3220/202

SCOTTISH CERTIFICATE OF EDUCATION 1999

FRIDAY, 14 MAY
1.00 PM – 3.30 PM

PHYSICS
HIGHER GRADE
Paper II

Read carefully

1 All questions should be attempted.

2 Enter the question number clearly in the margin beside each question.

3 Any necessary data will be found in the Data Sheet on page two.

4 Care should be taken not to give an unreasonable number of significant figures in the final answers to calculations.

5 Square-ruled paper (if used) should be placed inside the front cover of the answer book for return to the Scottish Qualifications Authority.

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MCB 3220/202 6/3/3/17120

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}$ m s^{-1}	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Charge on electron	e	$-1{\cdot}60 \times 10^{-19}$ C	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Glycerol	1·47
Crown glass	1·50	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49		

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 } 10 590 }	Infrared
Helium-neon	633	Red

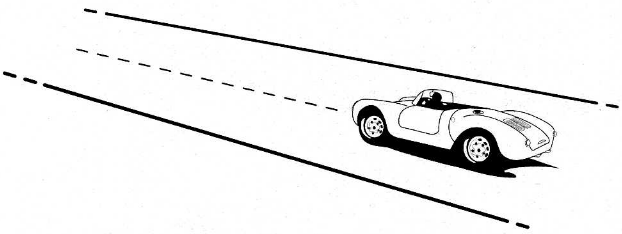
PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/ kg m^{-3}	*Melting Point*/ K	*Boiling Point*/ K	*Specific Heat Capacity*/ J kg^{-1} K^{-1}	*Specific Latent Heat of Fusion*/ J kg^{-1}	*Specific Latent Heat of Vaporisation*/ J kg^{-1}
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623	$9{\cdot}02 \times 10^{2}$	$3{\cdot}95 \times 10^{5}$	....
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853	$3{\cdot}86 \times 10^{2}$	$2{\cdot}05 \times 10^{5}$	....
Glass	$2{\cdot}60 \times 10^{3}$	1400	....	$6{\cdot}70 \times 10^{2}$	....	....
Ice	$9{\cdot}20 \times 10^{2}$	273	....	$2{\cdot}10 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	....
Glycerol	$1{\cdot}26 \times 10^{3}$	291	563	$2{\cdot}43 \times 10^{3}$	$1{\cdot}81 \times 10^{5}$	$8{\cdot}30 \times 10^{5}$
Methanol	$7{\cdot}91 \times 10^{2}$	175	338	$2{\cdot}52 \times 10^{3}$	$9{\cdot}9 \times 10^{4}$	$1{\cdot}12 \times 10^{6}$
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377	$3{\cdot}93 \times 10^{3}$	....	....
Water	$1{\cdot}00 \times 10^{3}$	273	373	$4{\cdot}19 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	$2{\cdot}26 \times 10^{6}$
Air	1·29	....	....	....	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^{4}$	....	$4{\cdot}50 \times 10^{5}$
Nitrogen	1·25	63	77	$1{\cdot}04 \times 10^{3}$	....	$2{\cdot}00 \times 10^{5}$
Oxygen	1·43	55	90	$9{\cdot}18 \times 10^{2}$	....	$2{\cdot}40 \times 10^{5}$

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

Marks

1. (*a*) A sports car is being tested along a straight track.



(i) In the first test, the car starts from rest and has a constant acceleration of $4{\cdot}0\ \mathrm{m\,s^{-2}}$ in a straight line for $7{\cdot}0$ seconds.

Calculate the distance the car travels in the $7{\cdot}0$ seconds.

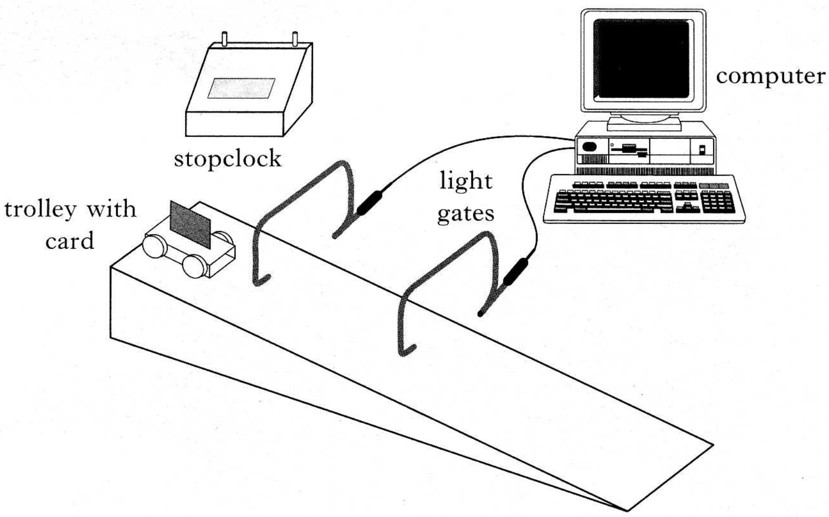
(ii) In a second test, the car again starts from rest and accelerates at $4{\cdot}0\ \mathrm{m\,s^{-2}}$ over twice the distance covered in the first test.

What is the **increase** in the final speed of the car at the end of the second test compared with the final speed at the end of the first test?

(iii) In a third test, the car reaches a speed of $40\ \mathrm{m\,s^{-1}}$. It then decelerates at $2{\cdot}5\ \mathrm{m\,s^{-2}}$ until it comes to rest.

Calculate the distance travelled by the car while it decelerates to rest. **7**

(*b*) A student measures the acceleration of a trolley as it moves freely down a sloping track.



The trolley has a card mounted on it. As it moves down the track the card cuts off the light at each of the light gates in turn. Both the light gates are connected to the computer which is used for timing.

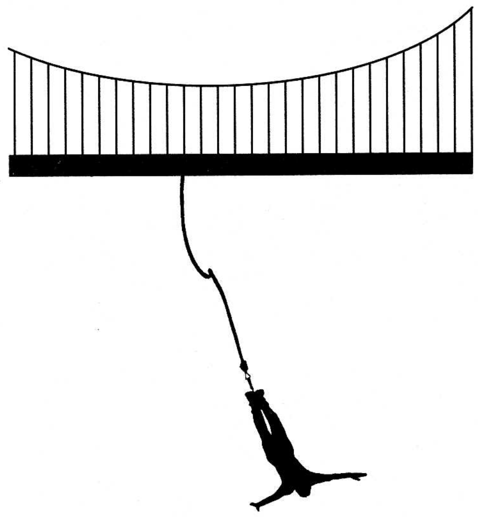
The student uses a stopclock to measure the time it takes the trolley to move from the first light gate to the second light gate.

(i) List all the **measurements** that have to be made by the student and the computer to allow the acceleration of the trolley to be calculated.

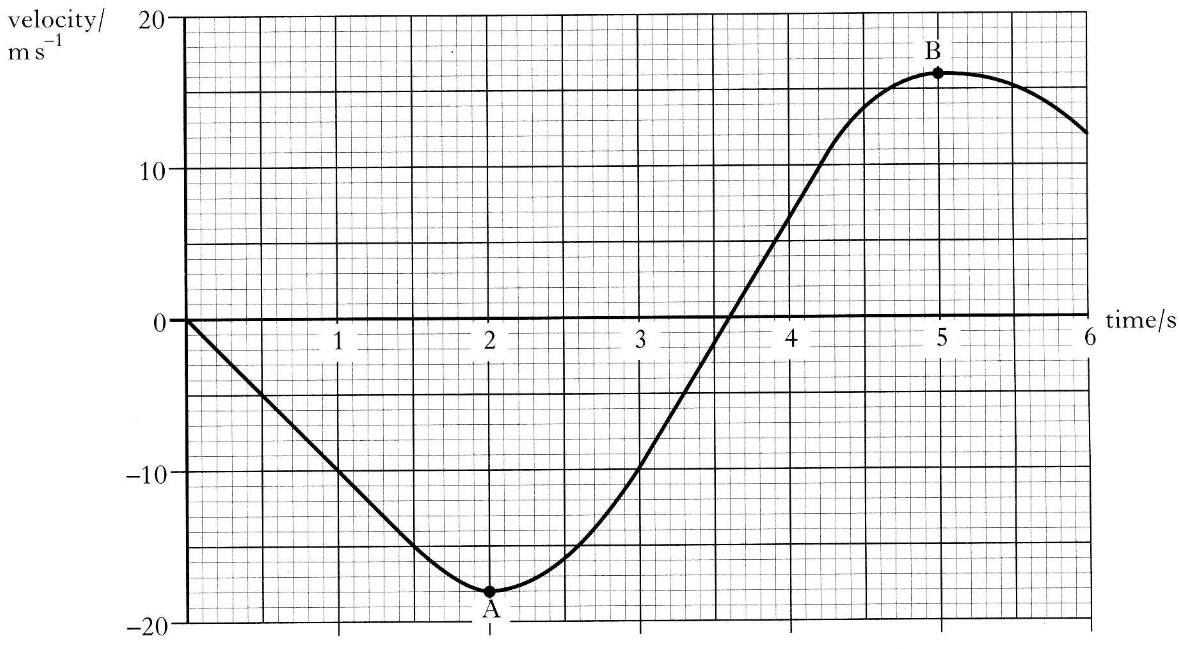
(ii) Explain fully how each of these measurements is used in calculating the acceleration of the trolley as it moves down the slope. **3**

(10)

2. A bungee jumper is attached to a high bridge by a thick elastic rope as shown.



The graph shows how the velocity of the bungee jumper varies with time during the first 6 seconds of a jump.



The mass of the bungee jumper is 55 kg.

(*a*) Using the information on the graph, state the time at which the bungee rope is at its maximum length. Justify your answer. **2**

(*b*) Calculate the average unbalanced force, in newtons, acting on the bungee jumper between the points A and B on the graph. **2**

(*c*) Explain, in terms of the force of the rope on the bungee jumper, why an elastic rope is used rather than a rope that cannot stretch very much. **2**

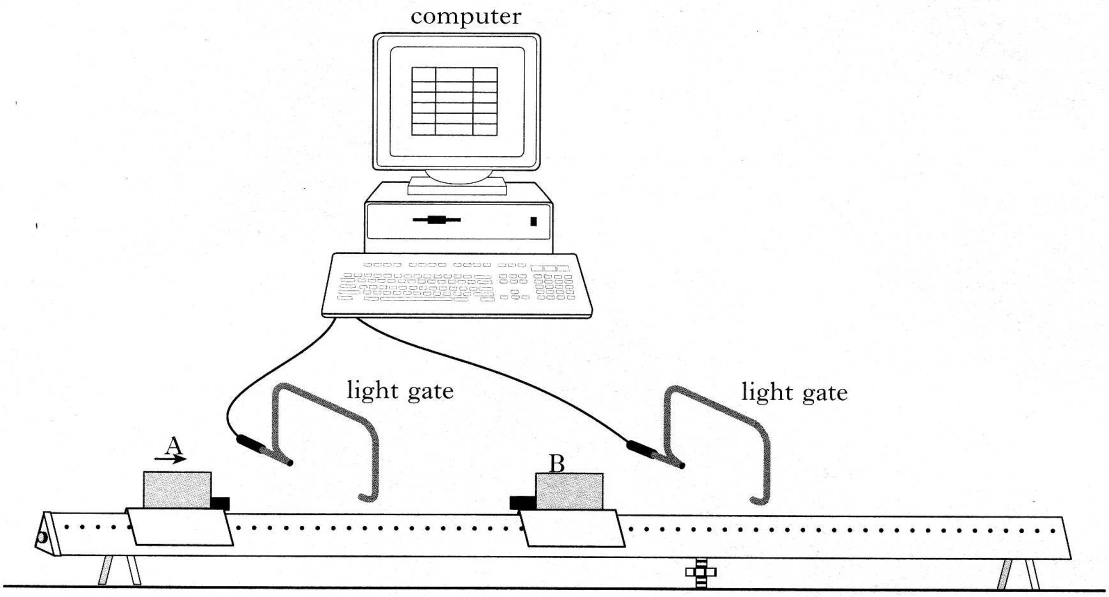
(6)

Marks

3. (*a*) State the law of conservation of linear momentum. **1**

(*b*) The diagram shows a linear air track on which two vehicles are free to move. Vehicle A moves towards vehicle B which is initially at rest.

A computer displays the speeds of the two vehicles before and after the collision.



The table of results below shows the mass and velocity of each vehicle before and after the collision.

Vehicle	*Mass*	*Velocity before collision*	*Velocity after collision*
A	0·75 kg	0·82 m s^{-1} to the right	0·40 m s^{-1} to the right
B	0·50 kg	0·00 m s^{-1}	0·63 m s^{-1} to the right

(i) Use these results to show that the change in momentum of vehicle A is equal in size but opposite in direction to the change in momentum of vehicle B.

(ii) Use the data in the table to show whether the collision is elastic or inelastic. **5**

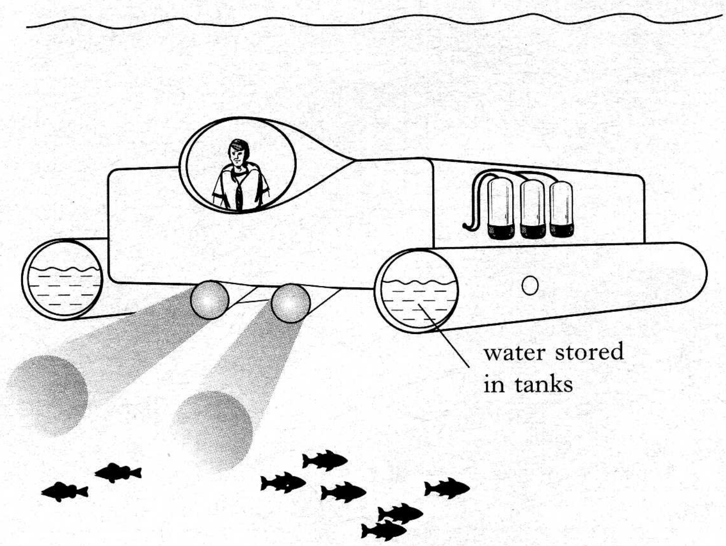
(6)

[Turn over

Marks

4. (a) Sketch a graph which shows how the pressure caused by a liquid depends on the depth below the surface of the liquid. Numerical values are not required but the axes should be clearly labelled. 1

(b) There is a buoyancy (upthrust) force on a submarine when it is submerged in sea water.



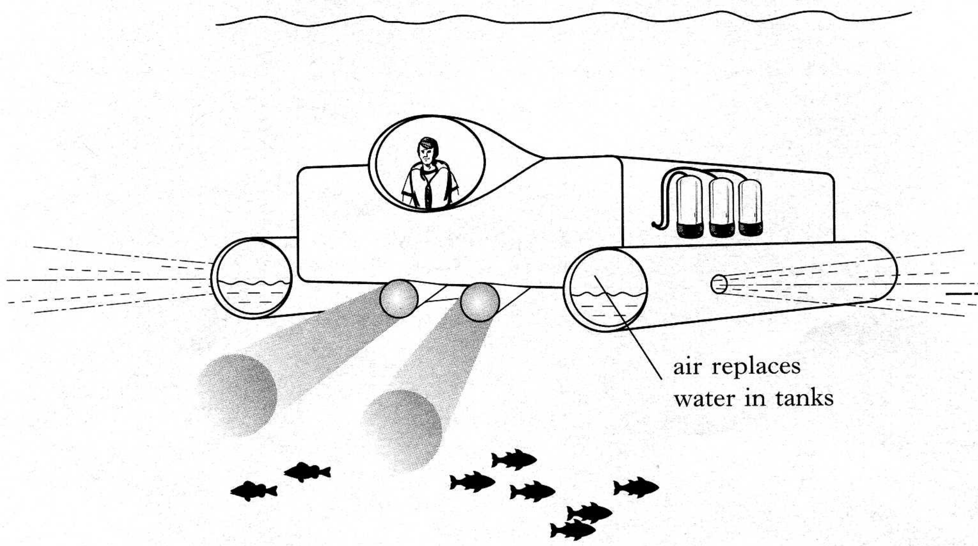
(i) Explain fully how the buoyancy force is produced on the submarine. You may make reference to your graph from (a).

(ii) The total volume of sea water displaced by the submarine is $14{\cdot}5\ m^3$.

Calculate the mass of sea water displaced by the submarine.

(iii) The submarine changes depth by altering the mass of water stored in tanks in the submarine.

Compressed air replaces some water in the tanks.

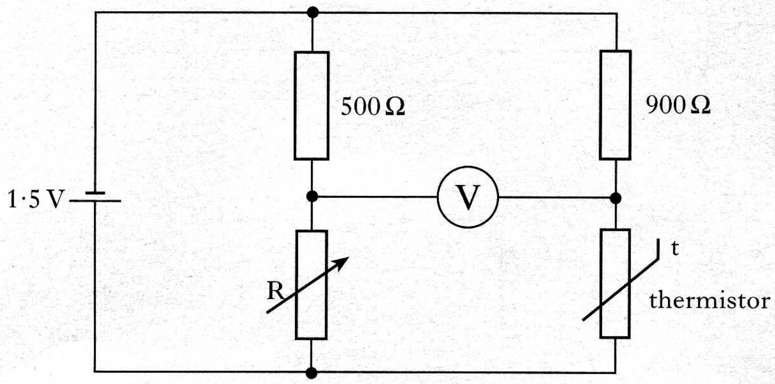


Explain, in terms of the forces acting on the submarine, why replacing water in the tanks with compressed air causes the submarine to accelerate upwards. 7

(8)

Marks

5. A pupil uses a Wheatstone bridge to investigate how the resistance of a thermistor is affected by its temperature. The circuit is shown below.



(*a*) The thermistor is placed in water at a temperature of 20 °C and the resistance of the variable resistor, R, is adjusted to 450 Ω to balance the bridge.

Calculate the resistance of the thermistor at this temperature. **2**

(*b*) Several pupils use the circuit to find the resistance of the thermistor when the water temperature is 30 °C. The values they obtain are as follows.

852 Ω 854 Ω 848 Ω 851 Ω 853 Ω

Calculate:

(i) the mean of the values;

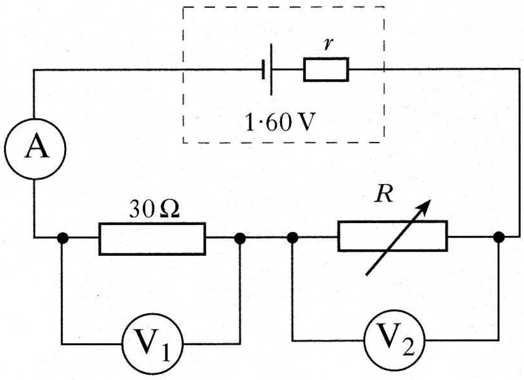
(ii) the random error in the mean. **3**

(*c*) Their teacher says that there may have been a *systematic error* in the investigation. Describe what is meant by a *systematic error*. **1**

(6)

[Turn over

6. The circuit below includes a cell with an e.m.f. of 1·60 V and internal resistance r.



The following readings are taken from the meters.

reading on the ammeter = 0·04 A
reading on the voltmeter V_1 = 1·20 V
reading on the voltmeter V_2 = 0·30 V

(*a*) Calculate the value of the lost volts in the circuit. **1**

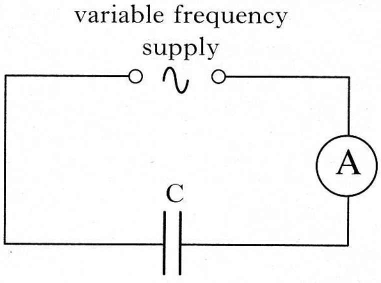
(*b*) Calculate the internal resistance, r, of the cell. **2**

(*c*) (i) The resistance of the variable resistor is altered so that the reading on the ammeter is 0·02 A. What is the resistance of the variable resistor now?

(ii) The resistance, R, of the variable resistor is now decreased. What effect has this on the terminal potential difference, V_{tpd}, of the cell? You must justify your answer. **5**

(8)

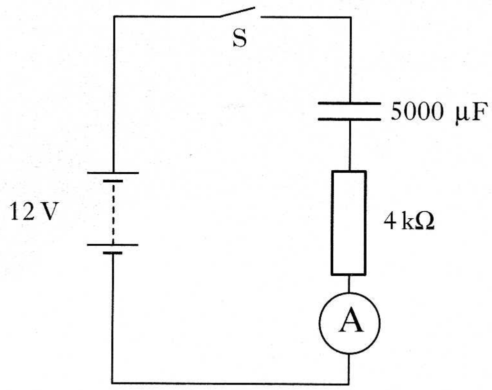
7. A capacitor is connected across a variable frequency supply as shown in the circuit below.
The output of the supply has constant amplitude.



(*a*) (i) At a certain frequency, the current in the circuit is 200 mA r.m.s. Calculate the value of the peak current in the circuit.

(ii) The frequency of the output from the supply is now slowly increased. Sketch the graph of current against frequency for this circuit. Numerical values are not required but the axes should be clearly labelled. **3**

(*b*) An uncharged capacitor and a resistor are connected across a 12 V d.c. supply with negligible internal resistance as shown below.



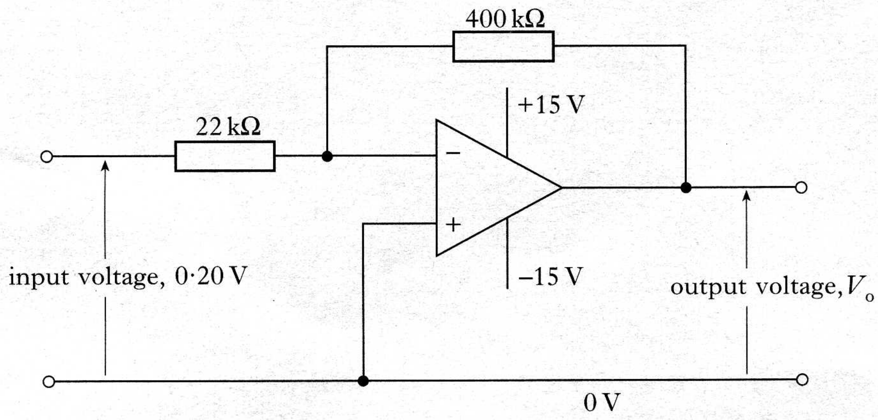
(i) The switch, S, is now closed and the capacitor charges. What charge is stored on the capacitor when the reading on the ammeter is 2 mA?

(ii) The capacitor is allowed to become fully charged. Calculate the energy now stored in the capacitor. **5**

(8)

[Turn over

8. (*a*) An op-amp is connected in a circuit as shown below.

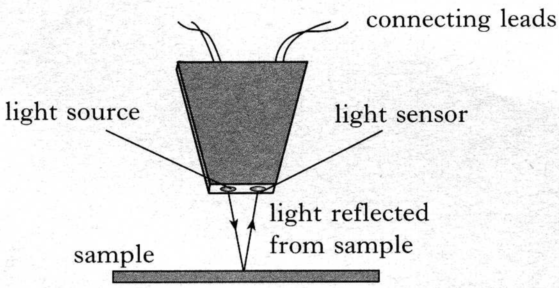


(i) Calculate the output voltage, V_o, when the input voltage is 0·20 V.

(ii) The 400 kΩ resistor develops a fault and its resistance increases to 10 MΩ. Describe the effect this has on the output voltage. **3**

(*b*) A paint manufacturer needs to make sure all paint of the same type has the same reflective properties.

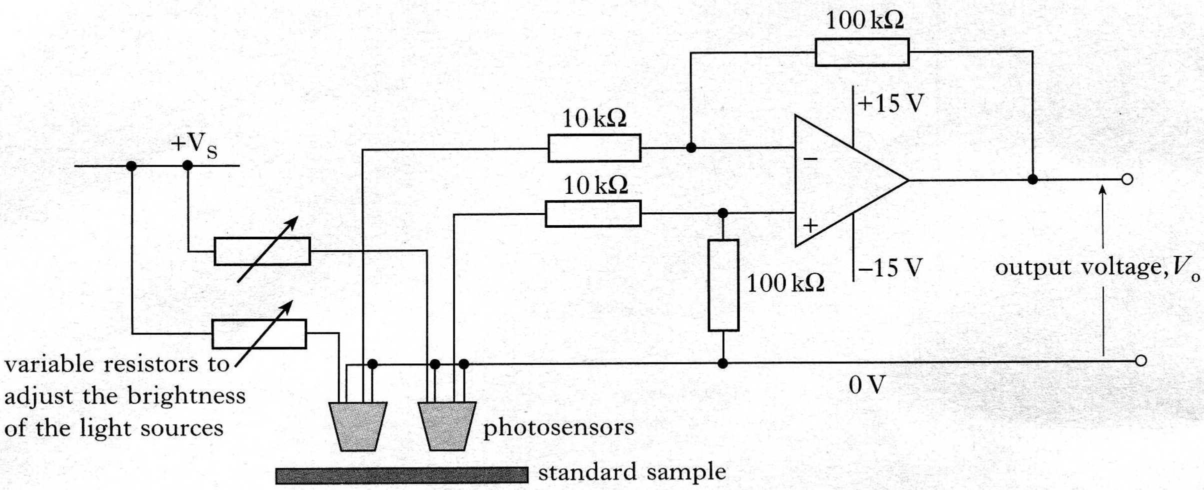
The reflective property of a sample of paint is tested using a circuit that includes photosensors. A photosensor is a device which contains a light source and a light sensor. Light from the light source in the photosensor is reflected from the sample of paint into the light sensor as shown in the diagram below.



The light sensor produces an output voltage that is directly proportional to the intensity of the light that is reflected from the paint.

8. (*b*) (continued)

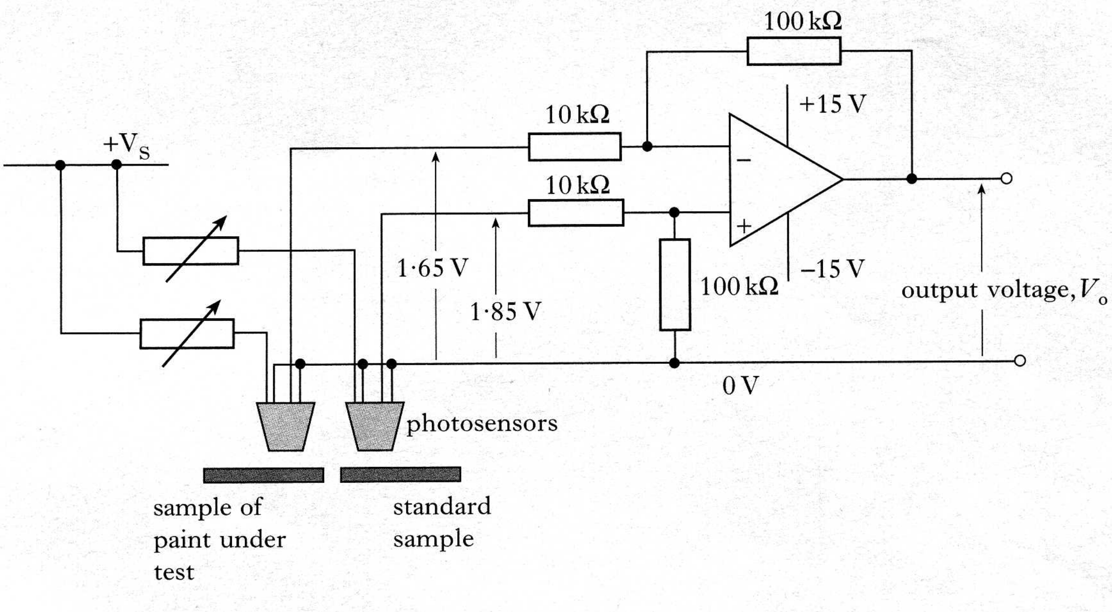
The circuit used to test the paint includes an op-amp and two photosensors. The circuit is used first of all with a standard sample placed under **both** photosensors as shown below.



(i) In what mode is this op-amp operating?

(ii) A technician adjusts the variable resistors until the light sources are equally bright. How will the technician know from the circuit when this has been achieved?

(iii) A sample of the paint under test and the standard sample are now placed under the photosensors as shown below.



The voltage inputs from the photosensors to the op-amp circuit are:

inverting input 1·65 V;

non-inverting input 1·85 V.

Calculate the value of the output voltage V_o.

(iv) The sample of paint under test is replaced by another slightly more reflective sample. This change causes the voltage from the photosensor above the new sample to increase. State and explain the effect on the output voltage, V_o, from the op-amp. **6**

(9)