Cheat Sheet C1: **Acids and Bases**

Medify

The general equation for acid dissociation is:

$$HA + H_2O \rightleftharpoons H_3O + A^-$$

The acid dissociation constant, K_a, is given by:

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} \qquad pK_a = -\log K_a$$

pH and pOH are defined as:

$$pH = -\log[H_3O^+] \qquad pOH = -\log[OH^-]$$

The ionic product of water is given by:

$$K_w = [OH^-][H_3O^+] = \underset{\text{at 298 K}}{10^{-14}} \qquad pK_w = pH + pOH = \underset{\text{at 298 K}}{14}$$

Buffer solutions obey the Henderson-Hasselbach equation:

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

All concentrations are in mol dm^{-3}.

1

A solution is made by dissolving 28 g of potassium hydroxide (molar mass = 56) in 100 mL of water. The solution is allowed to cool to 25°C.
What is the pH of this solution?

A. Less than 14

B. 14

C. Greater than 14 but less than 15

D. 15

2

At 25°C the pKa of $H_2PO_4^-$ is 7.21. In order to maintain a system at pH 6.2, the amount of NaH_2PO_4 sodium hydrogen phosphate in the buffer should be:

A. Twice the amount of Na_2HPO_4

B. Equal to the amount of Na_2HPO_4

C. One fifth the amount of Na_2HPO_4

D. Ten times the amount of Na_2HPO_4

Answers: 1C, 2D

Cheat Sheet C2: **Moles and Gas Laws**

Medify

A mole means 6.022×10^{23} particles.

Relative atomic mass of a sample of an element made of different isotopes:

$$A_r = \frac{m_1\,\text{abundance}_1 + m_2\,\text{abundance}_2 + m_3\,\text{abundance}_3 + \ldots}{\text{abundance}_1 + \text{abundance}_2 + \text{abundance}_3 + \ldots}$$

Conversion between mass and moles.

$$\text{Amount (mol)} = \frac{\text{mass (g)}}{\text{relative formula (or molecular) mass} \times M_u\ (\text{g mol}^{-1})}$$

where $M_u = 1\ \text{g mol}^{-1}$

Gas laws:	Boyle's law	$p_1V_1 = p_2V_2$
	Charles' law	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
	Gay-Lussac's law	$\frac{p_1}{T_1} = \frac{p_2}{T_2}$
	Avogadro's law	$\frac{V}{n}$
	Ideal Gas law	$pV = nRT$
	Kinetic Gas equation	$pV = \frac{mnC_{RMS}^2}{3}$
	Graham's law of diffusion	$\text{Rate}_1 \propto \frac{1}{\sqrt{M_1}}$
	Graham's law of diffusion 2	$\frac{\text{Rate}_1}{\text{Rate}_2} = \sqrt{\frac{M_2}{M_1}}$

Where m = mass, p = pressure, V = volume, n = number of molecules, T = temperature, R = the gas constant, C_{RMS} = root mean squared velocity, M_x is the molecular mass of gas x

1

At standard temperature and pressure, fluorine gas has a density of $1.696\ \text{gL}^{-1}$ and chlorine gas has a density of $3.214\ \text{gL}^{-1}$. Which of these is the best estimate of the relative rates of diffusion of fluorine and chlorine?

A. $Rate_{Cl} = \frac{1}{\sqrt{2}}\ Rate_F$

B. $Rate_{Cl} = \frac{1}{2}\ Rate_F$

C. $Rate_{Cl} = \sqrt{2}\ Rate_F$

D. $Rate_{Cl} = 2\ Rate_F$

2

An ideal gas is heated from 400 K to 900 K. What will happen the the root mean squared velocity (C_{RMS})?

A. The root mean squared velocity will not change

B. The root mean squared velocity will increase by a factor of $\frac{4}{9}$

C. The root mean squared velocity will increase by a factor of $\frac{3}{2}$

D. The root mean squared velocity will increase by a factor of $\sqrt{3} \times \frac{3}{2}$

Answers: 1A, 2C

Cheat Sheet C3: **Equilibrium**

Medify

$$aA + bB \rightleftharpoons cC + dD$$

When all species are aqueous, the equilibrium constant, K_C, can be expressed as:

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

When all species are gaseous, the equilibrium constant, K_P, can be expressed as:

$$K_P = \frac{(p_C)^c\ (p_D)^d}{(p_A)^a\ (p_B)^b}$$

where $p_A = x_A \times p_{tot}\ ;\ x_A = \frac{\text{no. moles of gas A}}{\text{total no. of moles of gas}}\ ;\ x_{tot} = x_A + x_B + x_C + x_D = 1$

Dalton's law: $p_{tot} + p_A + p_B + p_C + p_D$

Raoult's law: the vapour pressure of a solution, p, is equal to the vapour pressure of the pure solvent, p°_{solv}, multiplied by the mole fraction of the pure solvent, x_{solv}:

$$p = x_{solv} \times p^{\circ}_{solv}$$

Raoult's law applied to a mixture of two volatile liquids, A and B, at equilibrium:

$$p = x_A \times p^{\circ}_A + x_B + p^{\circ}_B$$

Henry's law: for real solutions at low concentrations:

$$p_C = x_C \times K_H$$

Note: K_C and K_P = equilibrium constants, $[X]$ = concentration of X, p_A = partial pressure of A, x_A = mole fraction of A, p_{tot} = total pressure, K_H is Henry's constant.

1

600 g of ethane (Mw = 30 gmol^{-1}) is mixed with 220 g propane (Mw = 44 gmol^{-1}). The total pressure of the system is 120 mm Hg. What is the partial pressure of propane?

A. 24 mm Hg

B. 30 mm Hg

C. 90 mm Hg

D. 96 mm Hg

2

A mixture of water and acetone boils at 80˚C under atmospheric pressure (1 atm) The vapour pressures of acetone and water under these conditions are approximately 2 atm and 0.5 atm respectively. What is the mole fraction of water?

A. $\frac{1}{4}$

B. $\frac{1}{3}$

C. $\frac{2}{3}$

D. $\frac{3}{4}$

Answers: 1B, 2C

Cheat Sheet C4: **Rates and Thermodynamics**

Rates

For any reaction, the rate is given by:

$$\text{Rate} = k[A]^a [B]^b [C]^c \ldots$$

where k is the rate constant; A,B, and C are reactants which appear in the rate determining step; a,b,c and are their stoichiometric coefficients.

The rate constant varies with temperature according to the Arrhenius equation:

$$k = Ae^{\frac{-E_a}{RT}}$$

$$\ln(k) = \ln(A) - \frac{E_a}{RT}$$

where A is the Arrhenius constant, E_a is the activation energy, R is the gas constant and T is the temperature in kelvin.

For enzyme reactions of the form:

$$E + S \underset{k_r}{\overset{k_f}{\rightleftharpoons}} ES \xrightarrow{k_{cat}} E + P$$

The Michaelis-Menten equation applies:

$$V_0 = \frac{d[P]}{dt} = V_{max}\frac{[S]}{K_M + [S]}$$

where V_0 = initial rate; V_{max} = maximum rate; and

$$K_M = \frac{k_r + k_{cat}}{k_f}$$

Thermodynamics

The heat produced from a reaction can be calculated using:

$$Q = mc\Delta T$$

where Q = heat produced; m = mass of reactants; ΔT = temperature change; c = specific heat capacity.

Hess' law states that the enthalpy change of reaction, ΔH_{net} , is independent of the route taken:

$$\Delta H_{net} = \sum \Delta H_r$$

Entropy is a measure of disorder. The entropy change for a reaction, ΔS_r, is given by:

$$\Delta S_r = \sum S^\circ(\text{products}) - \sum S^\circ(\text{reactants})$$

For an internally reversible, isothermal process:

$$\Delta S_r = \frac{Q}{T}$$

Gibbs free energy change, ΔG°, is defined as:

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$
$$\Delta G^\circ = -RT\ln(K)$$

where K = an equilibrium constant.

1

For an enzyme with K_M = 0.75 mmol dm^{-3} and a V_{max} of 400 mmol s^{-1}, what substrate concentration will result in a rate which is $\frac{1}{4}$ of the maximum?

A. $\frac{1}{4}$ mmol dm^{-3}

B. $\frac{1}{2}$ mmol dm^{-3}

C. 4 mmol dm^{-3}

D. $5\frac{1}{3}$ mmol dm^{-3}

2

The hydrophobic effect is when a non polar molecule, such as a protein, aggregates on addition to water. Which of the following is true regarding the thermodynamics of aggregation?

A. ΔG° is positive

B. ΔS° is negative

C. It is an endothermic reaction

D. ΔG° is independent of temperature

Answers: 1A, 2B

Cheat Sheet P1: **Mechanics • Linear and Angular**

Medify

Equations of Linear Motion:

When there is no acceleration (a = 0): $s = vt$

At constant acceleration: $v = u + at$; $s = ut + \frac{1}{2}at^2$; $s = \frac{1}{2}(u + v)t$; $v^2 = u^2 + 2as$

Momentum and kinetic energy: $\rho = mv$; $E_K = \frac{1}{2}mv^2$

Remember, velocity and acceleration are the first and second derivatives of displacement

Equations of Angular Motion:

When there is no acceleration (a = 0): $\omega = \frac{\Delta\theta}{\Delta t}$; $\theta = \theta_0 + \omega t$

At constant acceleration: $\omega = \omega_0 + \alpha t$; $\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$; $\omega^2 = \omega_0{}^2 + 2\alpha\Delta\theta$

Angluar momentum, rotational kinetic energy and angular speed:

$L = I\omega$; $E_K = \frac{1}{2} I{=}^2$; $\omega = 2\pi f = \frac{2\pi}{t}$

Magnitude of angular terms (v, a, and F are perpendicular to r):

$\omega = \frac{v}{r}$; $\alpha = \frac{a}{r}$; $L = mvr$; $\tau = Fr$; $I = mr^2$

Where v = final velocity, u = initial velocity, a = linear acceleration, s = displacement, t = time, ρ = momentum, m = mass, E_K = kinetic energy, ω = angular velocity, ω_0 = angular velocity at t = 0, $\Delta\theta$ = angular displacement, L = angular momentum, I = moment of inertia, f = frequency, r = radius, τ = torque and F = force

1

An object accelerating at a rate of 2 ms^{-2} has an initial velocity of 10 ms^{-1} and a final velocity of 15 ms^{-1}. What distance does the object travel (answers given to 2 s. f.)?

A. 5.0 m

B. 23 m

C. 31 m

D. 38 m

2

A gramophone reads music from a record at a constant rate. When the gramophone switches from playing a song at the inner edge of a record to the outer edge the frequency drops from 10 Hz to 4 Hz. What is the effect on the rotational kinetic energy of the record?

A. It remains constant

B. It decreases by 40%

C. It decreases by 60%

D. It decreases by 84%

Answers: 1C, 2D

Cheat Sheet P2: **Mechanics • Forces, Energy & Gravity**

Medify

Force:

$$F = ma$$

$$F = \frac{\Delta (mv)}{\Delta t}$$

Impulse:

$$I = F\Delta t = \Delta(mv)$$

Moment:

$$\text{moment} = F\,d\cos\theta$$

Energy, Work and Power

$$E_K = \frac{1}{2}mv^2$$

$$\Delta E_P = mg\Delta h$$

At constant force:

$$W = \int F \,.\, ds$$

$$P = \frac{\Delta W}{\Delta t} = Fv$$

Gravitational Fields

Force between two masses:	$F = \frac{Gm_1m_2}{r^2}$	
The gravitational field strength:	$F = m\,g;$	$g = \frac{GM}{r^2}$
Gravitational potential:	$E_P = -\frac{GmM}{r};$	$g = -\frac{\Delta E_P}{\Delta r}$

Where F = force, a = acceleration, I = impulse, v = velocity, t = time, m = mass, E_K = kinetic energy, E_P = gravitational potential energy, h = height, g = gravitational acceleration, W = work done, s = displacement, θ = angle between applied force and displacement, P = power, r = distance, G = gravitational constant, M = mass of Earth.

1

The mass of the Earth is approximately 100 times larger than the mass of the Moon. There is a point, P, between the Moon and the Earth at which the gravitational field strength is zero. Which of the following is true?

A. P is equidistant from the Earth and the Moon

B. P is 10 times closer to the Moon than the Earth

C. P is 100 times closer to the Moon than the Earth

D. P is 10,000 times closer to the Moon than the Earth

2

Which of the following statements is not true of the velocity needed to escape the gravitational pull of the Earth?

A. The velocity is independent of the mass of the escaping object

B. The velocity is dependent on the gravitational constant of the Earth

C. The velocity will be affected by atmospheric friction

D. The velocity is inversely proportional to the squared distance between the object and the Earth's surface

Answers: 1B, 2D

Cheat Sheet P3: **Structural Properties of Matter**

Stress, Strain and Hooke's Law

Stress: $\sigma = \frac{F_n}{A}; \qquad \tau = \frac{F_p}{A}$

Strain: $\varepsilon = \frac{\Delta l}{l_0} = \frac{\sigma}{E}$

$\gamma = \frac{s}{d} = \frac{\tau}{G}$

Hooke's law: $k = E\frac{A}{l_0}; \qquad F = -kx$

Where σ = normal stress, F_n = normal force perpendicular to area, A = area, τ = shear stress, F_p = shear force in the plane of the area, ε = strain (unitless), Δl = change of length, l_0 = initial length, E = Young's modulus, γ = shear strain (unitless), s = displacement of the faces, d = distance between faces, G = Shear modulus of elasticity, k = spring constant, F = force and x = length of extension.

Fluid Dynamics

$\rho = \frac{m}{v}$

$p = \frac{F}{A}$

$p = p_0 + \rho g h$

Bernoulli equation: $p = \frac{1}{2}\rho v^2 + \rho g h = constant$

Continuity principle: $A_1 v_1 = A_2 v_2 = constant$

Where ρ = density, m = mass, V = volume, p = pressure, p_0 = initial pressure, F = force, A = area, g = gravitational acceleration, h = depth of fluid, v = fluid velocity.

1

A force of 10 kN is applied to the end of a circular steel rod with a modulus of elasticity of 200×10^9 Nm^{-2}, a length of 2 m and a diameter of 10 mm. What is the change, in metres, of the length of the rod?

A. $\frac{1}{\pi} \times 10^{-11}$

B. $\frac{1}{25\pi} \times 10^{-8}$

C. $\frac{1}{1000\pi}$

D. $\frac{1}{250\pi}$

2

Water flows through a horizontal pipe at a velocity of 5 ms^{-1}. The cross-sectional area of the pipe then reduces by a factor of two. Which of these statements is true?

A. Both the fluid pressure and fluid velocity increase.

B. Both the fluid pressure and the volume flow rate decrease.

C. The fluid pressure increases but the fluid velocity decreases.

D. The fluid pressure decreases and the volume flow rate remains constant.

Answers: 1D, 2D

Cheat Sheet P4: **Waves and Sound**

Wave Phenomena

$$v = f\lambda$$

$$T = \frac{t}{n}; \quad f = \frac{1}{T}$$

$$y(x,t) = A \sin(kx - \omega t)$$

$$\lambda = \frac{2\pi}{k}; \quad v = \lambda f = \frac{\omega}{k}; \quad I \propto A^2$$

Where v = wave velocity, f = frequency, λ = wavelength, T = period, t = time, n = number of cycles, A = amplitude, ω = angular frequency, k = angular wave number, I = intensity, x = co-ordinate along the direction of the wave.

Sound

Doppler effect: $f_o = f_s\left(\frac{v \pm v_o}{v \pm v_s}\right)$

Intensity of sound: $\beta = 10\log_{10}\left(\frac{I}{I_{10}}\right)$

Superposition: $I_{max} = |A_1 + A_2|^2; \quad I_{min} = |A_1 - A_2|^2$

Two sinusoidal waves with same amplitude, angular frequency and angular wave number but different phase result in:

$$y = A \sin\left(kx - \omega t + \frac{\Phi}{2}\right)$$

Interference of coherent waves where amplitude and angular frequency are equal:

$$A = 2A_1 \cos\left(\frac{\Phi}{2}\right); \quad I = 4I_1\left(\cos\left(\frac{\Phi}{2}\right)\right)^2$$

If $\Phi = 0, 2\pi, 4\pi, \ldots$ then the interference is constructive, if $\Phi = \pi, 3\pi, 5\pi\ldots$ then the interference is destructive.

Where Φ = phase, f_o = observed frequency, f_s = source frequency, v = wave velocity, v_s = source velocity, v_0= observer velocity, β = intensity level in decibel, I = intensity, v_0 = intensity of a reference signal.

1

Noise cancelling headphones produce sound waves to destructively interfere with detected external sound waves. What is the phase and intensity of the speaker relative to the external sound?

A. $\phi = 0$ and $I_{speaker} > I_{external}$

B. $\phi = \pi$ and $I_{speaker} = I_{external}$

C. $\phi = 2\pi$ and $I_{speaker} = I_{external}$

D. $\phi = 2\pi$ and $I_{speaker} > I_{external}$

2

The speed of sound on Mars is approximately 240 ms^{-1}. Two space buggies are both moving at a speed of 40 ms^{-1} towards each other. If one buggy sends a signal with a frequency of 100 Hz, what wavelength will be perceived by the other buggy?

A. 100 cm

B. 140 cm

C. 171 cm

D. 338 cm

Answers: 1B, 2C

Cheat Sheet P5: **Waves and Light**

Medify

Wave Phenomena

$$v = f\lambda$$

$$T = \frac{t}{n}; \quad f = \frac{1}{T}$$

$$y(x,t) = A\sin\left(2\pi\left(\frac{x}{\lambda} - ft\right) + \Phi\right)$$

$$y(x,t) = A\sin(kx - \omega t + \Phi)$$

Where v = wave velocity, f = frequency, λ = wavelength, T = period, t = time, n = number of cycles, A = amplitude, Φ = phase, ω = angular frequency, k = angular wave number.

Light

The law of reflection: $\theta_i = \theta_r$

The index of refraction: $n = \frac{c}{v_{apparent}}$

Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Critical angle for total internal reflection: $\theta_c = \sin^{-1}\left(\frac{n_2}{n_2}\right)$

Lateral magnification: $M = \frac{h'}{h}$

Lens maker's formula and the thin lens equation: $\frac{1}{f} = \frac{n_2 - n_1}{n_1}\left(\frac{1}{r_1} - \frac{1}{r_2}\right); \quad \frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

where θ_i = angle of incidence, θ_r = angle of reflection, n = index of refraction, c = speed of light, v = velocity, M = magnification, h = actual height of object, h' = height of image, f = focal length, r_x = radius of curvature, u = object distance, v = image distance.

Young's Double Slit Experiment $\lambda = \frac{ax}{D}$

where λ = wavelength of source, a = distance between centres of the slit, x = fringe width, D = distance from double slit to the screen.

The Diffraction Grating $d\sin\theta = n\lambda; \quad d = \frac{1}{N}$

where d = spacing between adjacent slits, θ = angular separation between maxima, n = order of maxima, λ = wavelength of source.

1

With reference to the thin lens formula, which of the following will result in a virtual, upright image 60 cm from the lens?

A. An object distance of 20 cm and a focal length of 15 cm

B. An object distance of 65 cm and a focal length of 5 cm

C. An object distance of 15 cm and a focal length of 20 cm

D. An object distance of 30 cm and a focal length of 30 cm

2

When Young's double slit experiment is conducted using orange light of wavelength 6.0×10^{-7} m a fringe separation of 2.0 mm is obtained. The light source is changed to violet light of wavelength 4.0×10^{-7} m. What is the new fringe separation?

A. 0.66 mm

B. 1.3 mm

C. 2.6 mm

D. 3.0 mm

Answers: 1C, 2B

Cheat Sheet P6: **Electostatics and Magnetism**

Medify

Coulomb's Law $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2} = k\frac{Q_1 Q_2}{r^2}$

Force on a charge and work done: $F = EQ;$ $\Delta W = Q\Delta V$

Field strength (uniform field) and radial field strength: $E = \frac{V}{d};$ $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

Electric potential: $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

Capacitance: $C = \frac{Q}{V};$ $E = \frac{1}{2}QV$

$Q = Q_0(1 - e^{\frac{-t}{RC}})$

Where F = force, ε_0 = permittivity of free space (constant), Q = charge, r = distance, k = the Coulomb constant, E = electric field strength, V = potential difference, W = work done, C = capacitance, R = resistance, t = time.

Magnetic force: $F = BIl;$ $F = BQv$

Magnetic flux: $\Phi = BA;$ $\Phi = BA\cos\theta;$ $\varepsilon = N\frac{\Delta\Phi}{\Delta t}$

Rotating coil: $\varepsilon = BAN\omega\sin\omega t$

Alternating current: $I_{rms} = \frac{I_0}{\sqrt{2}};$ $V_{rms} = \frac{V_0}{\sqrt{2}}$

Transformers: $\frac{N_s}{N_p} = \frac{V_s}{V_p};$ efficiency = $\frac{I_s V_s}{I_p V_p}$

Where F = force, B = magnetic field strength, l = length, Q = charge, v = velocity, Φ = magnetic flux, A = area, θ = angle between a perpendicular vector to the area and the magnetic field, ε = induced voltage, N = number of turns on coil, t = time, ω = angular momentum, V_{rms} = root mean squared voltage, V_0 = initial voltage, I_{rms} = root mean squared current, I_0 = initial current, N_p = number of turns on primary coil, N_s = number of turns on secondary coil, V_p = voltage across primary coils, V_s = voltage across secondary coils, I_p = current (primary coil), I_s = current (secondary coil).

1

What is the direction of the electric field which accelerates a negative charge in a westerly direction?

A. North

B. South

C. East

D. West

2

A surface carries a uniform magnetic field of flux density *3 T*. A horizontal straight wire of length 0.1 m carrying a current of 0.2 A floats above the surface. What is the mass of the wire? (recall *F = mg*)

A. 0.6 g

B. 6 g

C. 0.06 kg

D. 0.6 kg

Answers: 1C, 2B

Cheat Sheet P7: **Electric Circuits**

Medify

Ohm's Law:	$I = \frac{\Delta Q}{\Delta t}$; $V = \frac{W}{Q}$; $R = \frac{V}{I}$
Resistivity	$R = \frac{\rho L}{A}$
Resistors in Series	$R_T = R_1 + R_2 + R_3 + \ldots$
Resistors in Parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$
Kirchhoff's Current Law:	$\sum_{k=1}^{n} I_k = 0$
Kirchhoff's Voltage Law:	$\sum_{k=1}^{n} V_k = 0$
Power	$P = VI = I^2R = \frac{V^2}{R}$
EMF	$\varepsilon = \frac{E}{Q} = I(R + r)$

Where I = current, Q = charge, t = time, V = potential difference, W = work done, R = electrical resistance, ρ = specific resistivity, L = length, A = area, ε = electromotive force, E = Energy in the circuit, r = internal resistance of the cell.

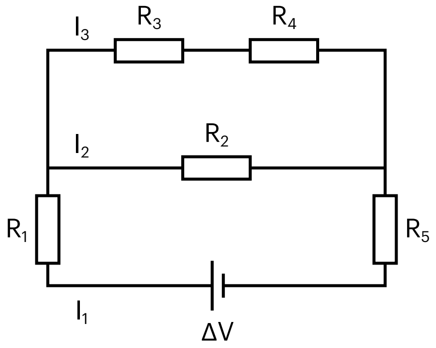
1

Five lamps are connected in parallel to a 12 V battery. The resistance of each lamp is 6 Ω. The current flowing through the battery and the power consumed by each lamp is:

A. 10 A and 24 W
B. 10 A and 600 W
C. 2 A and 24 W
D. 2 A and 48 W

2

Consider the following circuit. Which of the following is the correct expression with regards to the following circuit?



A. $I_2R_2 + I_3(R_3 + R_4) = 0$
B. $-I_2R_2 + I_3(R_3 + R_4) = 0$
C. $\Delta V - I_1(R_1 + R_5) + I_3(R_3 + R_4) = 0$
D. $\Delta V + I_1(R_1 + R_5) - I_3(R_3 + R_4) = 0$

Answers: 1A, 2B

Cheat Sheet P8: **Nuclear Physics and Imaging**

Medify

Photons and Energy Levels:

Photon energy: $E = hf = \frac{hc}{\lambda}$

Photoelectricity and energy levels: $Ek_{(max)} = hf - \Phi;$ $hf = E_1 - E_2$

De Broglie wavelength: $\lambda = \frac{h}{p} = \frac{h}{mv}$

Where E = energy, h = Planck's constant, f = frequency, c = speed of light, λ = photon wavelength, $E_{k(max)}$ = maximum kinetic energy of ejected electron, Φ = threshold energy, p = linear momentum, m = mass, v = velocity.

Radiation:

Inverse square law (γ radiation): $I \propto \frac{1}{x^2}$

Radioactive decay: $A = -\frac{\Delta N}{\Delta t} = \lambda N;$ $N = N_0 e^{-\lambda t};$

Half-lives: $T\frac{1}{2} = \frac{\ln 2}{\lambda};$ $T\frac{1}{2} = \frac{\ln 2}{\lambda};$

Where I = intensity, x = distance from source, A = activity, N = number of particles, t = time, λ = decay constant, N_0 = number of particles at t=0, $T\frac{1}{2}$ = half–life.

X-Rays and Ultrasound:

$I = I_0 e^{-\mu x};$ $\mu_m = \frac{\mu}{\rho}$

$Z = \rho c;$ $\frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$

Where I = transmitted intensity, I_0 = incident intensity, μ = linear attenuation coefficient, μ_m = mass attenuation coefficient, ρ = density, x = path length, Z = characteristic impedance, c = speed of sound in the material, I_r= intensity of reflected wave, I_i= intensity of incident wave, Z_1 = acoustic impedance of material 1, Z_2 = acoustic impedance of material 2.

1

A sample contains two radioactive nuclei, A and B. The half lives of A and B are 3 and 9 minutes respectively. After 18 minutes, the sample contains an equal amount of A and B. What was the initial ratio of A:B?

A. 1:1

B. 4:1

C. 16:1

D. 32:1

2

An ultrasound wave is directed at a tissue boundary. What percentage reflection would be expected if $Z_1 = 3 Z_2$?

A. 0.25 %

B. 25 %

C. $25 \sqrt{Z_2}$ %

D. $25 \times \frac{1}{\sqrt{Z_2}}$ %

Answers: 1C, 2B