A Level Physics Online

OCR B Physics – H557

Module 3: Physics in Action

You should be able to demonstrate and show your understanding of:	**Progress and understanding:**			
	1	**2**	**3**	**4**
3.1: Communication				
3.1.1: Imaging and Signalling				
The formation of a real image by a thin converging lens; the lens changes the curvature of the incident wave-front [curvature = 1/r, where r is the radius of the circle that would be formed if the path of the wave front were continued to form a circle]				
Wave and ray diagrams of the passage of light through a converging lens				
Power of a converging lens is P = 1/f, it is the curvature added to the wave fronts as they pass through the converging lens				
Use of $\frac{1}{v}=\frac{1}{u}+\frac{1}{f}$ where v is the image distance, u is the object distance and f is the focal length (fl) of the lens (the distance from the lens to the focal point (fp), the point where incoming parallel rays converge)				
The value of u, the object distance is always negative, due to the Cartesian convention of taking one direction as positive and the other as negative				
Source Position: Light from object closer to lens than fl: focus beyond fp Light from distant object (parallel incoming rays): focus at fp Light from near object but beyond fl (at a distance u): focus at a distance v Light from object at fl: focus at a long distance (rays are made parallel)				
Linear magnification; $m=\frac{image\ height}{object\ height}=\frac{v}{u}$ On a magnification diagram, the triangles formed by the paths of the light rays before and after the lens are congruent				
Magnification values: Negative: Image is inverted m < 1: Image is smaller and closer to lens than the object (source) m = 1: Image is same size and distance from lens to the object (source) m > 1: Image is larger and further from lens than the object (source)				

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v = f λ and f = 1/T, where is the period of the wave				
Electromagnetic waves are transverse and when unpolarised they oscillate in a randomly changing plane. When polarised they oscillate in one fixed plane				
Using a metal grate and a microwave transmitter (and detector), if the wave oscillates in a plane parallel to the grate alignment, the wave is absorbed as the electrons in the grate can move the length of the grate so can absorb higher energy photons. If the grate is rotated through 90 degrees so the wave oscillates perpendicular to the grate alignment, the wave passes through as the electrons in the metal grate can only move the width of each bar of the grate; so, it cannot absorb the photons of the microwave as their energy is too large				
Pixel: a single 'picture element' created by light sensitive detectors Bit: smallest unit of digital information Byte: 8 bits = 1 byte = 256 alternatives				
Resolution is the scale of the smallest detail that can be distinguished $r = \frac{width\ of\ object\ in\ image}{number\ of\ pixels\ across\ it}$				
Images are stored in a computer as an array of numbers that can be manipulated to enhance the image <u>Changing brightness:</u> Brightening a dim image, by increasing the value on each pixel until the brightest is coded at 255 <u>Removing noise:</u> <u>Smoothing -</u> Blurring a sharp edge, each pixel is replaced with the mean of those around it <u>Noise Reduction -</u> Removing single 'noisy' pixels, each pixel is replaced with the median of those around it <u>Edge detection:</u> The mean of the surrounding eight pixels is subtracted from each pixel. It removes uniform areas of brightness <u>Changing contrast:</u> An image with little contrast won't use a full range of pixels. To improve contrast, it is stretched across the full range (256). The values are tended to 0 or 255 depending on which they are closer to				
A signal transfers information from one place to another, this can be coded into binary digits (0 or 1) to form a digital signal				
Analogue: A continuously varying signal ✗ Amplified when distorted by noise, however this amplifies noise too ✗ Noise can be filtered out, but this loses signal clarity				
Digital: A signal that only contains two 'modes', 0 or 1/on or off ✓ Doesn't lose detail when noise is filtered out ✓ Easy to detect, only takes 0 or 1 so can be regenerated perfectly ✓ Travels faster				

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✓ Carry more information ✗ Digital numbers can be changed or scrambled, threat for online banking ✗ Digitally enhanced images on films – achieve a level of reality we can't achieve				
Amount of information in an image = number of pixels x bits per pixel				
N = 2^b, b = $\log_2 N$, where b is the number of bits and N is the number of alternatives				
<u>Noise:</u> Random variation on a signal				
<u>Sampling:</u> Process where the displacement of a continuous (analogue) signal is measured at small Δt and turned into a string of binary numbers, samples <u>Sampling rate/frequency:</u> Number of samples per second - To sample a varying signal accurately, the time between samples must be shorter than the time between when important changes in the signal occur. With a larger Δt, detail of the original signal is lost <u>Quantisation levels:</u> The signal being quantised can be represented graphically, with voltage (amplitude) on the y axis and time on the x axis. Number of levels = 2^b. Actually, the number of levels is 2^b-1 (taking away the level at V = 0) but these are so close that just 2^b is used for the number of levels is used. For a signal coded with 3 bits there are 2^3 = 8 levels - Increasing the number of quantisation levels causes a better signal match, however it also increases the demand on storage and transmission - If the spacing between subsequent quantisation levels is smaller than the size of the noise variation, then digitising the signal is useless as it would detail the noise, not reduce it $Max\ number\ of\ levels\ (2^b) = \frac{V_{total}}{V_{noise}}$ $Max\ number\ of\ bits\ per\ sample\ (b) = log_2(\frac{V_{total}}{V_{noise}})$ If b is a decimal round up! This ensures there are enough bits to provide the number of levels required <u>Quantisation error:</u> Difference between the signal value and the quantisation level value <u>Resolution (in this context):</u> The smallest change in p.d. than can be determined $resolution = \frac{p.d.\ range\ of\ signal}{number\ of\ quantisation\ levels}$				
There are two conditions for sampling: - The signal cannot contain frequencies above a certain maximum - The minimum sampling rate must be at least 2x the maximum frequency of the signal (the Nyquist rate) (The limit of human hearing is 20kHz, so the sampling frequency for music must be greater than 40kHz, the standard is 44.1kHz)				

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If frequencies are above a certain maximum, the signal won't be regenerated accurately and aliases will be generated. Also, if sampling is too slow, high frequencies are missed and creates these false, low frequency aliases too <u>Aliases:</u> low frequency values that were not in in the original signal				
<u>Bit rate:</u> The rate of transmission of digital information (units: bits^{-1}/Hz) bit rate = samples per second x bits per sample [Note: samples per second is the sampling rate/frequency]				
$signal\ duration = \frac{number\ of\ bits\ per\ signal}{bit\ rate}$				
3.1.2: Sensing				
Current (units: amps, A) is the rate of flow of charge, $I = \frac{\Delta Q}{\Delta t}$, where Q is the charge (units: coulombs, C) and ΔQ = Nq, where N is the total number of charged particles and q is the charge on one particle				
One coulomb is the charge flowing through a point in one second when there is a current of 1A				
Potential difference, p.d., (units: volts, V) is the energy transfer per unit charge when moving between two points $V = \frac{\Delta E}{Q} = \frac{W}{Q}$ where W is the work done between the two points (units: joules, J)				
$I = \frac{\Delta Q}{\Delta t}$ and $V = \frac{W}{Q}$ can be combined to show that W = ItV				
Resistance (units: ohms, Ω) is the measure of the difficulty of passing an electric current through a medium $R = \frac{V}{I} = \frac{1}{G}$ Resistors in series: $R_{TOT} = R_1 + R_2 + R_3 + \ldots$ Resistors in parallel: $R_{TOT} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$				
Conductance (units: siemens, S) is the measure of the ease of passing an electric current through a medium (opposite of resistance) $G = \frac{I}{V} = \frac{1}{R}$ Conductors in series: $G_{TOT} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3} + \cdots$ Conductors in parallel: $G_{TOT} = G_1 + G_2 + G_3 + \ldots$				
Ohm's law: The voltage across a component is proportional to the current through it, V = IR				
Heat dissipation is a thermal energy transfer per second resulting in an increase in energy of the surroundings, measured in watts, W. Electrons are accelerated by a p.d., their movement is obstructed by the metal cations in the wire. The potential energy lost does work on the wire,				

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heating it up $P = \frac{\Delta E}{\Delta t} = IV = I^2R$ Heat dissipation increases with increased R and decreases with increased G				
Parallel Circuits: Same p.d. all round Different I, split over each branch in inverse proportion to R (For multiple components on branches, add the resistances in series for each branch and then add the total resistance of each branch in parallel) Series Circuits: Different p.d., split over each component in proportion to R Same I all round				
Kirchhoff's First Law: At an electrical junction, $I_{in} = I_{out}$ (conservation of Q) Kirchhoff's Second Law: Around a circuit $\Sigma\ emfs = \Sigma\ p.d.s$ (conservation of E). In words, this means the sum of all the applied emfs from each cell in the circuit equals the sum of the voltage drops across all the components in a circuit equals -Remember that the long, thin line of the cell symbol is the positive terminal, and the short, bold line is the negative terminal [Note: Kirchhoff is pronounced *Ker – cof*] [http://physics.bu.edu/~duffy/PY106/Kirchoff.html This links to a useful example]				
I-V Graph for an ohmic resistor is a proportional, linear line through the origin. For a filament lamp it is an 'S' curve levelling off at large positive and large negative voltages. For a diode, at a specific voltage, charge begins to flow, so the gradient of the graph changes from zero to a positive constant				
Bulk/intensive property: property of the material e.g. density Extensive property: property of the specimen e.g. mass, volume				
Resistivity, ρ, (units: Ωm) is the measure of a material's opposition to the flow of charge. It is a bulk property. It is independent of temperature $\rho = \frac{RA}{L}$ where R is the resistance, A is the cross-sectional area of the wire, L is the length of the section of wire being considered. To measure resistivity of an insulator, small L, large A and a sensitive ammeter so current can be detected more easily				
Conductivity, σ, (units: Sm^{-1}) is the measure of a material's allowance of charge to flow. To measure conductivity of a metal, large L, small A $\sigma = \frac{L}{RA}$				
Insulators: No mobile charges, cations and electrons are fixed e.g. solid glass				
Semiconductors: Few mobile charges, when heated, the number of charge carriers increases, so conductivity increases (a σ-T graph is exponential)				

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Metals: When a p.d. is applied electrons experience a force; this produces a slow general drift in one direction, superimposed on the rapid random motion. So, a p.d. produces a rate of flow of charge, a current.				
The velocity of the electrons when a p.d. is applied is the drift velocity. 1) Number of free electrons, N = nAL (Where AL is volume) 2) $Current, I = \frac{\Delta Q}{t} = \frac{Nq}{t} = \frac{nALe}{t}$ 3) $Drift\ velocity, v = \frac{L}{t}$ (This is just speed=distance/time) 4) $Current, I = nAve$ 5) $Drift\ velocity, v = \frac{I}{nAe}$ Where n=number density (see below); A=cross sectional area; L=length of wire section being considered; e=charge of an electron; t=time for an electron to travel a distance L along the wire				
Number density, n, (units: m^{-3}): Number of mobile charge carriers per unit volume Drift Velocity: Mean velocity of charge carriers in a current carrying conductor. Collisions reduce the drift velocity. Overall, results in a trend in the motion of the electrons one way, the current				
Thermistor: Temperature sensors made of semiconducting material. As temperature increases, electrons are liberated, so conductivity increases, and resistance decreases significantly (for an NTC thermistor)				
LDR: Light sensors made of semiconducting material. As light intensity increases, electrons are liberated, so conductivity increases and resistance decreases				
Potential dividers: $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ So for a voltmeter reading V_{out} over a resistor R_2, the equation becomes, $V_{out} = \frac{R_2}{(R_1+R_2)} \times V_{in}$				
Electromotive force, emf, ε: The energy the source gives to the charges per coulomb flowing through the source.				
Internal resistance, r: The emf produces a current, including through the battery. Chemicals in the cell provide an internal resistance r. This causes a p.d. drop inside the battery $\varepsilon = V + V_r = V + Ir$ Where V is the load voltage (across the components in the circuit) and V_r is the voltage drop inside the battery				