

Engineering

OCR Level 3 Principal Learning in Engineering **F559**

Unit **F559**: Instrumentation and Control Engineering

Mark Scheme for January 2011

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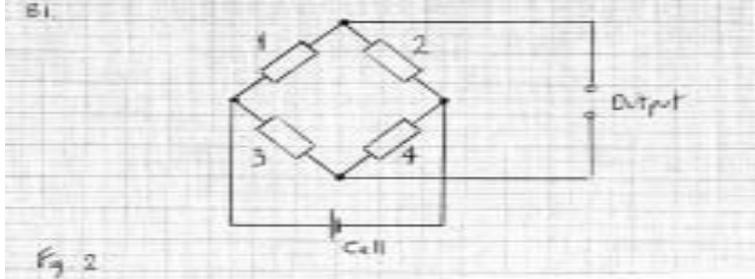
Question	Expected Answer	Mark	Rationale/Additional Guidance
1	<p>The block diagram in Fig. 1 shows the layout of a central heating system.</p> <p>Temp. sensor → Control unit → Boiler switch → Boiler and radiator pump</p> <p style="margin-left: 40px;">↑</p> <p style="margin-left: 100px;">Feedback</p>	[5]	Award one mark for each correctly labelled block.
2	<p>Name two types of system that use feedback control other than a central heating system.</p> <p>Temperature control Positional control Servo control Other suitable devices.</p>	[2]	Award one mark for each correct response.
3	<p>State which two of the following are passive transducers:</p> <p>Thermistor Strain gauge.</p>	[2]	Award one mark for each correct response.
4	<p>Name one input device and one output device used in a control system.</p> <p>Input devices: Potentiometer, thermistor or light dependent resistor, thermocouple Other suitable devices.</p> <p>Output devices: Bell, buzzer, signal lamp, light emitting diode or 7 segment display Other suitable devices.</p>	[2]	Award one mark for a correct input device and one mark for a correct output device.
5	<p>Explain what is meant by the term 'instrument display'.</p> <p>An instrument display is a device or an output unit that gives a visual representation of data</p>	[1] [1]	

Question	Expected Answer	Mark	Rationale/Additional Guidance
6	<p>State two difficulties encountered when transmitting signals using wires when the frequency of the system increases above 2500 MHz.</p> <p>The fields spread out around the wires ie are not concentrated Signal power may be reduced or lost Wires will tend to act like an aerial and therefore radiate some of the power involved Resistance of wire increases which causes signal weakening</p>	[2]	Accept any two correct difficulties stated.
7	<p>Explain what is meant by the term 'virtual test equipment'.</p> <p>Virtual test equipment is a piece of equipment which does not physically exist. Virtual Instrumentation adds the capability of simulating laboratory tests and measurements thanks to an accurate modelling of the instruments used for testing. Sequencing of instruments generates the sources and samples results with the probes.</p>	[1] [1]	

Question	Expected Answer	Mark	Rationale/Additional Guidance
8	<p>State the formula for overall gain in a system using positive feedback.</p> <p>Overall gain $G = A/(1 - \beta A)$.</p>	[1]	
9	<p>Explain why it is beneficial to have a video camera in a system capable of monitoring illegal activity.</p> <p>Insufficient police available to monitor all systems. Can be used for 24 hours per day etc. Camera has zoom, panning and angling facilities for close up observation. Evidence is available that suggests a properly installed and managed security camera system can dramatically reduce crime levels. Drops as high as 90% have been recorded. From the camera a record of the time of an illegal activity can be found and faces are often seen which can lead to the arrest of a person and a subsequent court case.</p>	[2]	Accept any correct explanation.
	Section Total	[20]	

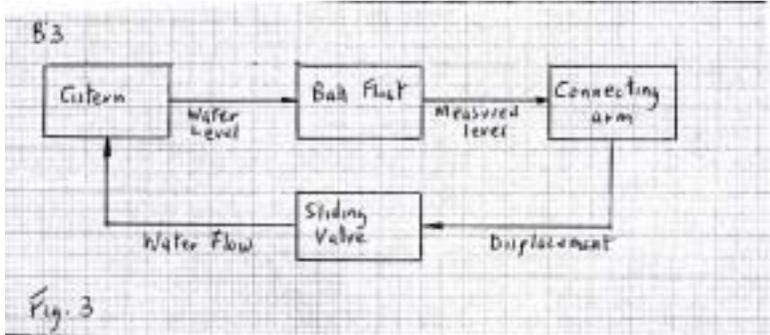
Section B

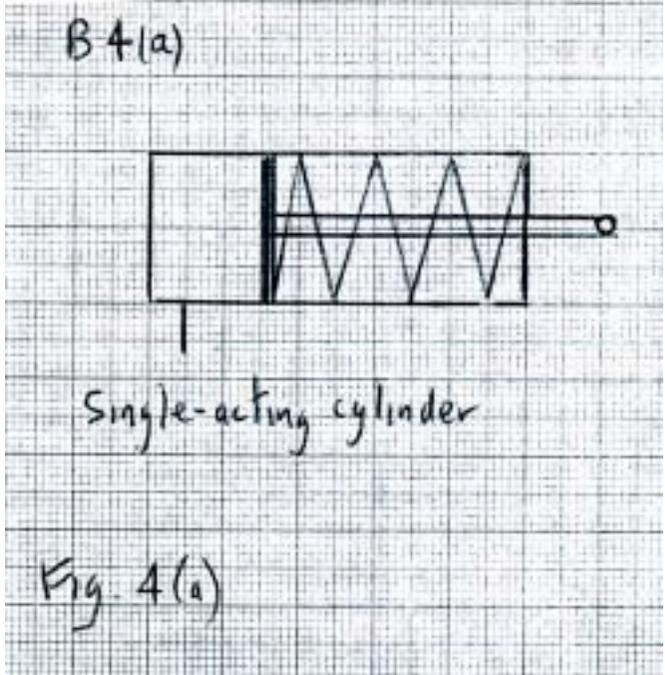
Question		Expected Answer	Mark	Rationale/Additional Guidance
1	(a)	<p>State the function of a strain gauge and give one reasons for measuring strain.</p> <p>The function of a strain gauge is to record accurately what is taking place when a structure is loaded. Strain is measured to check that a system is not being overworked.</p>	<p>[1]</p> <p>[1]</p>	
	(b)	<p>State three practical applications where a strain gauge is used.</p> <p>Packaging – process control/strain gauging of components/general weighing/repair and calibration.</p> <p>Engineering – test rig force monitoring/robotic/weighing of components/specialised load cells/machine control.</p> <p>Chemical – press force monitoring/silo weighing/load cells. Automotive – component test rigs/crash tests/production quality processes/special sensors.</p> <p>Measurement of movement in all types of structures.</p>	[3]	Accept any three correct applications.

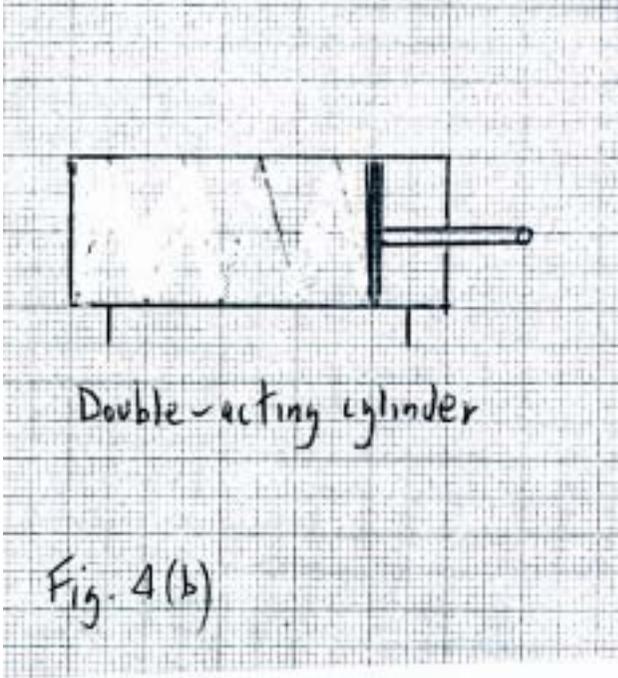
Question	Expected Answer	Mark	Rationale/Additional Guidance
1 (c)	<p>Describe, in detail, with the aid of a labelled diagram, how a strain gauge circuit is used in a control system of your choice.</p> <p>A number of control systems use strain gauges. A typical application is given with strain gauges being used for temperature compensation,</p>  <p>Correct diagram Correct labels Temperature compensation Strain gauges are used with other sensors such as diaphragm pressure gauges or load cells but temperature compensation is required. Four strain gauges are used connected in the form of a Wheatstone bridge. Gauges 1 and 2 are attached so that the applied force is in tension. Gauges 3 and 4 are in compression. Gauges 1 and 2 will increase in resistance and Gauges 3 and 4 will decrease in resistance. As all the gauges and so all arms of the bridge will be equally affected by any temperature change the arrangement is temperature compensated.</p>	<p>[1] [1] [1] [1] [1]</p>	<p>Any control system that is using this method will not be affected by temperature change within that system</p>
	Total	[10]	

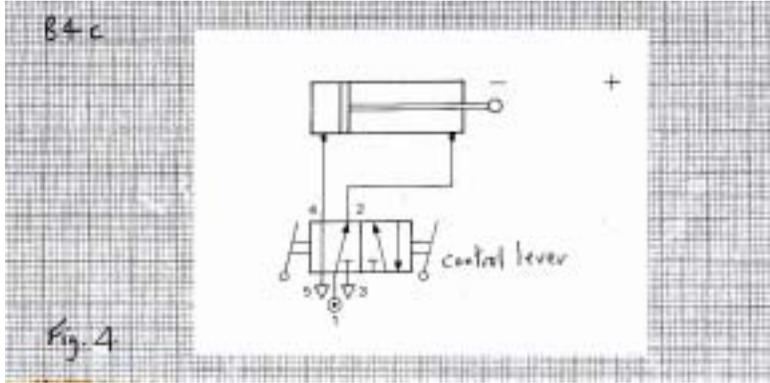
Question			Expected Answer	Mark	Rationale/Additional Guidance
2	(a)	(i)	<p>State which type of control system is required to maintain a room at a constant temperature.</p> <p>Closed loop control</p>	[1]	
		(ii)	<p>Name an input device used to sense temperature in a control system.</p> <p>Thermistor</p>	[1]	
	(b)		<p>Explain why it is important to monitor and control the temperature of a room.</p> <p>Depending on what the room is being used for, the temperature needed is controlled by using a thermostat set to a prescribed value. If the temperature is too high then goods could be damaged or people in the room would be uncomfortable. In some circumstances the heating system is switched of at intervals to conserve energy and reduce costs.</p>	[3]	
	(c)		<p>Describe, in detail, how the system in Fig. 2 can be used to control the temperature of a room.</p> <p>Closed loop with an on-off output from the controller The on-off device is essentially a switch which is activated by the error signal. This controller is a relay. The output signal from the sensor has to be processed in some way to make it suitable for display. This is carried out by the resistance to voltage converter The functional element is the thermistor which is a device that changes its resistance when heated. The differential amplifier amplifies the difference between two input signals. If the temperature of the room changes the differential amplifier will sense this and make adjustments to bring the temperature back to its prescribed value.</p>	[1] [1] [1] [1] [1]	
			Total	[10]	

Question		Expected Answer	Mark	Rationale/Additional Guidance
3	(a)	<p>Give the meaning of the term closed loop control.</p> <p>Closed loop control is a non-linear system which has feedback</p>	<p>[1] [1]</p>	
	(b)	<p>Explain, using an example, the advantages of a closed loop control system over an open loop control system.</p> <p>With closed loop control: an operator does not have to intervene in the process once the system has been set up in a negative feedback system the control action is always in the direction to return the system to its desired states available any undesirable changes in the output are automatically dealt with positive feedback is sometimes used to improve performance the control action is designed to act against a deviation from the desired value care must be taken that over compensation does not take place because this could lead to instability within the system</p>	<p>[3]</p>	Accept any three correct responses

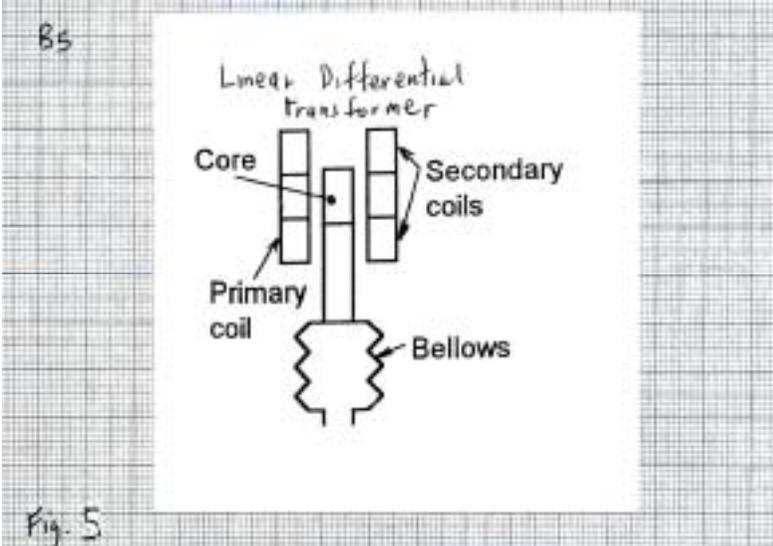
Question	Expected Answer	Mark	Rationale/Additional Guidance
<p>3 (c)</p>	<p>Describe in detail, with the aid of a labelled block diagram, how a mechanical closed loop system can be used to maintain the level of water in a storage tank.</p>  <p>Fig. 3</p> <p>Labelled block diagram</p> <p>There are four basic blocks. With the cistern empty the water level is low. The ball float is low. Water can then enter the cistern. The ball floats up raising the connecting arm. The sliding valve when fully in position blocks off the water. The cistern is now full with water at its prescribed level.</p>	<p>[2]</p> <p>[1]</p> <p>[1]</p> <p>[1]</p>	
	<p>Total</p>	<p>[10]</p>	

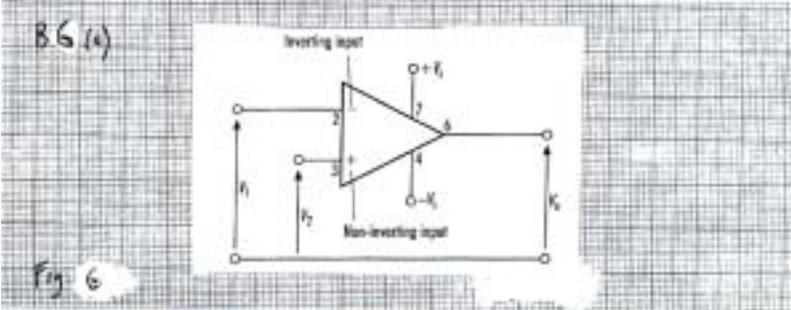
Question	Expected Answer	Mark	Rationale/Additional Guidance
4 (a)	<p data-bbox="367 209 1032 272">Draw, in the space provided, the symbol for the following pneumatic components:</p> <p data-bbox="297 309 898 341">(i) a single acting spring return cylinder.</p>  <p data-bbox="427 395 555 448">B 4(a)</p> <p data-bbox="443 762 846 831">Single-acting cylinder</p> <p data-bbox="405 932 591 1007">Fig. 4(a)</p>	[1]	

Question	Expected Answer	Mark	Rationale/Additional Guidance
(ii)	<p>a double acting cylinder.</p> 	[1]	
(b)	<p>Explain how a single acting cylinder is used in a pneumatic control system.</p> <p>A single acting cylinder has a port at one end only. When compressed air enters the port, the piston rod is pushed out, it goes positive. When the air is allowed to escape, the piston rod goes back, it goes negative.</p>	<p>[1] [1] [1]</p>	

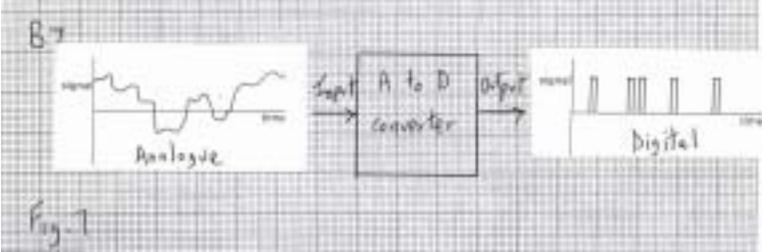
Question	Expected Answer	Mark	Rationale/Additional Guidance
(c)	<p data-bbox="367 209 1167 304">Describe, in detail, with the aid of a labelled diagram, how a double-acting cylinder can be used with a five-port valve.</p>  <p data-bbox="367 759 696 791">Correct labelled diagram</p> <p data-bbox="367 826 1122 890">The movement of the piston is powered in both directions, the air being directed by the use of the control lever.</p> <p data-bbox="367 895 869 927">The valve is supplied with air to port 1.</p> <p data-bbox="367 932 1106 995">It can now be switched to either port 2 to send the piston negative or to port 4 to send the piston positive.</p> <p data-bbox="367 1000 1144 1064">The diagram shows air going from port 1 to port 2 and on to the cylinder, so holding the piston negative.</p> <p data-bbox="367 1069 1137 1165">Port 5 is the exhaust port. When the air goes from port 1 to port 4 and on to the cylinder, the cylinder is held positive with the exhaust being port 3.</p>	<p data-bbox="1196 759 1256 791">[1]</p> <p data-bbox="1196 858 1256 890">[1]</p> <p data-bbox="1196 959 1256 991">[1]</p> <p data-bbox="1196 1031 1256 1062">[1]</p> <p data-bbox="1196 1131 1256 1163">[1]</p>	
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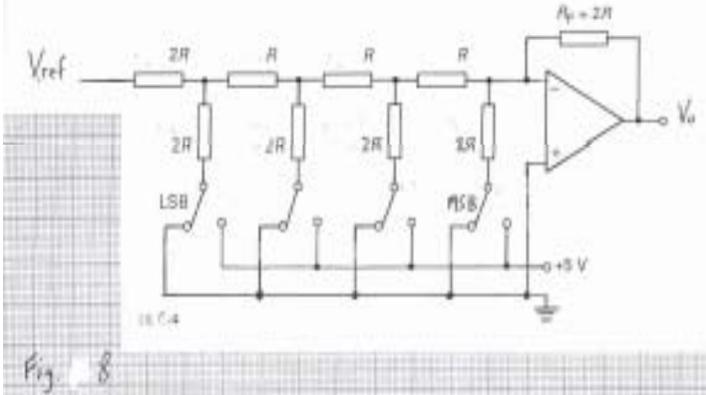
Question		Expected Answer	Mark	Rationale/Additional Guidance
5	(a)	<p>Give two practical applications where a pressure gauge is used.</p> <p>Boiler house system Monitoring the elastic deformation of diaphragms, bellows and tubes Moving the slider of a potentiometer Placed in situations that need a robust instrument For Gases and Low-Viscosity Liquids up to 60 C For corrosive process fluids and atmospheres A compressor/air receiver Tyre inflating gauge</p>	[2]	Accept any two correct applications
	(b)	<p>Explain the difference between absolute pressure and gauge pressure.</p> <p>Absolute pressure is the pressure measured with respect to zero pressure. Gauge pressure is the pressure as measured by a gauge. That is, the pressure which is in excess of the pressure of the atmosphere. Absolute pressure = gauge pressure + atmospheric pressure.</p>	[1] [1] [1]	

Question	Expected Answer	Mark	Rationale/Additional Guidance
(c)	<p>Describe, in detail, with the aid of a diagram, the construction and action of a bellows pressure gauge. Show how a change in pressure is converted into an analogue electrical signal.</p>  <p>Correct labelled diagram. Description of construction of a bellows pressure gauge showing mechanical and electrical components. Description of how pressure changes once converted into an electrical signal.</p>	<p>[2] [1] [1] [1]</p>	<p>Award one mark for a basic description and one mark for an expanded description.</p>
	Total	[10]	

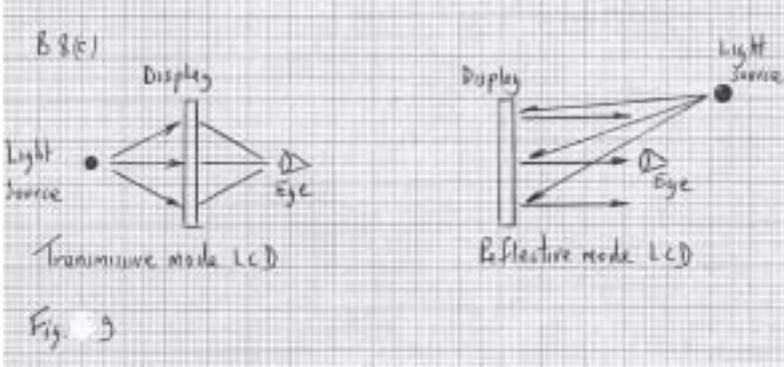
Question	Expected Answer	Mark	Rationale/Additional Guidance
6 (a)	<p>Draw a labelled diagram of an ideal operational amplifier.</p>  <p>Correct diagram Correct labels</p>	<p>[1] [1]</p>	
(b)	<p>Name three characteristics of an ideal operational amplifier.</p> <p>Infinite voltage gain Infinite input impedance Infinite bandwidth Zero output impedance Zero output when the differential inputs are identical</p>	<p>[3]</p>	<p>Accept any three correct responses</p>

Question	Expected Answer	Mark	Rationale/Additional Guidance
(c) (i)	<p>An amplifier with a voltage gain of 20000 is used in a negative feedback circuit with a feedback fraction of 0.02. Calculate, correct to two decimal place, the overall gain.</p> <p>Overall gain when $A = 20000$ Overall gain = $A/(1 + \beta A)$ = $20000/(1 + 0.02 \times 20000)$ = $20000/401$ = 49.88 correct to 2dp</p>	<p>[1]</p> <p>[1]</p>	
(ii)	<p>An amplifier having an open loop gain of 600 has overall negative feedback applied which reduces the overall gain to 100. Calculate the value of the feedback fraction.</p> <p>Overall gain = $A/(1 + \beta A)$ $100 = 600/(1 + 600\beta)$ $(1 + 600\beta) = 600/100$ $(1 + 600\beta) = 6$ $600\beta = 6 - 1$ $600\beta = 5$ $\beta = 5/600$ = 1/120</p>	<p>[1]</p> <p>[1]</p> <p>[1]</p>	
	Total	[10]	

Question	Expected Answer	Mark	Rationale/Additional Guidance
7 (a)	<p>Draw a block diagram, for an analogue-to-digital (A to D) converter. Show on your block diagram a typical input and output signal.</p>  <p>Block diagram Input and output signal</p>	<p>[1] [1]</p>	
(b)	<p>Explain why it is better to use an R-2R ladder DA converter as compared to a binary-weighted DA converter.</p> <p>There are only two resistance values no matter how many bits of resolution. Each resistor can be laser trimmed during manufacture for high accuracy. Current in the resistor is independent of the switch position. All resistor values are closely related so it is easy to integrate this on a monolithic circuit. Capable of high speed although the number of bits is limited for practical reasons to about eight. An input logic high is translated to about 0.9 volts to minimise the required switching voltage. Relative low cost as compared to other DA converters.</p>	<p>[3]</p>	<p>Accept any three correct responses</p>

Question	Expected Answer	Mark	Rationale/Additional Guidance
(c)	<p>Describe, in detail, with the aid of a circuit diagram, the principle of operation of a R-2R ladder DA converter.</p>  <p>Correct circuit diagram</p> <p>The only resistors required have the values R and 2R. The voltage source for the ladder network is a stable reference voltage V_{ref}. The output voltage V_o of the op amp is $V_o = iR_f$ where i = input current from ladder and R_f = feedback resistance. The four bit register holds the data word that is being converted. These logic outputs control electronic switches. The output voltage produced represents the analogue of the most significant bit (MSB) on the binary input.</p>	<p>[1]</p> <p>[1]</p> <p>[1]</p> <p>[1]</p> <p>[1]</p>	
	Total	[10]	

Question		Expected Answer	Mark	Rationale/Additional Guidance
8	(a)	<p>Give two practical applications for a liquid crystal display (LCD).</p> <p>Low current operating systems Expensive 70 inch HD TV Screens Projectors Watches and clocks Calculators Laptop computer Microwave CD Player Use in a pilots visor Car dashboard</p>	[2]	Accept any two correct applications.
	(b)	<p>Explain the advantages of using liquid crystal displays over other types of display.</p> <p>Consider:</p> <p>Lightweight Exceptional image quality Quick start and instant off functions Compact Small High contrast Brightness capability Lower power consumption Very portable Relatively inexpensive</p>	[3]	Accept any explanation that includes at least two correct advantages

Question	Expected Answer	Mark	Rationale/Additional Guidance
(c)	<p>Explain in detail, with the aid of diagrams, the difference between a transmissive mode LCD and a reflective mode LCD</p>  <p>Transmissive mode LCD</p> <p>Reflective mode LCD</p> <p>Fig. 9</p> <p>Transmissive mode diagram Reflective mode diagram Transmissive mode LCD The light source is seen through the crystal. Top and bottom electrodes are transparent with the light source supplied by a filament lamp. The energised section of the display will be visible in contrast to the transparent sections. Reflective mode LCD In this case the bottom electrode is reflecting. The light source now comes from the same side as the observer reflects from the LCD and is seen.</p>	<p>[1] [1] [1] [1] [1]</p>	
	Total	[10]	

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