

**9702 PHYSICS 2007**

**APPLICATIONS OF PHYSICS**

**SECTION VII: GATHERING AND COMMUNICATING INFORMATION**

**28. Direct Sensing**

Content

**28.1 Sensing devices**

<b>Learning outcomes</b>		<b>Suggested Teaching Activities</b>	<b>Resources</b>
Candidates should be able to:			
28.(a)	Show an understanding that an electronic sensor consists	Demonstration of potential divider circuit containing fixed resistor and	Reference should be made to the list of textbooks printed in the Syllabus document. Note that some of these texts are more suitable as reference texts for the teacher whilst others are more suitable as student texts. Reference should also be made to the Applications Booklet developed for this section of the Specification. Some internet sites are shown within certain topics. The list of sites is by no means comprehensive but provides examples of what is available. Examples of examination questions for this section can be obtained from the OCR A2 series of papers on Health Physics 2825/02 and Telecommunications 2825/05.

28.(b)	<p>of a sensing device and a circuit that provides an output voltage.</p> <p>Show an understanding of the change in resistance with light intensity of a light dependent resistor (LDR)</p>	<p>LDR. Show the p.d. across the resistor and the LDR depends on the value of the fixed resistor and on the light intensity incident on the LDR. Explain how the output voltage depends on the light intensity incident on the LDR</p> <p>Demonstration or class experiment: Measure the resistance of the LDR for different p.d.s across a lamp or for varying distances between the lamp and the LDR</p>	<p>Low voltage power supply, a number of fixed resistors, LDR, voltmeter, ammeter and light bulb with variable power supply Solderless breadboards may be used for these experiment examples.</p>
28.(c)	<p>Sketch the temperature characteristic of a negative temperature coefficient thermistor</p>	<p>Demonstration or class experiment: measure the resistance every 10 to 15°C between 20 and 90°C. Draw a graph to show the temperature characteristic of the thermistor.</p>	<p>Low voltage power supply, LDR, voltmeter, ammeter and light source with variable power supply.</p>
28.(d)	<p>Show an understanding of the action of a piezo-electric transducer and its application in a simple microphone.</p>	<p>Demonstration or class experiment: measure the resistance every 10 to 15°C between 20 and 90°C. Draw a graph to show the temperature characteristic of the thermistor.</p> <p>Explanation of the piezo electric effect and how the application of applying a p.d. across a material causes it to deform and it can then send vibrations through the air.</p>	<p>Thermistor, voltmeter, ammeter supply of hot water or cold water and means of heating the water from 20°C to 90°C. Low voltage power supply. Example Q1 4833 SCIENCES 2000</p>
28.(e)	<p>Describe the structure of a metal wire strain gauge.</p>	<p>Basic description of strain gauge.</p>	<p><a href="http://en.wikipedia.org/wiki/Piezoelectric#Sensors">http://en.wikipedia.org/wiki/Piezoelectric#Sensors</a> <a href="http://www.recipeland.com/encyclopaedia/index.php/Piezoelectricity">http://www.recipeland.com/encyclopaedia/index.php/Piezoelectricity</a></p>

28.(f)		Images and applications available on websites.	<a href="http://www.natmus.dk/cons/tp/strmsr/strainm2.htm">http://www.natmus.dk/cons/tp/strmsr/strainm2.htm</a>
28(g)	<p>Relate extension of a strain gauge to change in resistance of the gauge.</p> <p>Show an understanding that the output from sensing devices can be registered as a voltage.</p>	<p>Demonstrate the change in resistance of a strain gauge theoretical and or practically.</p> <p>Summary of how changes in the property of a sensor changes the output voltage of the device. Potential divider circuits using for example an LDR and a thermistor. Examples and questions</p>	<p>Electronics by Adams and Hutchings page 44 -5</p> <p>Question sheet on calculations of resistance change due to change in length and the output voltage change due to extension or compression of a strain gauge.</p> <p>Prepared worksheet with past questions as examples.</p>

Content

## 28.2 The ideal operational amplifier

### 28.3 Operational amplifier circuits

Learning outcomes		Suggested Teaching Activities	Resources
Candidates should be able to:			
28.(h)	Recall the main properties of the ideal operational amplifier (op-amp).	Discuss the need to amplify the output of a transducer (e.g. microphone) and the basic requirements of an ideal amplifier. Explain the details of an op-amp	Diagram of basic op-amp and graph of transfer characteristics Op-amp, power supply and potential divider, voltmeters.

28.(i)	Deduce, from the properties of an ideal operational amplifier, the use of an operational amplifier as a comparator.	i.e. voltage inputs and output, input and output impedance, transfer characteristics, saturation and gain. Active device needing a power supply.	
28.(j)	Show an understanding of the effects of negative feedback on the gain of an operational amplifier.	Demonstrate the use the op-amp in open-loop mode as a comparator. Discuss applications and explain slew rate. E.g. use with a thermistor to monitor refrigerator temperatures	LDR, resistor, op-amp and its supply voltage, led, protective resistor and protective diode Electronics by Adams and Hutchings page 110
28.(k)	Recall the circuit diagrams for both the inverting and the non-inverting amplifier single signal input.	Demonstrate the output voltage against the input voltage for an inverting and non-inverting amplifier. Discuss saturation and how the gain can be reduced by negative feedback.	Op- amp, potentiometer, dual power supply ( $\pm 15$ V), voltmeters, resistors of typical values 10, 22 33 k $\Omega$ )
28.(l)	Show an understanding of the virtual earth approximation and derive an expression for the gain of inverting amplifiers	Explain the circuit diagrams for the inverting and non-inverting amplifiers and the virtual earth approximation	Use the above apparatus to set up an inverting amplifier
28.(m)	Recall and use the expressions for the voltage gain of inverting and of non-inverting amplifiers.	Derive the gain for an inverting amplifier. Measure the gain for different input voltages	Use the above apparatus to set up a non-inverting amplifier

		<p>Show the derivation of the gain for non-inverting amplifiers. Measure the gain for different input voltages. Question sheet on the analysis of amplifiers.</p>	<p>Questions from past papers and or available text books</p>
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**28.4 Output devices**

<b>Learning outcomes</b>		<b>Suggested Teaching Activities</b>	<b>Resources</b>
Candidates should be able to:			
28.(n)	Show an understanding of the use of relays in electronic circuits.	Discuss examples of output transducers. Demonstrate use of a small current to a relay to switch on or off large currents.	Temperature or light activated input to a logic gate circuit. Output connected to relay and used to operate a lamp or motor.
28.(o)	Show an understanding of the use of light-emitting diodes (LEDs) as devices to indicate the state of the output of electronic circuits.	Discuss the uses of LEDs. Demonstrate the use of an LED and explain the need for a protective resistor. Demonstrate the characteristics of an LED	Similar arrangement to the above but with the addition of a relay in the output. LED, variable low voltage power supply, milliammeter and voltmeter.
28.(p)	Show an understanding of the need for calibration where digital or analogue meters are used as output devices.	Demonstrate the use of a voltmeter to measure temperature using a thermistor as the sensor. Calibration graph to be drawn of the temperature against p.d. across thermistor or against the current measured on the milliammeter.	Thermistor and water bath that can be heated, thermometer low voltage power supply, milliammeter and voltmeter

Content

**29.1 Production and use of X-rays**

	<b>Learning outcomes</b>	<b>Suggested Teaching Activities</b>	<b>Resources</b>
	Candidates should be able to:		
29.(a)	Explain in simple terms the need for remote sensing (non-invasive techniques of diagnosis) in medicine.	Discuss the possible injuries or illnesses that could require a diagnosis without or before the need for surgery.	<a href="http://www.nibib.nih.gov/eAdvances/071305.htm">http://www.nibib.nih.gov/eAdvances/071305.htm</a> Notes on possible internal injuries to bones or organs in the body where x-rays are useful and not applicable. Set of images using various techniques e.g. radiology, ultrasound, MRI nuclear medicine and thermography.
29.(b)	Explain the principles of the production of X-rays by electron bombardment of a metal target.	Describe the electromagnetic spectrum or question and answer session with students in order to obtain the wavelength / frequency / energy range of X-rays. Questions on the energy gained by an electron when accelerated through a p.d. Energy available when an electron is decelerated from various speeds. Energy levels of the electrons in metal atoms. Build up the possible X-ray spectra to show the range of frequencies / wavelengths /energies available from electrons with a given energy/speed.	<a href="http://www.plus2physics.com">http://www.plus2physics.com</a> <a href="http://www.med.harvard.edu/JPNM/physics/refs/refs.html">www.med.harvard.edu/JPNM/physics/refs/refs.html</a> <a href="http://www.colorado.edu/physics/2000/xray/">www.colorado.edu/physics/2000/xray/</a> <a href="http://dutch.phys.strath.ac.uk/CommPhys2004Exam/Shellay_Waugh/physics-xray.htm">http://dutch.phys.strath.ac.uk/CommPhys2004Exam/Shellay_Waugh/physics-xray.htm</a> Diagram of the electromagnetic spectrum. Question sheet using $E = hf$ , $c=f\lambda$ for various parts of the electromagnetic spectrum. Questions using $E = Ve$ and $E = \frac{1}{2} mv^2$ . Energy values needed for the excitation of electrons in a tungsten atom. Graph of X-ray spectra produced with different accelerating voltages for electrons when colliding with a tungsten target.

29.(c)	Describe the main features of a modern X-ray tube, including control of the intensity and hardness of the X-ray beam.	Use of a diagram of an X-ray tube to describe its main features. Describe or get the students to explain the production of the electrons, varying the number of electrons, accelerating the electrons, range of p.d.s used, production of the X-rays and cooling the target. Hence the how the intensity and hardness are controlled.	Image of an X-ray tube. Show the changes that occur to the graph of X-ray spectra to explain the effects of increasing the X-ray tube voltage and current. Also the use of filters to affect the hardness of the X-rays.
29.(d)	Show an understanding of the use of X-rays in imaging internal body structures, including a simple analysis of the causes of sharpness and contrast in X-ray imaging.	Discuss the images of a number of X-rays as examples that show images of various parts of the body. Explain the meaning of the terms contrast and sharpness. Explain how for X-rays the contrast and sharpness can be altered.	X-ray images required of various parts of the body e.g. teeth, bones and organs. Demonstration of sharpness using light bulb, slits, objects such as a hand or book, a white screen and a tank of water. Show the shadows produced with a different bulb to object and object to screen distances. Also with the object in the tank of water. X-rays of soft tissue or internal organs where contrast media are used.
29.(e)	Recall and solve problems by using the equation $I = I_0 e^{-\mu x}$ for the attenuation of X-rays in matter.	Explain the term attenuation and how X-rays are attenuated in matter. Using values for $\mu$ (of bone, flesh, organs) and $I_0$ get the	Worked examples and question sheet on the attenuation of X-rays using the equation $I = I_0 e^{-\mu x}$ .

29.(f)	Show an understanding of the purpose of computed tomography or CT scanning.	students to calculate I for various values of x. Plot graphs to show how the intensity varies with x. Discuss the application of the equation $I = I_0 e^{-\mu x}$ . Question sheet using the equation relating I and x.	
29.(g)	Show an understanding of the principles of CT scanning.	Review the production of X-rays by asking the students to prepare a document that discusses their need, the problems involved and the methods adopted to obtain X-rays.	<a href="http://www.compadre.org/informal/items/detail.cfm?ID=547">http://www.compadre.org/informal/items/detail.cfm?ID=547</a> Diagrams of CT scanners showing their operation. <a href="http://www.physicscentral.com/action/action-02-3.html">http://www.physicscentral.com/action/action-02-3.html</a> <a href="http://www.colorado.edu/physics/2000/tomography/">http://www.colorado.edu/physics/2000/tomography/</a>
29.(h)	Show an understanding of how the image of an 8-voxel cube can be developed using CT scanning.	Explain the reason for using CT scanning.  Use CT scans to explain the basic principles of a CT scan. Discuss or set questions on the advantages of CT scans compared to ordinary X-rays. Use examples of an 8-voxel cube to explain how it is developed using CT scanning. Question sheet for students to develop other examples.	CT scans to show the 3D effect produced.  Use the examples given in the recommended textbooks and the Applications Booklet available for this section.

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## 29.2 Production and use of ultrasound

Learning outcomes		Suggested Teaching Activities	Resources
Candidates should be able to:			
29.(i)	Explain the principles of the generation and detection of ultrasound waves using piezoelectric transducers.	Demonstration of the generation and detection of ultrasound. Explanation of piezoelectric transducers and their use in the production of ultrasound.	<a href="http://www.moh.gov.ae/moh_site/x_ray/">www.moh.gov.ae/moh_site/x_ray/</a> <a href="http://www.sheffcol.ac.uk/links/Science/Physics/Medical/Ultrasound/">http://www.sheffcol.ac.uk/links/Science/Physics/Medical/Ultrasound/</a> Diagrams showing the piezoelectric effect in crystals and a piezoelectric probe to demonstrate the resonance affect in the production of the required ultrasound frequencies. <a href="http://www.ob-ultrasound.net/">www.ob-ultrasound.net/</a>
29.(j)	Explain the main principles behind the use of ultrasound to obtain diagnostic information about internal structures.	Discuss the use of ultrasound to produce information about internal structures. Explain how various ultrasound scans are produced. Discuss the issues of X-rays or ultrasound for diagnosis. Question sheet on the use of $c=f\lambda$ and echoes applied to ultrasound.	Ultrasound scans. Question sheet on ultrasound, echoes and basic A scans.  Table of ultrasound properties from Medical Physics by M Hollins.
29.(k)	Show an understanding of the meaning of acoustic impedance and its importance to the intensity reflection coefficient at a boundary.	Explain acoustic impedance. Discuss how an ultrasound scan is produced by reflection at a boundary. Explain the term intensity reflection coefficient and the problems caused and how they	Examples and questions on impedance and reflection coefficient.

		are overcome. Use of the expression for acoustic impedance and reflection coefficient in examples	
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**29.3 Use of magnetic resonance as an imaging technique**

Learning outcomes		Suggested Teaching Activities	Resources
Candidates should be able to:			
29.(l)	Explain the main principles behind the use of magnetic resonance to obtain diagnostic information about internal structures.	Discuss magnetic resonance. Describe how magnetic resonance is produced. Explain how the MRI scan is produced with reference to 29. (m). Refer to MRI scans and indicate the information it gives about internal structures of in particular soft tissue.	<a href="http://www.physics.union.edu/newman/2000/mri.htm">www.physics.union.edu/newman/2000/mri.htm</a> <a href="http://dutch.phys.strath.ac.uk/.../MRI.htm">dutch.phys.strath.ac.uk/.../MRI.htm</a> <a href="http://science.uniserve.edu.au/school/curric/stage6/phys/medphys.html">http://science.uniserve.edu.au/school/curric/stage6/phys/medphys.html</a> Diagrams of an MRI scanner, basic apparatus required for an MRI, the effects of magnetic fields on nuclei. MRI ultrasound and X-ray scans.
29.(m)	Show an understanding of the function of the non-uniform field, superimposed on the large constant magnetic field, in the diagnosis using magnetic resonance.	Describe the function of each of the magnetic fields in the production of magnetic resonance and hence of MRI scans. Students should make a presentation or write a paper that discusses the production of MRI scans and their advantages and disadvantages over X-rays and ultrasound scans.	Diagrams of the magnetic fields and the effect produced on the nuclei.  <a href="http://hsc.csu.edu.au/physics/options/medical/3019/PHY964netdraft.html">http://hsc.csu.edu.au/physics/options/medical/3019/PHY964netdraft.html</a> <a href="http://faculty.washington.edu/chudler/nobel03.html">http://faculty.washington.edu/chudler/nobel03.html</a> <a href="http://physics.about.com/od/imaging/">http://physics.about.com/od/imaging/</a>

### 30. Communicating Information

Content

#### 30.1 Principles of modulation

#### 30.2 Sidebands and bandwidth

Learning outcomes		Suggested Teaching Activities	Resources
Candidates should be able to:			
30.(a)	Understand the term modulation and be able to distinguish between amplitude modulation (AM) and frequency modulation (FM).	<p>Revise the characteristics of waveforms, amplitude, frequency, wavelength, time period, wave speed.</p> <p>Graph work adding of waves with the same frequencies and very different frequencies.</p> <p>Demonstration of the production of an AM wave.</p> <p>Demonstration of the production of a FM wave.</p>	<p>Prepared work sheet involving graphs of different frequencies, amplitudes, wavelengths and calculations using <math>f = 1/T</math> and <math>v = f\lambda</math>.</p> <p>Prepared diagrams of the information signal, the carrier wave and the resulting modulated carrier wave (AM) or use of two signal generators (one with AM/FM facilities and an oscilloscope or reproduced diagrams from textbook (Telecommunications – OCR).</p> <p><a href="http://www.gcse.com/waves/radio.htm">www.gcse.com/waves/radio.htm</a></p> <p>Reference Telecommunications – OCR</p> <p><a href="http://scienceworld.wolfram.com/physics/RadioWave.html">http://scienceworld.wolfram.com/physics/RadioWave.html</a></p> <p><a href="http://hyperphysics.phy-astr.gsu.edu/hbase/class/p22129.html">http://hyperphysics.phy-astr.gsu.edu/hbase/class/p22129.html</a></p> <p>Q1 AND 3 SCIENCES 2000 4838 OCR</p>
30.(b)	Recall that a carrier wave, amplitude modulated by a single audio frequency, is equivalent to the carrier wave frequency together with two sideband frequencies.	<p>Discussion of the properties of an AM carrier wave including the graph of the amplitude of each frequency component.</p>	

30.(c)	Understand the term bandwidth.	Define the term bandwidth and give examples for speech, music, AM and FM etc.	Prepared question sheet on examples of bandwidth.
30.(d)	Demonstrate an awareness of the relative advantages of AM and FM transmissions.	Students prepare a presentation on a comparison between AM and FM and the relative advantages of each.	Prepared checklist to ensure all major points are covered by the students work.

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### 30.3 Transmission of information by digital means

Learning outcomes		Suggested Teaching Activities	Resources
Candidates should be able to:			
30.(e)	Recall the advantages of the transmission of data in digital form.	Students prepare a presentation on the advantages of the transmission of data in digital form. Or discussion lesson on the advantages of the transmission of data in digital form.	Prepared checklist to ensure all major points are covered by the students work.
30.(f)	Understand that the digital transmission of speech or music involves analogue-to-digital-conversion (ACD) on transmission and digital-to-analogue conversion (DAC) on reception.	Develop the processes involved with the transmission of analogue signals in digital form.	Block diagram to show the conversion necessary for the transmission of an analogue signal in digital form. Graphs to show the information in analogue form, the sampled signal at different time intervals and the reconstituted output.

30.(g)	Show an understanding of the effect of the sampling rate and the number of bits in each sample on the reproduction of an input signal.	Examples given of the effect of sampling rate on the output signal.	Prepared question sheet showing the effect of varying the information signal, the sampling rate and the reconstituted signal. Q4 SCIENCES 2000 4838 OCR
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### 30.4 Different channels of communication

Learning outcomes		Suggested Teaching Activities	Resources
Candidates should be able to:			
30.(h)	Appreciate that information may be carried by a number of different channels, including wire-pairs, coaxial cables, radio and microwave links and optical fibres.	Students prepare a discussion paper/presentation on telecommunication using wire-pairs, coaxial cables, radio and microwave links and optical fibres.	Checklist required ensuring the students cover all relevant points.
30.(i)	Discuss the relative advantages and disadvantages of channels of communication in terms of available bandwidth, noise cross-linking, security, signal attenuation, repeaters and regeneration, cost and	Students prepare a discussion paper/presentation. One set of students could prepare 30.(h) and another 30.(i).	Checklist of advantages and disadvantages of the various channels of communication. Q7 SCIENCES 2000 4838 OCR

30.(j)	<p>convenience.</p> <p>Describe the use of satellites in communication.</p>	<p>Brief description of the limits of world-wide communication by radio wave transmission. (Surface, sky and space waves)</p>	<p>Chapter 7 Telecommunications (OCR)  <a href="http://collections.ic.gc.ca/satellites/english/index.html">http://collections.ic.gc.ca/satellites/english/index.html</a></p>
30.(k)	<p>Recall the relative merits of both geostationary and polar orbiting satellites for communicating information.</p>	<p>Revisit section 8 (Gravitational Field) (i) and (j).</p> <p>Develop the expression for the time period of a satellite.          Explain the differences between low orbiting and geostationary satellites.          Discuss the use of orbiting satellites.          Conditions for a satellite to be geostationary.          Uses of geostationary satellites.          Polar orbiting satellites and their uses.          GPS and their uses.          Students produce discussion paper on the relative merits of satellite communications compared to other methods</p>	<p>Prepared question sheet on satellite orbits periods, speeds etc.          Examples of satellite pictures          Prepared diagrams of the Earth and possible satellite orbits and telecommunication coverage          Chapter 8 Telecommunications (OCR)          Telecommunications by J Allen Ch 5.  <a href="http://physics.uwstout.edu/wx/wxsat/types.htm">http://physics.uwstout.edu/wx/wxsat/types.htm</a>  <a href="http://www.smgaels.org/physics/97/MGRAHLFS.HTM">http://www.smgaels.org/physics/97/MGRAHLFS.HTM</a>          Check list on the merits on satellite communications.          Example Q5 4833 SCIENCES 2000 OCR          Q6 AND Q8 SCIENCES 4838 OCR</p>
30.(l)	<p>Recall the frequencies and wavelengths used in different channels of communication.</p>	<p>Examples on frequency and corresponding wavelengths for varying channels of</p>	<p>Prepared table of the frequencies and wavelengths used in communications.          Chapter 4 Telecommunications J Allen</p>
30.(m)	<p>Understand and use signal</p>	<p>Examples on frequency and corresponding wavelengths for varying channels of</p>	<p>Chapter 5 Telecommunications (OCR)</p>

30.(n)	attenuation expressed in dB and dB per unit length.  Recall and use the expression <i>number of dB = 10 lg(P<sub>1</sub>/P<sub>2</sub>)</i> for the ratio of two powers.	communication.  Worked examples on attenuation of signals.	Prepared question sheet on signal attenuation Q5 SCIENCES 2000 4838 OCR
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### 30.5 The mobile-phone network

Learning outcomes	Suggested Teaching Activities	Resources
Candidates should be able to:		
30.(o)	Understand that in a mobile-phone system, the public switched telephone network (PSTN) is linked to base stations via a cellular exchange.	Develop a PSTN network
30.(p)	Understand the need for an area to be divided into a number of cells, each cell served by a base station.	Develop the principles of a cellular mobile phone network
30.(q)	Understand the role of	Chapter 9 Telecommunications (OCR) <a href="http://science.uniserve.edu.au/school/curric/stage6/phys/world.html">http://science.uniserve.edu.au/school/curric/stage6/phys/world.html</a>  Prepared question sheet on the mobile phone system  Review the methods available for transporting telephone signals (30. (h))

30.(r)	the base station and the cellular exchange during the making of a call from a mobile phone handset. Recall a simplified block diagram of a mobile phone handset and understand the function of each block.	Develop a block diagram of a mobile phone handset	Diagram on page 21 Applications booklet
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