission, -5.00 eV→-2.00 eV

An electron drops from a level at -2.00 eV to -5.00 eV. Photon energy and wavelength?

$$\Delta E = -2.00 - (-5.00) = 3.00 \text{ eV} \qquad \text{energy released}$$

$$\lambda = \frac{1240}{3.00} = 413 \text{ nm} \qquad \text{emitted photon}$$

Answer

3.00 eV, 413 nm

Emission, -10.00 eV→-4.00 eV

An electron drops from a level at -4.00 eV to -10.00 eV. Photon energy and wavelength?

$$\Delta E = -4.00 - (-10.00) = 6.00 \text{ eV} \quad \text{energy released}$$

$$\lambda = \frac{1240}{6.00} = 207 \text{ nm} \quad \text{emitted photon}$$

Answer

6.00 eV, 207 nm

Emission, -6.00 eV→-1.50 eV

An electron drops from a level at -1.50 eV to -6.00 eV. Photon energy and wavelength?

$$\Delta E = -1.50 - (-6.00) = 4.50 \text{ eV} \quad \text{energy released}$$

$$\lambda = \frac{1240}{4.50} = 276 \text{ nm} \quad \text{emitted photon}$$

Answer

4.50 eV, 276 nm

Emission, -8.00 eV→-2.00 eV

An electron drops from a level at -2.00 eV to -8.00 eV. Photon energy and wavelength?

$$\Delta E = -2.00 - (-8.00) = 6.00 \text{ eV} \quad \text{energy released}$$

$$\lambda = \frac{1240}{6.00} = 207 \text{ nm} \quad \text{emitted photon}$$

Answer

6.00 eV, 207 nm

Emission, -13.60 eV→-0.85 eV

Z4

An electron drops from a level at -0.85 eV to -13.60 eV. Photon energy and wavelength?

$$\Delta E = -0.85 - (-13.60) = 12.75 \text{ eV} \quad \text{energy released}$$

$$\lambda = \frac{1240}{12.75} = 97 \text{ nm} \quad \text{emitted photon}$$

Answer

12.75 eV, 97 nm

Absorption, 10.2 eV

Levels sit at -13.6 and -3.4 eV. Is a 10.2 eV photon absorbed?

$$\Delta E = -3.4 - (-13.6) = 10.2 \text{ eV} \quad \text{gap between levels}$$

$$\text{match?} = 10.2 = 10.2 \quad \text{absorbed}$$

Answer

absorbed

Absorption, 9.0 eV

Levels sit at -13.6 *and* -3.4 *eV. Is a* 9.0 *eV photon absorbed?*

$$\Delta E = -3.4 - (-13.6) = 10.2 \text{ eV} \qquad \text{gap between levels}$$

$$\text{match?} = 9.0 \neq 10.2 \qquad \text{not absorbed}$$

Answer

not absorbed

Absorption, 1.9 eV

Levels sit at -3.4 and -1.5 eV. Is a 1.9 eV photon absorbed?

$$\Delta E = -1.5 - (-3.4) = 1.9 \text{ eV} \quad \text{gap between levels}$$

$$\text{match?} = 1.9 = 1.9 \quad \text{absorbed}$$

Answer

absorbed

Absorption, 3.0 eV

Levels sit at -5.0 and -2.0 eV. Is a 3.0 eV photon absorbed?

$$\Delta E = -2.0 - (-5.0) = 3.0 \text{ eV} \quad \text{gap between levels}$$

$$\text{match?} = 3.0 = 3.0 \quad \text{absorbed}$$

Answer

absorbed

Composition of $^{12}_{6}\mathrm{C}$

How many protons and neutrons are in $^{12}_{6}C$?

$$\text{protons} = Z = 6 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 12 - 6 = 6 \qquad \text{mass number minus } Z$$

Answer

6 p, 6 n

Composition of $^{14}_{6}\mathrm{C}$

How many protons and neutrons are in $^{14}_{6}C$?

$$\text{protons} = Z = 6 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 14 - 6 = 8 \qquad \text{mass number minus } Z$$

Answer

6 p, 8 n

Composition of $^{16}_{8}\mathrm{O}$

How many protons and neutrons are in $^{16}_{8}O$?

$$\text{protons} = Z = 8 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 16 - 8 = 8 \qquad \text{mass number minus } Z$$

Answer

8 p, 8 n

Composition of $^{23}_{11}\mathrm{Na}$

How many protons and neutrons are in $^{23}_{11}Na$?

$$\text{protons} = Z = 11 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 23 - 11 = 12 \qquad \text{mass number minus } Z$$

Answer

11 p, 12 n

Composition of $^{56}_{26}\mathrm{Fe}$

How many protons and neutrons are in $^{56}_{26}Fe$?

$$\text{protons} = Z = 26 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 56 - 26 = 30 \qquad \text{mass number minus } Z$$

Answer

26 p, 30 n

Composition of $^{235}_{92}\mathrm{U}$

How many protons and neutrons are in $^{235}_{92}U$?

$$\text{protons} = Z = 92 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 235 - 92 = 143 \qquad \text{mass number minus } Z$$

Answer

92 p, 143 n

Composition of $^{238}_{92}\mathrm{U}$

How many protons and neutrons are in $^{238}_{92}U$?

$$\text{protons} = Z = 92 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 238 - 92 = 146 \qquad \text{mass number minus } Z$$

Answer

92 p, 146 n

Composition of $^{4}_{2}\mathrm{He}$

How many protons and neutrons are in $^{4}_{2}He$?

$$\text{protons} = Z = 2 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 4 - 2 = 2 \qquad \text{mass number minus } Z$$

Answer

2 p, 2 n

Composition of $^{20}_{10}\mathrm{Ne}$

How many protons and neutrons are in $^{20}_{10}Ne$?

$$\text{protons} = Z = 10 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 20 - 10 = 10 \qquad \text{mass number minus } Z$$

Answer

10 p, 10 n

Composition of $^{206}_{82}\mathrm{Pb}$

How many protons and neutrons are in $^{206}_{82}Pb$?

$$\text{protons} = Z = 82 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 206 - 82 = 124 \qquad \text{mass number minus } Z$$

Answer

82 p, 124 n

Composition of $^{27}_{13}\mathrm{Al}$

How many protons and neutrons are in $^{27}_{13}Al$?

$$\text{protons} = Z = 13 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 27 - 13 = 14 \qquad \text{mass number minus } Z$$

Answer

13 p, 14 n

Composition of $^{31}_{15}\mathrm{P}$

How many protons and neutrons are in $^{31}_{15}P$?

$$\text{protons} = Z = 15 \qquad \text{the bottom number}$$

$$\text{neutrons} = A - Z = 31 - 15 = 16 \qquad \text{mass number minus } Z$$

Answer

15 p, 16 n

Alpha decay of $^{238}_{92}\mathrm{U}$

$^{238}_{92}U$ *undergoes alpha decay. Identify the daughter nucleus.*

$$\alpha = {}^{4}_{2}\mathrm{He}\ \text{emitted} \qquad Z \to Z-2,\ A \to A-4$$

$$\text{daughter} = {}^{234}_{90}\mathrm{Th}$$

Answer

$^{234}_{90}\mathrm{Th}$

Alpha decay of $^{226}_{88}\mathrm{Ra}$

$^{226}_{88}Ra$ *undergoes alpha decay. Identify the daughter nucleus.*

$$\alpha = {}^{4}_{2}\mathrm{He}\ \text{emitted} \qquad Z \to Z-2,\ A \to A-4$$

$$\text{daughter} = {}^{222}_{86}\mathrm{Rn}$$

Answer

$^{222}_{86}\mathrm{Rn}$

Alpha decay of $^{210}_{84}$Po

$^{210}_{84}$*Po undergoes alpha decay. Identify the daughter nucleus.*

$$\alpha = {}^{4}_{2}\text{He emitted} \qquad Z \to Z-2,\ A \to A-4$$

$$\text{daughter} = {}^{206}_{82}\text{Pb}$$

Answer

$^{206}_{82}$Pb

Alpha decay of $^{232}_{90}\mathrm{Th}$

$^{232}_{90}Th$ *undergoes alpha decay. Identify the daughter nucleus.*

$$\alpha = {}^{4}_{2}\mathrm{He}\ \text{emitted} \qquad Z \to Z-2,\ A \to A-4$$

$$\text{daughter} = {}^{228}_{88}\mathrm{Ra}$$

Answer

$^{228}_{88}\mathrm{Ra}$

Alpha decay of $^{235}_{92}\mathrm{U}$

$^{235}_{92}U$ *undergoes alpha decay. Identify the daughter nucleus.*

$$\alpha = {}^{4}_{2}\mathrm{He}\ \text{emitted} \qquad Z \to Z-2,\ A \to A-4$$

$$\text{daughter} = {}^{231}_{90}\mathrm{Th}$$

Answer

$^{231}_{90}\mathrm{Th}$

Alpha decay of $^{212}_{83}\mathrm{Bi}$

$^{212}_{83}Bi$ *undergoes alpha decay. Identify the daughter nucleus.*

$$\alpha = {}^{4}_{2}\mathrm{He}\ \text{emitted} \qquad Z \to Z-2,\ A \to A-4$$

$$\text{daughter} = {}^{208}_{81}\mathrm{Tl}$$

Answer

$^{208}_{81}\mathrm{Tl}$

Beta decay of $^{14}_{6}\mathrm{C}$

$^{14}_{6}C$ undergoes β^- decay. Identify the daughter nucleus.

$$\beta^- = \text{neutron} \rightarrow \text{proton} + e^- \qquad Z \rightarrow Z+1,\ A \text{ same}$$

$$\text{daughter} = {}^{14}_{7}\mathrm{N}$$

Answer

$^{14}_{7}\mathrm{N}$

Beta decay of $^{131}_{53}\mathrm{I}$

$^{131}_{53}I$ *undergoes* β^- *decay. Identify the daughter nucleus.*

$$\beta^- = \text{neutron} \rightarrow \text{proton} + e^- \qquad Z \rightarrow Z+1,\ A \text{ same}$$

$$\text{daughter} = {}^{131}_{54}\mathrm{Xe}$$

Answer

$^{131}_{54}\mathrm{Xe}$

Beta decay of $^{60}_{27}\mathrm{Co}$

$^{60}_{27}Co$ undergoes β^- decay. Identify the daughter nucleus.

$$\beta^- = \text{neutron} \rightarrow \text{proton} + e^- \qquad Z \rightarrow Z+1,\ A \text{ same}$$

$$\text{daughter} = {}^{60}_{28}\mathrm{Ni}$$

Answer

$^{60}_{28}\mathrm{Ni}$

Beta decay of $^{90}_{38}\mathrm{Sr}$

$^{90}_{38}\mathrm{Sr}$ undergoes β^- decay. Identify the daughter nucleus.

$$\beta^- = \text{neutron} \rightarrow \text{proton} + e^- \qquad Z \rightarrow Z+1,\ A \text{ same}$$

$$\text{daughter} = {}^{90}_{39}\mathrm{Y}$$

Answer

$^{90}_{39}\mathrm{Y}$

Beta decay of $^{3}_{1}\mathrm{H}$

$^{3}_{1}H$ undergoes β^- decay. Identify the daughter nucleus.

$$\beta^- = \text{neutron} \rightarrow \text{proton} + e^- \qquad Z \rightarrow Z+1,\ A \text{ same}$$

$$\text{daughter} = {}^{3}_{2}\mathrm{He}$$

Answer

$^{3}_{2}\mathrm{He}$

Beta decay of $^{234}_{90}\mathrm{Th}$

$^{234}_{90}Th$ *undergoes* β^- *decay. Identify the daughter nucleus.*

$$\beta^- = \text{neutron} \rightarrow \text{proton} + e^- \qquad Z \rightarrow Z+1,\ A \text{ same}$$

$$\text{daughter} = {}^{234}_{91}\mathrm{Pa}$$

Answer

$^{234}_{91}\mathrm{Pa}$

Fraction after 1 half-lives

Z7

After 1 *half-lives, what fraction of a radioactive sample remains?*

$$\begin{aligned} \text{fraction} &= \left(\tfrac{1}{2}\right)^{1} && \text{half each half-life} \\ &= 50.00\% \end{aligned}$$

Answer

50.00%

Fraction after 2 half-lives

Z7

After 2 half-lives, what fraction of a radioactive sample remains?

$$\text{fraction} = \left(\tfrac{1}{2}\right)^{2} \qquad \text{half each half-life}$$
$$= 25.00\%$$

Answer

25.00%

Fraction after 3 half-lives

Z7

After 3 half-lives, what fraction of a radioactive sample remains?

$$\text{fraction} = \left(\tfrac{1}{2}\right)^{3} \qquad \text{half each half-life}$$
$$= 12.50\%$$

Answer
12.50%

Fraction after 4 half-lives

Z7

After 4 half-lives, what fraction of a radioactive sample remains?

$$\text{fraction} = \left(\tfrac{1}{2}\right)^4 \qquad \text{half each half-life}$$
$$= 6.25\%$$

Answer

6.25%

Fraction after 5 half-lives

After 5 *half-lives, what fraction of a radioactive sample remains?*

$$\text{fraction} = \left(\tfrac{1}{2}\right)^{5} \qquad \text{half each half-life}$$
$$= 3.12\%$$

Answer

3.12%

Mass after 15 yr, T=5 yr

A 80 g sample has half-life $T = 5$ yr. How much remains after 15 yr?

$$n = \frac{15}{5} = 3 \qquad \text{number of half-lives}$$

$$m = 80\left(\tfrac{1}{2}\right)^3 = 10.0\ \text{g}$$

Answer

10.0 g

Mass after 24 yr, T=8 yr

A 100 g sample has half-life $T = 8$ yr. How much remains after 24 yr?

$$n = \frac{24}{8} = 3 \qquad \text{number of half-lives}$$

$$m = 100\left(\tfrac{1}{2}\right)^{3} = 12.5 \text{ g}$$

Answer

12.5 g

Mass after 18 yr, T=6 yr

A 240 g sample has half-life $T = 6$ yr. How much remains after 18 yr?

$$n = \frac{18}{6} = 3 \qquad \text{number of half-lives}$$

$$m = 240\left(\tfrac{1}{2}\right)^{3} = 30.0\ \text{g}$$

Answer

30.0 g

Mass after 10 yr, T=2 yr

A 64 g sample has half-life $T = 2$ yr. How much remains after 10 yr?

$$n = \frac{10}{2} = 5 \qquad \text{number of half-lives}$$

$$m = 64\left(\tfrac{1}{2}\right)^{5} = 2.0 \text{ g}$$

Answer

2.0 g

Mass after 30 yr, T=10 yr

A 500 g sample has half-life $T = 10$ yr. How much remains after 30 yr?

$$n = \frac{30}{10} = 3 \qquad \text{number of half-lives}$$

$$m = 500\left(\tfrac{1}{2}\right)^{3} = 62.5 \text{ g}$$

Answer

62.5 g

How many half-lives to 6.25%?

Z7

A sample decays to 6.25% (1/16) of its original amount. How many half-lives passed?

$$\left(\tfrac{1}{2}\right)^{n} = 0.0625 = 1/16 \qquad \text{set equal}$$

$$n = 4 \qquad \text{since } 2^4 = 16$$

Answer

4

How many half-lives to 12.50%?

Z7

A sample decays to 12.50% *(*1/8*) of its original amount. How many half-lives passed?*

$$\left(\tfrac{1}{2}\right)^{n} = 0.1250 = 1/8 \qquad \text{set equal}$$

$$n = 3 \qquad \text{since } 2^3 = 8$$

Answer

3

How many half-lives to 25.00%?

A sample decays to 25.00% (1/4) of its original amount. How many half-lives passed?

$$\left(\tfrac{1}{2}\right)^{n} = 0.2500 = 1/4 \qquad \text{set equal}$$

$$n = 2 \qquad \text{since } 2^2 = 4$$

Answer

2

How many half-lives to 3.12%?

Z7

A sample decays to 3.12% *(*1/32*) of its original amount. How many half-lives passed?*

$$\left(\tfrac{1}{2}\right)^{n} = 0.0312 = 1/32 \qquad \text{set equal}$$

$$n = 5 \qquad \text{since } 2^{5} = 32$$

Answer

5

Binding energy, helium-4

The mass defect of helium-4 is $\Delta m = 0.0304$ u. Find its binding energy (1 u = 931.5 MeV).

$$E_b = \Delta m \cdot c^2 = 0.0304 \times 931.5 \quad \text{convert u to MeV}$$

$$E_b = 28.3 \text{ MeV} \quad \text{energy holding it together}$$

Answer

28.3 MeV

Binding energy, carbon-12

Z8

The mass defect of carbon-12 is $\Delta m = 0.0989$ u. Find its binding energy (1 u = 931.5 MeV).

$$E_b = \Delta m \cdot c^2 = 0.0989 \times 931.5 \quad \text{convert u to MeV}$$

$$E_b = 92.1 \text{ MeV} \quad \text{energy holding it together}$$

Answer

92.1 MeV

Binding energy, iron-56

The mass defect of iron-56 is $\Delta m = 0.5280$ u. Find its binding energy (1 u = 931.5 MeV).

$$E_b = \Delta m \cdot c^2 = 0.5280 \times 931.5 \quad \text{convert u to MeV}$$

$$E_b = 491.8 \text{ MeV} \quad \text{energy holding it together}$$

Answer

491.8 MeV

Binding energy, uranium-235

The mass defect of uranium-235 is $\Delta m = 1.9300$ u. Find its binding energy (1 u = 931.5 MeV).

$$E_b = \Delta m \cdot c^2 = 1.9300 \times 931.5 \quad \text{convert u to MeV}$$

$$E_b = 1797.8 \text{ MeV} \quad \text{energy holding it together}$$

Answer

1797.8 MeV

Binding energy, deuterium

The mass defect of deuterium is $\Delta m = 0.0212$ u. Find its binding energy (1 u = 931.5 MeV).

$$E_b = \Delta m \cdot c^2 = 0.0212 \times 931.5 \quad \text{convert u to MeV}$$

$$E_b = 19.7 \text{ MeV} \quad \text{energy holding it together}$$

Answer

19.7 MeV

Practice more, then watch the walk-through

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