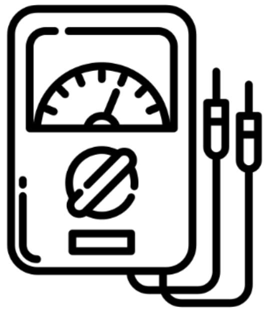
ESAT Physics Prep

Week 1 – Electricity



ANSWERS

Week 1 – Electricity

Week 2 – Magnetism

Week 3 – Mechanics

Week 4 – Thermal physics

Week 5 – Matter

Week 6 – Waves

Week 7 – Radioactivity

There is one sample ESAT test – note that they use the same questions from NSAA 2020 specimen paper. Past NSAA & ENGAA questions are the most relevant.

There are no calculators in the ESAT.

Electricity Spec

P1.1 Electrostatics:

a. Know and understand that insulators can be charged by friction.
b. Know and understand that charging is caused by gain or loss of electrons.
c. Know and understand that like charges repel and unlike charges attract.
d. Understand applications and hazards associated with electrostatics, including the role of earthing.

P1.2 Electric circuits:

a. Know and recognise the basic circuit symbols and diagrams, including: cell, battery, light source, resistor, variable resistor, ammeter, voltmeter, switch, diode.
b. Understand the difference between alternating current (ac) and direct current (dc).
c. Understand the difference between conductors and insulators, and recall examples of each type.
d. Know and be able to apply: $\text{current} = \frac{\text{charge}}{\text{time}}$, $I = \frac{Q}{t}$
e. Know and understand the use of voltmeters and ammeters.
f. Know and be able to apply: $\text{resistance} = \frac{\text{voltage}}{\text{current}}$, $R = \frac{V}{I}$
g. Recall and interpret V–I graphs for a fixed resistor and a filament lamp.
h. Know the properties of NTC (negative temperature coefficient) thermistors, LDRs (light-dependent resistors) and ideal diodes.
i. Know and understand the current and voltage rules for series and parallel circuits.
j. Calculate the total resistance for resistor combinations in series.
k. Understand that the total resistance of a parallel combination is less than that of any individual resistor.
l. Know and be able to apply: $\text{voltage} = \frac{\text{energy}}{\text{charge}}$, $V = \frac{E}{Q}$
m. Know and be able to apply: power = current × voltage, $P = IV = I^2R$
n. Know and be able to apply: energy transfer = power × time, $E = VIt$

or $P = IV$ so $V = \frac{P}{I}$

Q24 Section 1 NSAA 2020 Specimen

24 Which of the following is a correct unit of potential difference (voltage)?

A amp per ohm

B coulomb per joule

C joule per second

D newton per coulomb

E watt per amp

$V = \frac{E}{Q}$

$[V] = \frac{[J]}{[C]} = \frac{[J]}{[As]} = \frac{[W]}{[A]}$

Q28 Section 1 NSAA 2020 Specimen

28 An electric motor is used to lift a load of 3.0 kg from rest through a height of 5.0 m in a time of 1.5 s. At the end of the lift the load is at rest again. The motor is connected to a 25 V dc supply.

Assuming that the system is 100% efficient, what is the average current in the motor during the lift?

(gravitational field strength = 10 N kg^{-1})

$\frac{mgh}{t} = P = IV$

A 0.40 A

B 0.60 A

C 0.80 A

D 4.0 A

E 9.0 A

$\frac{3 \times 10 \times 5.0}{1.5} = 100 = 25I$

$I = \frac{100}{25} = 4.0A$

Q36 Section 1 NSAA 2020 Specimen

36 Two resistors with resistance R_1 ohms and R_2 ohms are connected in series with a battery that has a voltage V across its terminals.

Which formula gives the power dissipated by the resistor with resistance R_1 ohms?

$V = IR_T \qquad I = \frac{V}{R_1 + R_2}$

$P = I^2 R_1 = \frac{V^2}{(R_1 + R_2)^2} \times R_1$

A $\frac{VR_1}{R_1 + R_2}$

B $\frac{V^2 R_1}{R_1 + R_2}$

C $\frac{VR_1}{(R_1 + R_2)^2}$

D $\frac{V^2 R_1}{(R_1 + R_2)^2}$

E $\frac{VR_1^2}{(R_1 + R_2)}$

F $\frac{V^2 R_1^2}{(R_1 + R_2)^2}$

Q23 Section 1 NSAA 2018

23 A filament lamp working at its operating voltage converts electrical energy at a rate of 100 W.

The lamp has an efficiency of 5.0%.

How much energy is wasted by the lamp in 10 minutes?

Total energy used in 10 mins = 100 × (10 × 60)
= 60 000 J

95% wasted ⇒ $\frac{95}{100} \times 60\,000$
= 57 000 J

A 50 J

B 950 J

C 1000 J

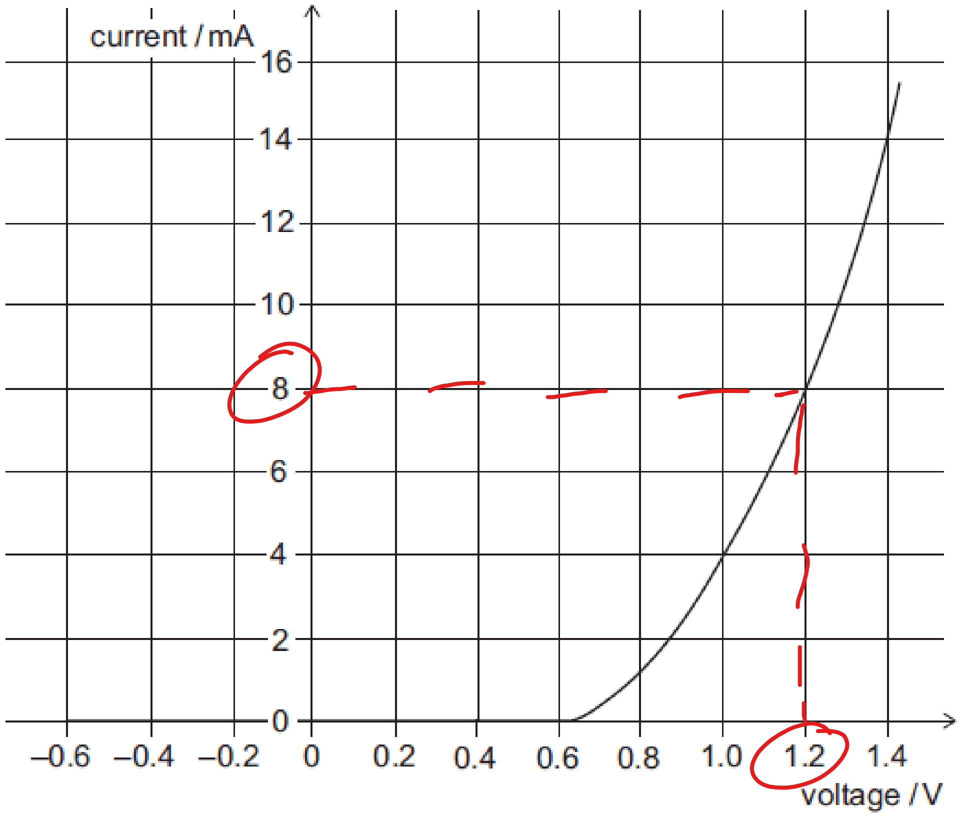
D 3000 J

E 57 000 J

F 60 000 J

Q2 Section 1 ENGAA 2019

2 The current–voltage graph for a diode is shown.



The diode is connected in series with a resistor and a 6.0 V battery. The current in the circuit is 8.0 mA.

What is the resistance of the resistor?

(Assume that the battery has negligible resistance.)

1.2 V across diode so 4.8 V across resistor

$R = \frac{V}{I} = \frac{4.8}{0.008} = 600\,\Omega$

A 0.15 Ω

B 0.60 Ω

C 0.75 Ω

D 4.8 Ω

E 150 Ω

F 600 Ω

G 750 Ω

Q8 Section 1 ENGAA 2019

8 The secondary coil of an ideal, 100% efficient transformer is connected to a resistor by cables of total resistance 1500 Ω. The current in the primary coil is 4.0 A. There are 240 turns in the primary coil and 4800 turns in the secondary coil.

What is the power produced as heat in the cables?

A 60 W

B 300 W

C 6000 W

D 24 000 W

E 120 000 W

F 9 600 000 W

$\frac{4800}{240} = 20$

Current decreases by 20:

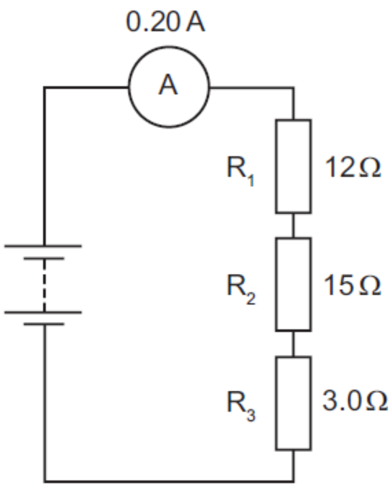
$\frac{4.0}{20} = 0.2$

$P = I^2R = (0.2)^2 \times 1500$

$= 60\ W$

Q20 Section 1 NSAA 2018

20 The diagram shows three resistors R_1, R_2 and R_3 connected in series with a battery of constant voltage. The resistance of each resistor and the corresponding current are also shown.



$V = IR$

$= 0.20 \times (12 + 15 + 3)$

$= 0.20 \times 30$

$= 6.0V$

Resistor R_3 is now removed and the circuit is reconnected.

What is the new current in the circuit?

A 0.20 A

B 0.22 A

C 0.33 A

D 0.40 A

E 0.50 A

F 2.0 A

G 6.0 A

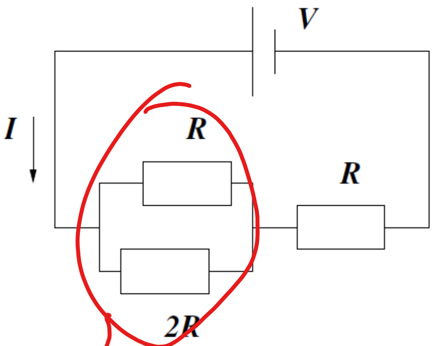
New current:

$I = \frac{V}{R} = \frac{6.0}{27}$

$= \frac{2}{9} = 0.22A$

Q9 PAT 2017

9. What is the value of the current I in the circuit below? [2]



A	B	C	D	E
$\frac{V}{4R}$	$\frac{3V}{5R}$	$\frac{4V}{3R}$	$\frac{5V}{3R}$	$\frac{3V}{4R}$

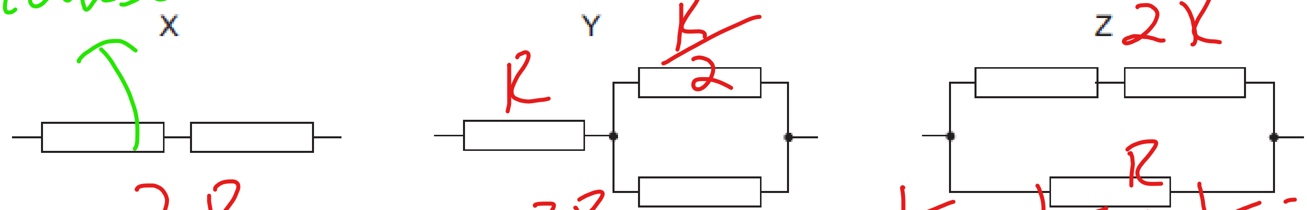
$\frac{1}{R_T} = \frac{1}{R} + \frac{1}{2R} = \frac{3}{2R} \Rightarrow R_T = \frac{2R}{3}$

Total $R = R + \frac{2R}{3} = \frac{5R}{3}$

$I = \frac{V}{R} = \frac{V}{\frac{5R}{3}} = \frac{3V}{5R}$

Q2 Section 2 ENGAA 2019

2 Identical resistors are used to produce three different arrangements X, Y and Z.



Lowest P — X: $2R$; Y: R, $\frac{R}{2}$, $\frac{3R}{2}$; Z: $2R$, R, $\frac{1}{R_T} = \frac{1}{2R} + \frac{1}{R} = \frac{3}{2R}$, $R_T = \frac{2R}{3}$ — highest P

Each arrangement is connected, in turn, across the same battery which has a negligible internal resistance.

The total power developed in each of the arrangements is determined.

What is the order of the arrangements when placed in order of **increasing** power?

A X, Y, Z

B X, Z, Y

C Y, X, Z

D Y, Z, X

E Z, X, Y

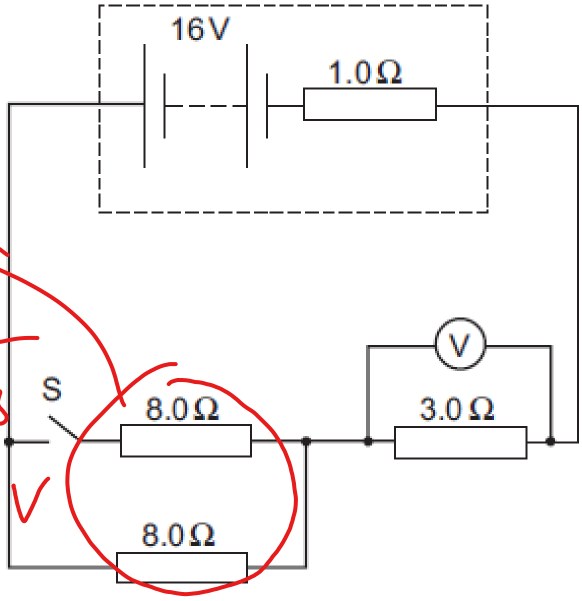
F Z, Y, X

$P = \frac{V^2}{R}$

p.d. is fixed. Highest power means lowest R.

Q4 Section 2 ENGAA 2019

4 The battery in the circuit shown has an emf of 16 V and an internal resistance of 1.0 Ω.



when closed
$R_T = 4.0\Omega$
so $V_1 = \frac{V_0 R_1}{R_1 + R_2 + R_3}$
$V_1 = \frac{16 \times 3.0}{8.0} = 6.0\text{ V}$

Which line in the table gives the voltmeter readings when switch S is in its open and closed states?

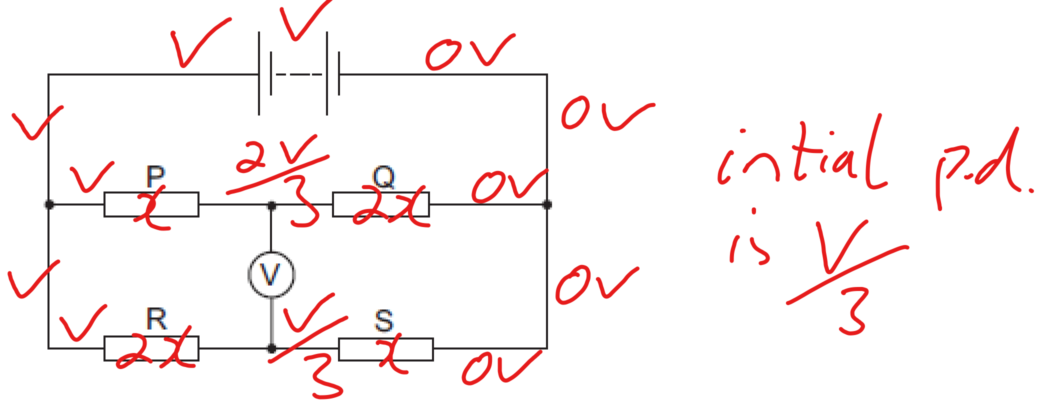
	voltmeter reading / V	
	when S is open	*when S is closed*
A	$\frac{4.0}{3.0}$	2.0
B	4.0	6.0
C	4.0	2.4
D	6.0	2.4
E	6.0	4.0
F	$\frac{48}{11}$	$\frac{48}{19}$
G	$\frac{48}{11}$	$\frac{48}{7.0}$
H	$\frac{128}{11}$	$\frac{64}{7.0}$

when open
$V_1 = \frac{16 \times 3}{12}$
$= 4.0\text{ V}$

Q15 Section 2 ENGAA 2019

15 Four resistors, P, Q, R and S, are connected to a battery with negligible internal resistance, as shown in the diagram.

P and S each have resistance x. Q and R each have resistance $2x$.

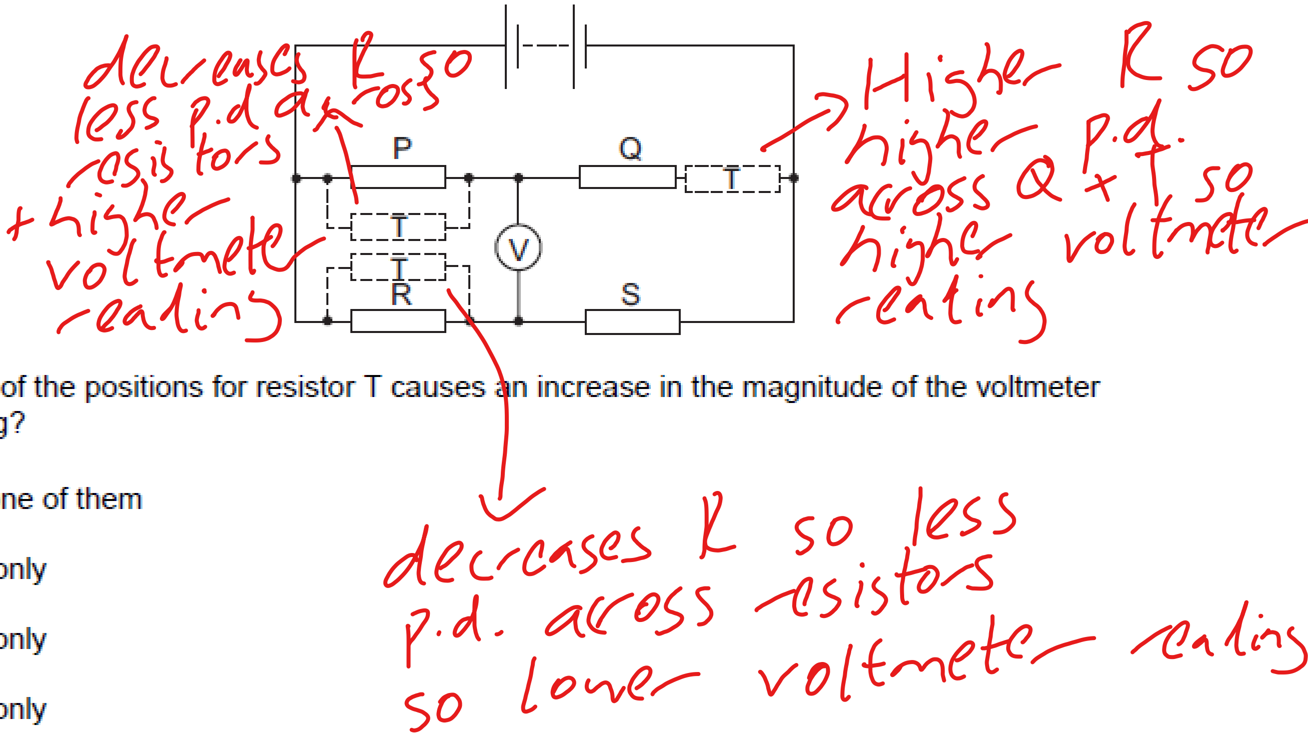


A fifth resistor, T, which has resistance x, is to be added to the circuit in one of the following listed positions, as shown in the diagram:

1 in parallel with P

2 in series with Q

3 in parallel with R



Which of the positions for resistor T causes an increase in the magnitude of the voltmeter reading?

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

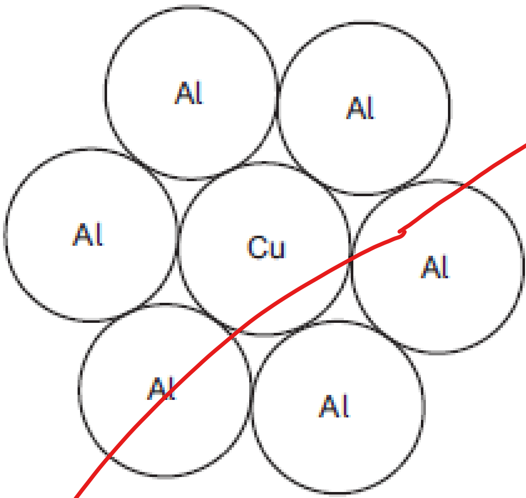
F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

Q16 Section 2 ENGAA 2018

16 A power cable consists of a cylindrical copper (Cu) wire surrounded by six cylindrical aluminium (Al) wires. All the wires are of the same cross-sectional area as shown:



The table gives the densities and resistivities of aluminium and copper.

material	*density*	*resistivity*
aluminium	d	3ρ
copper	$3d$	2ρ

The cable has mass M and length L.

Which expression gives the resistance between the two ends of the cable?

A $\dfrac{18\rho dL^2}{5M}$

B $\dfrac{21\rho dL^2}{M}$

C $\dfrac{81\rho dL^2}{5M}$

D $\dfrac{180\rho dL^2}{M}$

E $\dfrac{12\rho dL^2}{5M}$

F $\dfrac{28\rho dL^2}{3M}$

G $\dfrac{36\rho dL^2}{5M}$

H $\dfrac{80\rho dL^2}{M}$

$R = \dfrac{\rho L}{A}$

$R_T = \dfrac{2\rho L}{5\left(\frac{M}{9dL}\right)} = \dfrac{18\rho d L^2}{5M}$

$d = \dfrac{M}{V} = \dfrac{M}{AL}$

$\dfrac{1}{R_T} = \dfrac{1}{R_{Cu}} + \dfrac{6}{R_{Al}} = \dfrac{A}{2\rho L} + \dfrac{6A}{3\rho L} = \dfrac{5A}{2\rho L}$

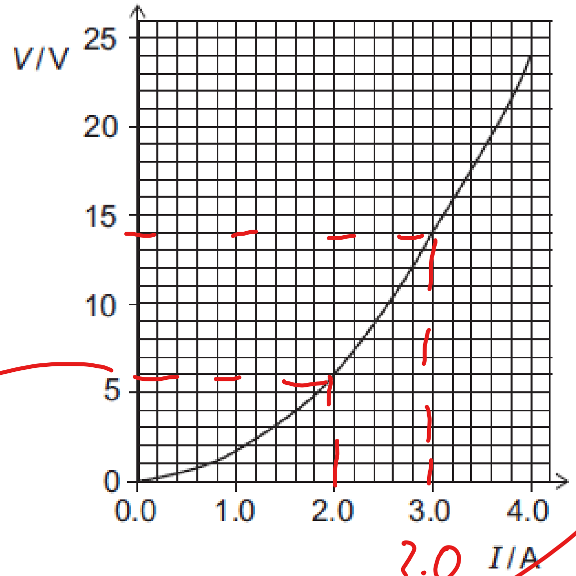
$R_T = \dfrac{2\rho L}{5A}$

$M = \underbrace{(3dAL)}_{Al} + \underbrace{(6dAL)}_{Cu} = 9dAL \Rightarrow A = \dfrac{M}{9dL}$

Q35 NSAA 2018

35 A filament lamp and a 0-10 Ω variable resistor are connected in series with a power supply of constant voltage.

The graph shows the voltage–current (*V–I*) characteristic of the filament lamp.



6 V across lamp

$R = \frac{V}{I} = \frac{14}{3}$

When the resistance of the variable resistor is 4.0 Ω, the current in the lamp is 2.0 A.

What is the power dissipated in the lamp when the resistance of the variable resistor is zero?

A 12 W

B 14 W

C 16 W

D 28 W

E 42 W

F 96 W

$V = IR = 2.0 \times 4.0$
$= 8.0$ V across variable resistor

Total p.d. = 14 V

when 14 V across lamp: $P = I^2R$
$= 3.0^2 \times \frac{14}{3}$
$= 3.0 \times 14$
$= 42$ W

Q24 NSAA 2022

$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{6.0^2}{0.075} = 480\,\Omega$ (0.075 W across each)

24 Two identical resistors are connected in parallel to a 6.0 V battery. The two resistors dissipate a total power of 0.15 W.

One of these resistors is removed from the circuit and connected to a 12 V battery.

How much charge passes through this resistor in 6.0 minutes?

A 0.025 C

B 0.050 C

C 0.15 C

D 0.30 C

E 0.75 C

F 1.5 C

G 9.0 C

H 18 C

$I = \frac{V}{R} = \frac{12}{480} = 0.025$

$Q = It = 0.025 \times (6.0 \times 60) = 9\ C$

Q28 NSAA 2022

28 Power is supplied to an electric motor at 0.800 kW. = 800 W

The motor has an efficiency of 60% and is switched on for half an hour.

How much energy is **wasted** during this time?

A 0.160 J

B 0.240 J

C 160 J

D 240 J

E 576 J

F 864 J

G 576 000 J

H 864 000 J

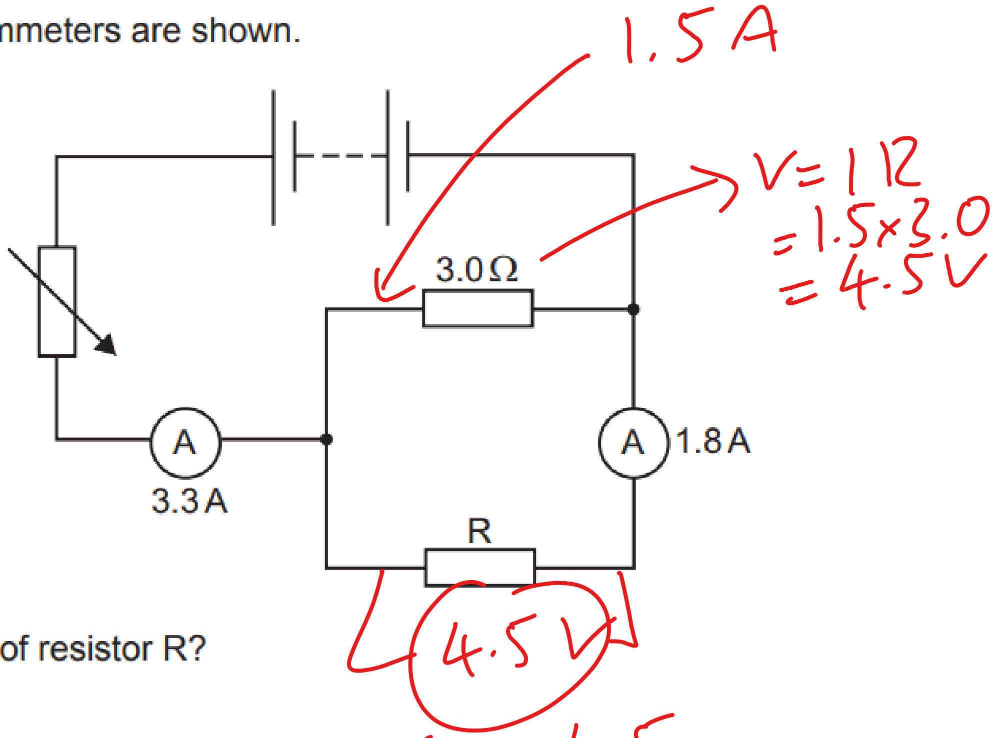
wasted power $= 800 \times \frac{60}{100} = 8 \times 60 = 480\ W$

$E = Pt = 480 \times (30 \times 60) = 480 \times 1800 = 864\,000\ J$

Q29 NSAA 2022

29 The diagram shows a circuit that includes two ammeters and a resistor R.

The readings on the ammeters are shown.



What is the resistance of resistor R?

A 0.40 Ω

B 2.5 Ω

C 3.0 Ω

D 3.6 Ω

E 5.5 Ω

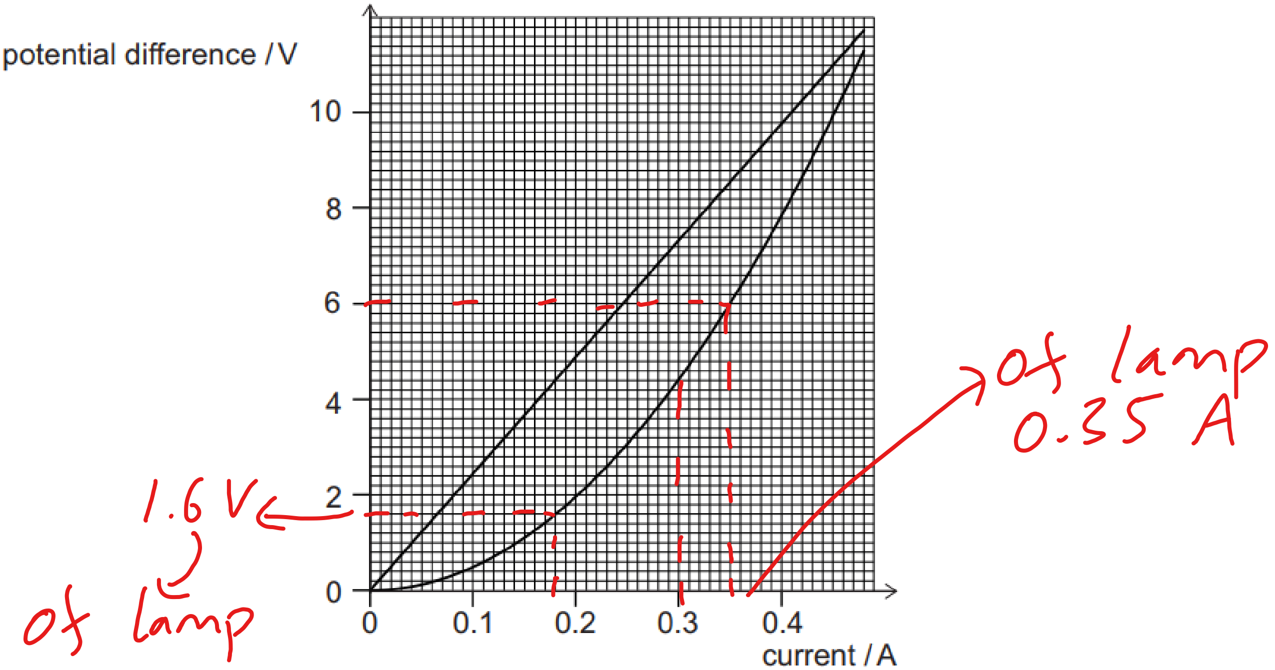
F 8.5 Ω

$R = \frac{V}{I} = \frac{4.5}{1.8}$

$= 2.5\ \Omega$

Q30 NSAA 2022

30 The graph shows potential difference plotted against current for a filament lamp and a resistor.



The lamp and the resistor are connected in parallel with each other to a 6.0 V power supply and the current in the lamp, I, is recorded.

→ 6.0V across lamp

In a second circuit, the lamp and the resistor are now connected in series with each other to the same power supply, and the current in the resistor is 0.18 A. The potential difference across the lamp, V, is recorded.

→ same current in lamp

What are the values of I in the first circuit and V in the second circuit?

	I / A	V / V
A	0.25	1.6 ✓
B	0.25	3.0 ✗
C	0.25	4.4 ✗
(D)	0.35 ✓	1.6 ✓
E	0.35	3.0 ✗
F	0.35	4.4 ✗

Q21 NSAA 2021

21 A resistor has a constant voltage of 9.00 V across it.

A total charge of 180 C passes through the resistor in 4.00 minutes.

What is the power dissipated in the resistor?

A 0.750 W

B 6.75 W

C 12.0 W

D 81.0 W

E 108 W

F 405 W

G 1620 W

H 6480 W

$Q = It$

$I = \frac{Q}{t} = \frac{180}{4 \times 60} = \frac{180}{240} = \frac{3}{4}$ A

$P = IV = \frac{3}{4} \times 9 = \frac{27}{4} = 6.75$ W

Q28 NSAA 2021

28 A set of decorative lights consists of 20 lamps connected in series to a dc supply of constant voltage.

The total power transferred by all the lamps is *P*.

The set is designed so that if one of the lamps fails, that lamp becomes short-circuited and it then has zero resistance. The remaining lamps are still lit.

If this happens, with the set connected to the same supply, what is the new total power transferred by the remaining 19 lamps?

(Assume that the resistance of each functioning lamp remains constant.)

A $\left(\frac{19}{20}\right)^2 P$

B $\left(\frac{19}{20}\right) P$

C P

D $\left(\frac{20}{19}\right) P$

E $\left(\frac{20}{19}\right)^2 P$

same V

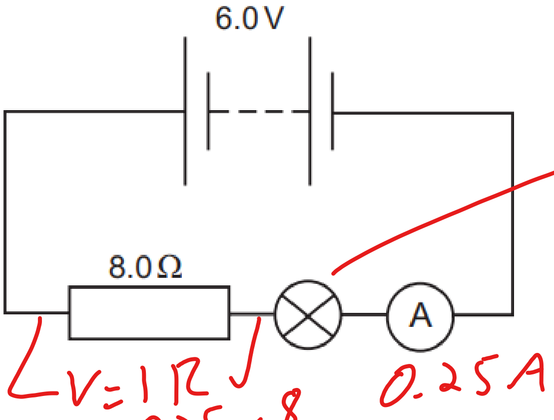
initially $20R$ now $19R$

$P = \frac{V^2}{R}$ → lower R so higher P

$R \downarrow \times \frac{19}{20}$

Q31 NSAA 2021

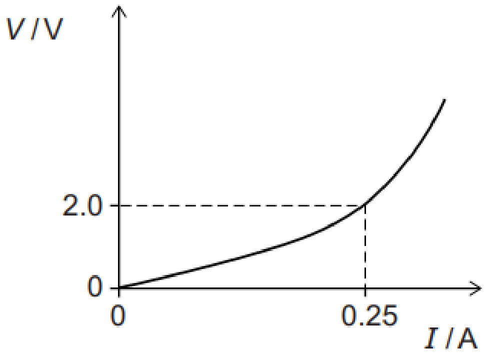
31 A 6.0 V battery is connected to an 8.0 Ω resistor and a filament lamp as shown in the circuit diagram.



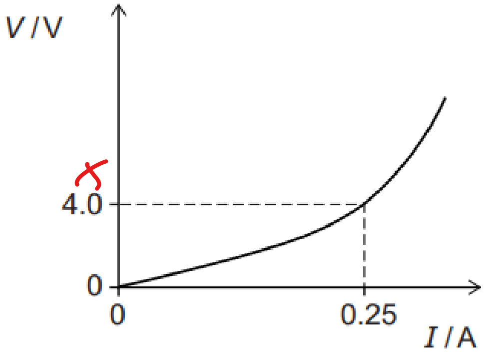
The reading on the ammeter is 0.25 A.

Which graph is a possible V–I graph for the filament lamp?

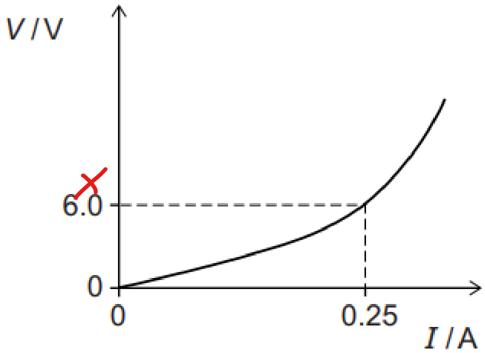
A



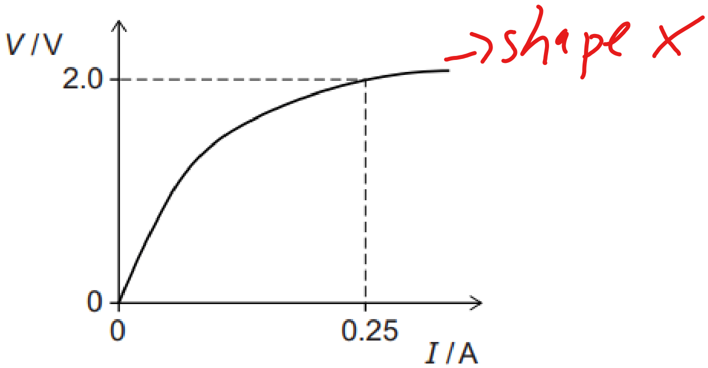
B



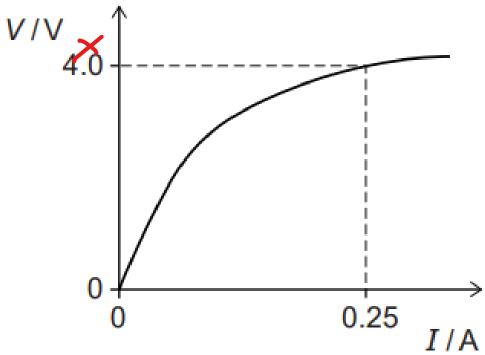
C



D



E



F