



Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2019

Centre Number

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Candidate Number

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Physics

StemUp Model Solution

Assessment Unit AS 1

assessing

Forces, Energy and Electricity



[SPH11]

SPH11

TUESDAY 14 MAY, MORNING

TIME

1 hour 45 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen.**

Answer **all ten** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.

Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.

You may use an electronic calculator.



1 (a) The kilogram, the ampere and the second are three of the SI base units.

(i) What is a base unit?

A fundamental unit from which all other units are derived.

[1]

(ii) State three other SI base units.

metre (m)

kelvin (K)

mole (mol)

[3]

(iii) The joule is the SI unit of energy. Express the joule in base units.

Work done = force $\times$ distance ($W = Fs$)

Force $F = ma$, so units of $N = \text{kg} \times \text{m s}^{-2} = \text{kg m s}^{-2}$

Units of distance $s = \text{m}$

$J = N \text{ m} = \text{kg m s}^{-2} \times \text{m}$

$J = \text{kg m}^2 \text{ s}^{-2}$

Base units of the joule = $\text{kg m}^2 \text{ s}^{-2}$

[3]



- (b) The Three Gorges Dam plant in China consists of a series of 32 hydroelectric power generators. It is estimated that the total energy output of this facility is 84700 GW h (gigawatt hours) per year.

- (i) Show that 1 GW h is equal to 3.6×10^{12} J.

$$1 \text{ GW} = 1 \times 10^9 \text{ W}$$

$$1 \text{ hour} = 60 \times 60 = 3600 \text{ s}$$

$$1 \text{ GW h} = 1 \times 10^9 \text{ W} \times 3600 \text{ s}$$

$$1 \text{ GW h} = 3.6 \times 10^{12} \text{ J}$$

[2]

- (ii) Calculate the average power output of **each** generator.

$$\text{Total energy per year} = 84700 \times 3.6 \times 10^{12} = 3.05 \times 10^{17} \text{ J}$$

$$\text{Energy of each generator} = 3.05 \times 10^{17} \div 32 = 9.53 \times 10^{15} \text{ J}$$

$$1 \text{ year} = 365 \times 24 \times 3600 = 31536000 \text{ s}$$

$$P = E \div t = 9.53 \times 10^{15} \div 31536000$$

$$P = 3.02 \times 10^8 \text{ W}$$

$$\text{Average power output} = \underline{3.02 \times 10^8} \text{ W}$$

[3]

[Turn over]



- 2 (a) State the principle of conservation of energy.

Energy cannot be created or destroyed, but it can be changed from one form to another.

[1]

- (b) A hockey ball, initially at rest, is struck by a hockey stick and leaves the stick with a velocity of 19.6 m s^{-1} . The ball has a mass of 156 g .

- (i) Calculate the kinetic energy of the ball as it leaves the stick.

$$KE = \frac{1}{2}mv^2, \quad m = 156 \text{ g} = 0.156 \text{ kg}$$

$$KE = \frac{1}{2} \times 0.156 \times 19.6^2$$

$$KE = 30.0 \text{ J}$$

Kinetic energy = 30.0 J

[3]

- (ii) The constant force with which the ball was struck was 80.0 N . Assuming energy losses are negligible, calculate the distance over which the ball remained in contact with the stick.

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$$

$$30.0 - 0 = 80.0 \times s$$

$$s = 30.0 \div 80.0 = 0.375 \text{ m}$$

Distance = 0.375 m

[2]



(iii) Calculate the power generated by the hockey player when hitting the ball.

$P = Fv$, where v is the average speed while in contact with the stick

Average speed = $(0 + 19.6) \div 2 = 9.8 \text{ m s}^{-1}$

$P = 80.0 \times 9.8$

$P = 784 \text{ W}$

Power = 784 W

[3]

[Turn over



3 (a) (i) State Newton's second law.

The acceleration of a body is directly proportional to the resultant force acting on it and inversely proportional to its mass, and the acceleration is in the same direction as the resultant force.

[3]

(ii) When a lift is accelerating upwards, why do passengers feel heavier than normal even though their mass has not changed?

To accelerate upwards there must be a resultant upward force on the passengers, so the normal reaction from the floor is larger than their normal weight. They feel this larger reaction, so feel heavier.

[2]

(b) A lift, of mass 1075 kg when empty, and a 1100 kg counterweight are connected by a cable that passes over a large frictionless pulley as shown in Fig. 3.1.

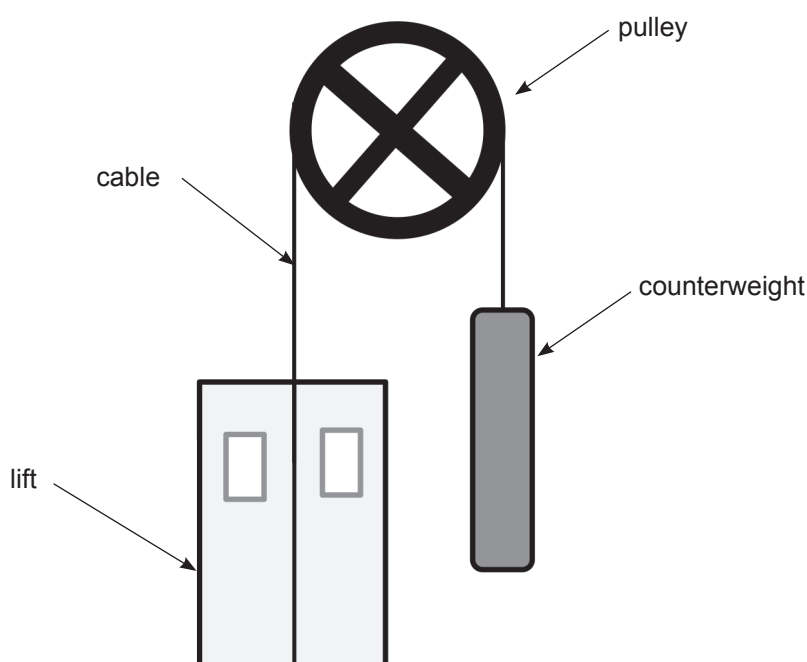


Fig. 3.1



Two passengers of masses 72.0 kg and 53.0 kg enter the lift.

- (i) Calculate the magnitude and direction of the resultant force, acting on the lift and passengers, if the lift were allowed to move freely without a brake.

$$\text{Mass of lift and passengers} = 1075 + 72.0 + 53.0 = 1200 \text{ kg}$$

$$\text{Weight of lift side } W = 1200 \times 9.81 = 11772 \text{ N}$$

$$\text{System: } a = (1200 - 1100) \times 9.81 \div (1200 + 1100) = 0.427 \text{ m s}^{-2}$$

$$\text{Tension } T = 1100 \times (9.81 + 0.427) = 11260 \text{ N}$$

$$\text{Resultant force on lift} = 11772 - 11260 = 512 \text{ N}$$

$$\text{Resultant force} = \underline{512} \text{ N}$$

$$\text{Direction} = \underline{\text{downwards}}$$

[4]

- (ii) Calculate the acceleration of the lift and passengers.

$$\text{Resultant force on the lift and passengers } F = ma$$

$$512 = 1200 \times a$$

$$a = 512 \div 1200$$

$$a = 0.427 \text{ m s}^{-2}$$

$$(\text{Check using whole system: } a = (11772 - 10791) \div 2300 = 0.427 \text{ m s}^{-2})$$

$$\text{Acceleration} = \underline{0.427} \text{ m s}^{-2}$$

[3]

[Turn over]



- 4 A scientist studying the motion of projectiles fires an object at an angle to the horizontal on a level surface. **Fig. 4.1** shows the initial trajectory of the projectile, launched at an angle of 40.0° to the surface and initial velocity 12.3 m s^{-1} .

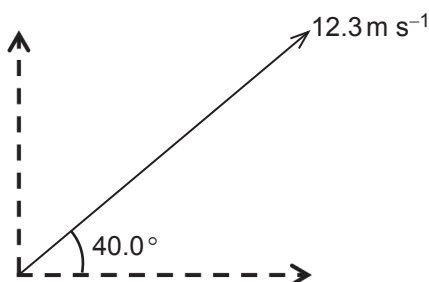


Fig. 4.1

- (a) What is projectile motion?

Motion with a constant (zero acceleration) horizontal velocity and a constant vertical acceleration (g) in the perpendicular direction.

[2]

- (b) (i) Calculate the horizontal and vertical components of the initial velocity.

Vertical: $u_v = 12.3 \sin 40.0^\circ = 7.91 \text{ m s}^{-1}$

Horizontal: $u_h = 12.3 \cos 40.0^\circ = 9.42 \text{ m s}^{-1}$

Vertical component = 7.91 m s⁻¹

Horizontal component = 9.42 m s⁻¹

[2]



(ii) Calculate the maximum height of the projectile.

At maximum height vertical velocity $v = 0$

$$v^2 = u^2 + 2as$$

$$0 = 7.91^2 - 2 \times 9.81 \times s$$

$$s = 62.6 \div 19.62 = 3.19 \text{ m}$$

Maximum height = 3.19 m [3]

(iii) Calculate the time taken to reach the maximum height.

$$v = u + at$$

$$0 = 7.91 - 9.81 t$$

$$t = 7.91 \div 9.81 = 0.806 \text{ s}$$

Time = 0.806 s [3]

(iv) Calculate how far from the starting position the projectile landed.

$$\text{Time of flight} = 2 \times 0.806 = 1.612 \text{ s}$$

$$\text{Horizontal distance } s = u_h t$$

$$s = 9.42 \times 1.612$$

$$s = 15.2 \text{ m}$$

Distance = 15.2 m [3]

[Turn over]



- 5 A parachute landing fall is a safety technique that allows a parachutist to practice landing without injury by stepping off an elevated static platform onto firm ground.

- (a) (i) An experienced parachutist, of mass 87 kg, is to practice jumping from a 3.20 m high platform. Calculate the impulse experienced by the parachutist when landing at a velocity of 7.92 m s^{-1} .

$$\begin{aligned}\text{Impulse} &= \text{change in momentum} = mv - mu \\ &= (87 \times 0) - (87 \times 7.92) \\ &= -689 \text{ N s, so magnitude of impulse} = 689 \text{ N s}\end{aligned}$$

$$\text{Impulse} = \underline{689} \text{ N s}$$

[3]

- (ii) If the parachutist remains stiff-legged on impact, the time of impact is 4.80 ms. Calculate the magnitude of the average resultant force acting on his legs.

$$\begin{aligned}\text{Impulse} &= Ft \\ 689 &= F \times 4.80 \times 10^{-3} \\ F &= 689 \div 4.80 \times 10^{-3} \\ F &= 1.44 \times 10^5 \text{ N}\end{aligned}$$

$$\text{Average resultant force} = \underline{1.44 \times 10^5} \text{ N}$$

[3]



- (b) The parachutist would most likely be injured during this jump. Discuss how he could improve his landing technique and explain why it works.

He should bend his legs (knees) on landing so his body crumples,

which increases the time of impact over which he is brought to rest.

His change in momentum is the same and $F = \Delta p \div t$, so the average

impact force on his legs decreases.

[3]

[Turn over



- 6 In a hotel, a lift travels non-stop from the ground floor to the 12th floor. The lift accelerates uniformly from rest for 5.0 s. It then travels at a constant velocity for 8.2 s and then decelerates uniformly for 5.0 s before stopping. Each floor of the hotel is 4.09 m high.

- (a) (i) Sketch a velocity/time graph on the axes in **Fig. 6.1** for the lift during this journey.

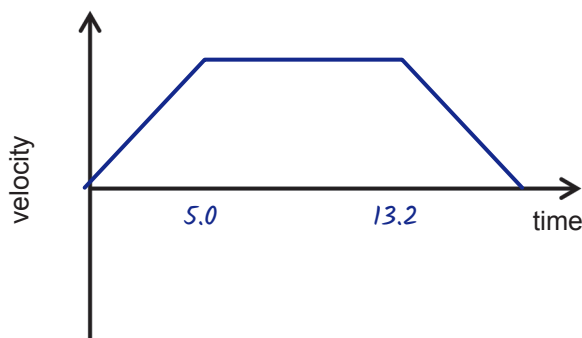


Fig. 6.1

[1]

- (ii) Calculate a value for the maximum velocity reached by the lift during this journey.

$$\text{Distance travelled} = 12 \times 4.09 = 49.08 \text{ m}$$

$$\text{Distance} = \text{area under velocity/time graph}$$

$$\text{Area} = \left(\frac{1}{2} \times v \times 5.0\right) + (8.2 \times v) + \left(\frac{1}{2} \times v \times 5.0\right) = 13.2v$$

$$13.2v = 49.08$$

$$v = 49.08 \div 13.2 = 3.72 \text{ m s}^{-1}$$

$$\text{Maximum velocity} = \underline{3.72} \text{ m s}^{-1}$$

[4]



(b) On **Fig. 6.2** and **Fig. 6.3**, sketch graphs of the displacement and the acceleration of the lift from the ground floor to the 12th floor.

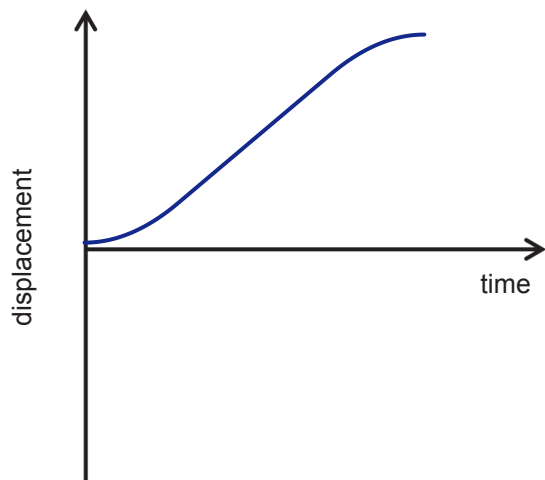


Fig. 6.2

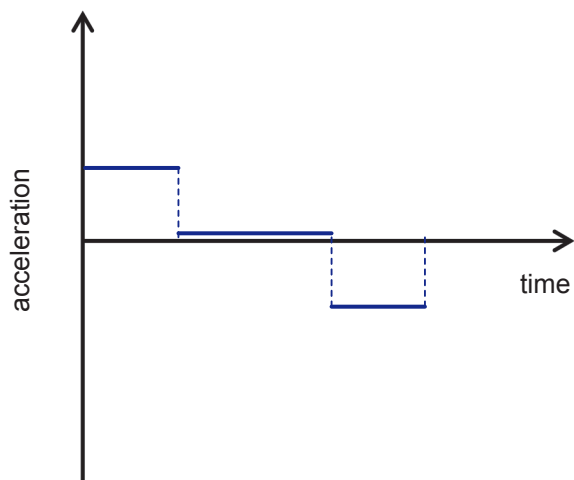


Fig. 6.3

[6]



- 7 A lighting circuit containing 6 identical bulbs is shown in Fig. 7.1.

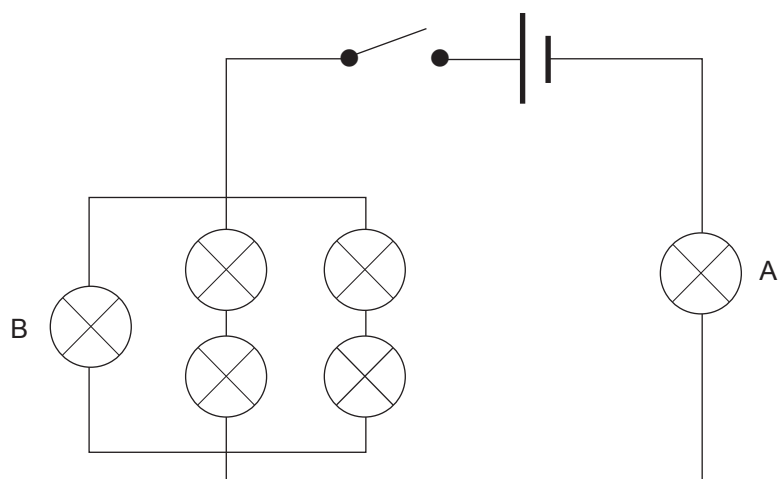


Fig. 7.1

- (a) When the switch is closed, 18×10^{19} electrons flow through bulb A every minute.

Calculate the current through bulb A.

$$Q = ne = 18 \times 10^{19} \times 1.6 \times 10^{-19} = 28.8 \text{ C}$$

$$I = Q \div t = 28.8 \div 60$$

$$I = 0.48 \text{ A}$$

Current = 0.48 A

[3]



- (b) The resistance of each bulb is $6.0\ \Omega$. Calculate the potential difference across the cell.

Each series pair: $R = 6.0 + 6.0 = 12\ \Omega$

Two pairs in parallel: $1/R = 1/12 + 1/12$, so $R = 6.0\ \Omega$

With bulb B in parallel: $1/R = 1/6.0 + 1/6.0$, so $R = 3.0\ \Omega$

Total circuit resistance $R_T = 3.0 + 6.0$ (bulb A) $= 9.0\ \Omega$

$V = IR_T = 0.48 \times 9.0$

$V = 4.32\ \text{V}$

Potential difference = 4.32 V

[5]

- (c) Calculate the current that flows through bulb B when the switch is closed.

p.d. across parallel section $= 0.48 \times 3.0 = 1.44\ \text{V}$

$I_B = V \div R = 1.44 \div 6.0$

$I_B = 0.24\ \text{A}$ (current splits 2 : 1 : 1)

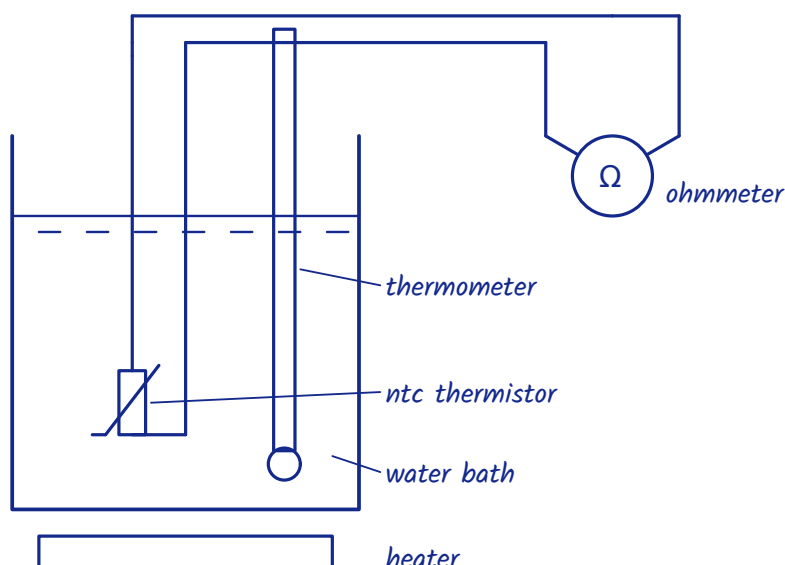
Current = 0.24 A

[2]

[Turn over]



- 8 (i) In the space below, draw and label the apparatus and circuit required for a student to investigate how the resistance of a negative temperature coefficient (ntc) thermistor varies with temperature.



[2]

- (ii) Describe how the apparatus drawn in (i) is used to obtain accurate results.

Place the thermistor and the thermometer close together in the water

bath. Heat the water, stir it and wait until the temperature is steady.

Record the temperature on the thermometer and the resistance on the

ohmmeter at that temperature.

Change the temperature of the water bath each time (e.g. in 10 °C

steps from 0 °C to 100 °C) and repeat, to obtain at least 5 sets of

valid results; repeat each and take the mean.

[4]



- (iii) On **Fig. 8.1**, sketch the graph to show how the resistance of a negative temperature coefficient (ntc) thermistor varies with temperature.

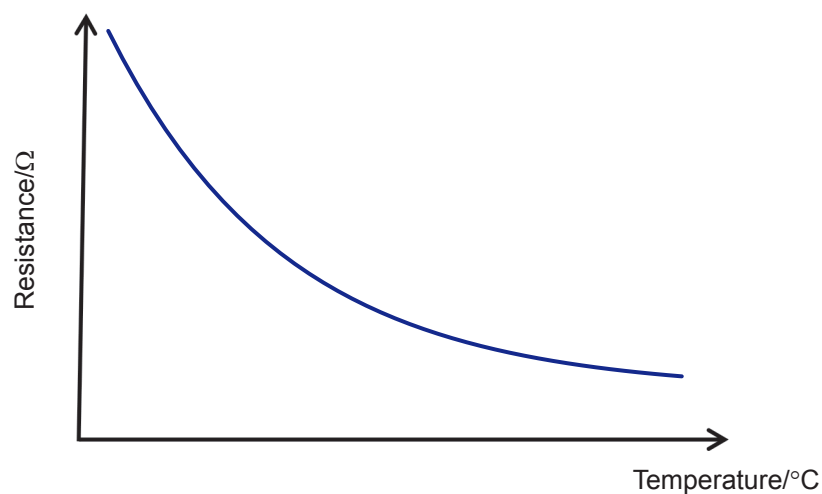


Fig. 8.1

[1]

- (iv) Explain in detail why the resistance of the ntc thermistor varies with temperature in the way described by your graph.

As the temperature increases, more electrons gain enough energy to

break free from their atoms, so there are more free charge carriers.

So for the same p.d. the current increases and the resistance decreases.

The ions do vibrate more, increasing resistance as in a metal, but this

effect is much smaller than the increase in the number of free

electrons.

[3]

[Turn over]



- 9 (a) Define, including the types of energy involved, the **electromotive force (e.m.f.)** of a battery.

The e.m.f. is the chemical energy converted into electrical energy per coulomb (unit charge) of charge passing through the battery.

[2]

- (b) A battery with e.m.f. of 6.0 V and internal resistance, r , is connected to a circuit containing a $25\ \Omega$ resistor as shown in Fig. 9.1.

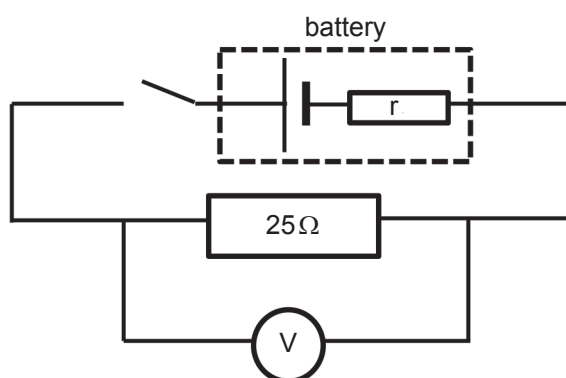


Fig. 9.1

The voltmeter used to measure the potential difference across the $25\ \Omega$ resistor has a resistance of $230\ \Omega$. The reading on the voltmeter is 5.88 V. Calculate the internal resistance of the battery.

Parallel combination: $1/R = 1/230 + 1/25$, so $R = 22.5\ \Omega$

Current $I = V \div R = 5.88 \div 22.5 = 0.26\ \text{A}$

$V = E - Ir$: $5.88 = 6.0 - 0.26r$

$r = 0.12 \div 0.26$

$r = 0.46\ \Omega$

Internal resistance = 0.46 Ω

[5]





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10 (a) A potential divider circuit is set up as shown in Fig. 10.1.

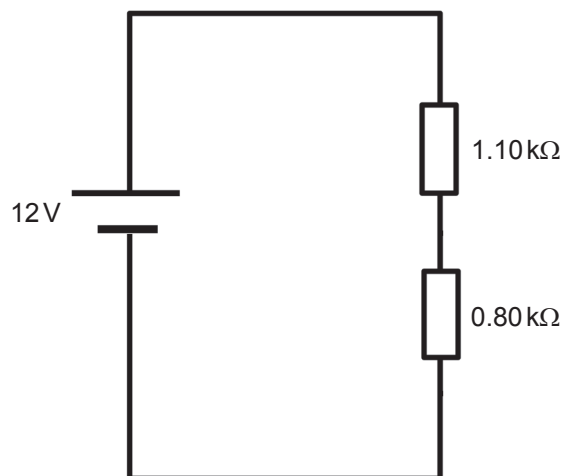


Fig. 10.1

Calculate the potential difference across the 0.80 kΩ resistor.

$$V_{out} = R_1 V_{in} \div (R_1 + R_2)$$

$$V_{out} = (0.80 \div (0.80 + 1.10)) \times 12 = (0.80 \div 1.90) \times 12$$

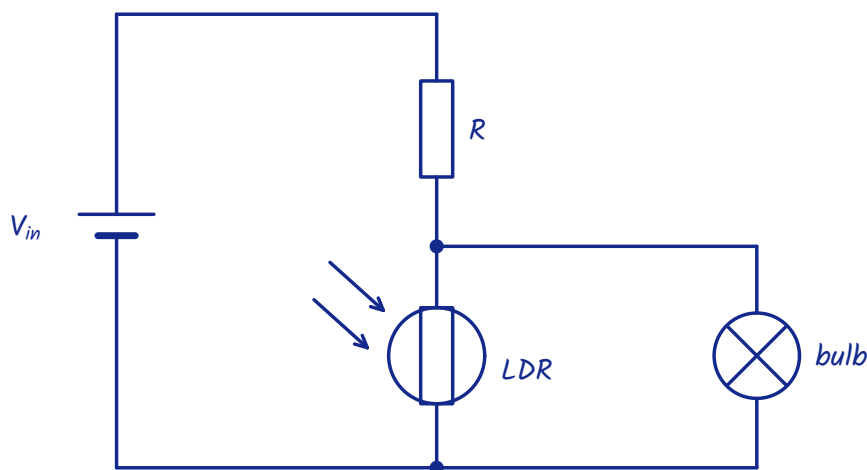
$$V_{out} = 5.05 \text{ V}$$

Potential difference = 5.05 V

[3]



- (b) (i) In the space below, draw a circuit diagram to show how a light dependent resistor, LDR, can be used in a potential divider circuit to automatically switch on a light bulb when it gets dark.



[2]

- (ii) Explain briefly how this circuit allows the light bulb to be turned on automatically.

As the light level falls, the resistance of the LDR increases, so the

LDR takes a larger share of the supply p.d.

So V_{out} across the LDR (and bulb) increases and the bulb (lighting circuit) switches on.

[2]

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Rewarding Learning

**ADVANCED SUBSIDIARY
General Certificate of Education**

Physics

Assessment Units AS 1 and AS 2

[SPH11/SPH21]

DATA AND FORMULAE SHEET

for use from 2017 onwards

Data and Formulae Sheet for AS 1 and AS 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
acceleration of free fall on the Earth's surface	$g = 9.81 \text{ m s}^{-2}$
electron volt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$
the Hubble constant	$H_0 \approx 2.4 \times 10^{-18} \text{ s}^{-1}$

Useful formulae

The following equations may be useful in answering some of the questions in the examination:

Mechanics

conservation of energy	$\frac{1}{2} mv^2 - \frac{1}{2} mu^2 = Fs$ for a constant force
------------------------	--

Waves

two-source interference	$\lambda = \frac{ay}{d}$
diffraction grating	$d \sin \theta = n\lambda$

Light

lens equation

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Electricity

terminal potential difference

$$V = E - Ir \text{ (e.m.f., } E; \text{ Internal Resistance, } r)$$

potential divider

$$V_{\text{out}} = \frac{R_1 V_{\text{in}}}{R_1 + R_2}$$

Particles and photons

Einstein's equation

$$\frac{1}{2} m v_{\text{max}}^2 = hf - hf_0$$

de Broglie equation

$$\lambda = \frac{h}{p}$$

Astronomy

red shift

$$z = \frac{\Delta\lambda}{\lambda}$$

recession speed

$$z = \frac{v}{c}$$

Hubble's law

$$v = H_0 d$$

