AS Revision Test – Particle Physics and Electricity – The Solutions

Q1. A neutral atom of carbon is represented by ${}^{14}_{6}C$.

(i) Name the constituents of this atom and state how many of each are present.
Protons, neutrons and electrons (1 mark) or up and down quarks and electrons (1 mark)
6 protons (1 mark) and 8 neutrons **(1 mark)** [or 20u (1 mark) and 22d **(1 mark)**]
6 electrons **(1 mark) (MAX 3)**

(ii) Which constituent of an atom has the largest charge-to-mass ratio?

Electron **(1 mark)**

(iii) Carbon has several isotopes. Explain the term *isotope*.

Isotopes of an element have nuclei which contain the same number of protons but different numbers of neutrons. (**2 marks** – 1 lost if English is poorly expressed!) You cannot explain what an isotope is 'singly' you have to compare two isotopes of the same element!

(Total 6 marks)

Q2. In a particle accelerator a proton and an antiproton, travelling at the same speed, undergo a head-on collision and produce subatomic particles.

(a) The total kinetic energy of the two particles just before the collision is 3.2×10^{-10} J.

(i) What happens to the proton and antiproton during the collision?

They are annihilated **(1 mark) (OR** The mass is converted to electromagnetic energy in the form of a pair of gamma rays (or photons)) The gamma rays will be virtual if the then produce other particles – but may just be gamma rays that we could detect… they are then not virtual. Only call them virtual when they are exchange particles.

(ii) State why the total energy after the collision is more than 3.2×10^{-10} J.

On annihilation the rest mass of the particles is converted to energy therefore the total energy after the collision is the KE before plus the mass conversion energy.

(2)

(b) In a second experiment the total kinetic energy of the colliding proton and antiproton is greater than 3.2×10^{-10} J.

State **two** possible differences this could make to the subatomic particles produced.

This relates to the subatomic particles produced NOT the gamma rays from the annihilation. You should therefore not be talking about frequency of gamma etc. The question infers that the gammas produced result in particle production – not simple annihilation.

Therefore there may be more particles – more massive particles – or particles with a greater kinetic energy. (Any 2 points for **2 marks)**

(2)
(Total 4 marks)

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Q3. (a) State whether or not each of the following properties of a baryon is conserved when it decays by the weak interaction.

charge YES baryon number YES strangeness NO (**2 marks** for all correct – lose a mark for each wrong)

(b) State, with a reason, whether or not each of the following particle reactions is possible.

(i) $p + \pi^- \rightarrow K^- + \pi^+$

Here you have:

proton (baryon) + pion (meson) → kaon (strange meson) + pion (meson)

Charge:	1 -1 = -1 + 1 (balances)
Baryon Number:	1 + 0 = 0 + 0 (no balance)
Lepton Number:	0 + 0 = 0 + 0 (balances)
Strangeness:	0 + 0 = -1 + 0 (doesn't balance)

No **(1 mark) because** strangeness [or baryon number] is not conserved **(1)**

(ii) $p + \bar{\nu} \rightarrow n + e^+$

proton (baryon) + antineutrino (antilepton) → neutron (baryon) + positron (antilepton)

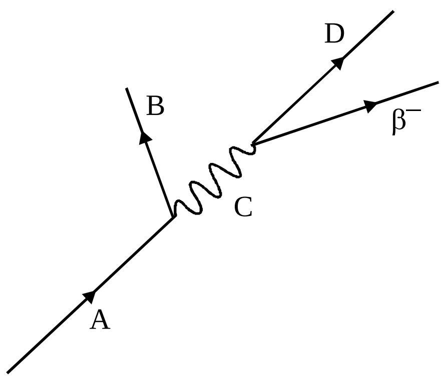
Charge:	1 + 0 = 0 + 1 (balances)
Baryon Number:	1 + 0 = 1 + 0 (balances)
Lepton Number:	0 - 1 = 0 - 1 (balances)
Strangeness:	0 + 0 = 0 + 0 (balances)

Yes (1 mark) because all of the above properties are conserved (1)

(4)

(Total 6 marks)

Q4. The Feynman diagram represents the emission of a beta particle from a neutron-rich nucleus. A and B each represent a quark.



The highlighted fact was missed by a good number of candidates – you MUST read the question! Use a highlighter!

(a) Identify the particles labelled A, B, C and D.

A ....down quark....... B ....up quark...................

C .....w- boson .... D ....antineutrino...........

(b) The beta particle in the Feynman diagram was produced when particle C decayed.
State **two differences** between particle C and a gamma photon.

When asked to give differences never say ' da-di-da is different' – you have to say how they differ... 1 is more massive than 2, rather than 1 and 2 differ in mass... Don't be VAGUE!!!

The w boson and gamma photon are both exchange particles... but

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The w-boson is an exchange particle for the weak nuclear force whereas the gamma photon is the exchange particle for the electromagnetic force. **(1 mark)**

A w- boson has a negative charge – but a gamma photon has no charge. **(1 mark)**

The w- boson has non-zero rest mass – but a gamma ray does have zero rest mass. **(1 mark)**

The w- boson has a shorter life than a gamma photon (photons have infinite lifetimes) (1 mark) **(MAX 2 marks)**

(Total 6 marks)

Q5. (a) (i) What class of particle is represented by the combination of three antiquarks, $\bar{q}\bar{q}\bar{q}$?

The anti (1 mark) baryon (1 mark)

(ii) Name a hadron that has an antiparticle identical to itself.

The neutral pion $\pi°$ [or $\eta°$] – but that is not on the syllabus!

(3)

(b) The kaon K^+ has a strangeness of +1.

(i) Give its quark composition.

$u\bar{s}$ **(1) (1)** **((1) for quark + antiquark)**

(ii) The K^+ may decay via the process

$$K^+ \rightarrow \pi^+ + \pi^0.$$

State the interaction responsible for this decay.

Strangeness is not conserved – so it must be a weak interaction.

(iii) The K^+ may also decay via the process

$$K^+ \rightarrow \mu^+ + \nu_\mu.$$

Change each particle in this equation to its corresponding antiparticle in order to complete an allowed decay process for the negative kaon K^-.

$$K^- \rightarrow \mu^- + \bar{\nu}_\mu \quad \textbf{(1 mark)}$$

(iv) Into what class of particle can both the μ^+ and the ν_μ be placed? Lepton **(1 mark)**

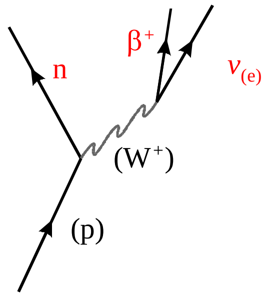
(v) State **one** difference between a positive muon, μ^+, and a positron, e^+.

The mass (or rest energy) of a positive muon is greater than the mass of a positron.

OR The positron is more stable than the positive muon. **(1mark)**

(6)

(c) The figure below shows a partially completed Feynman diagram of β^+ decay.



Complete the figure and label all the particles involved. (3) (Total 12 marks)

Q6.

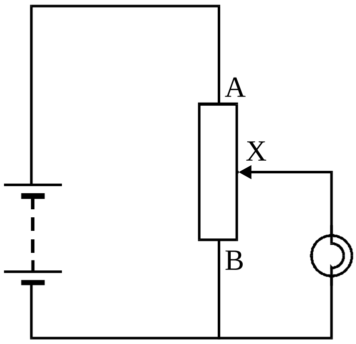


figure 1

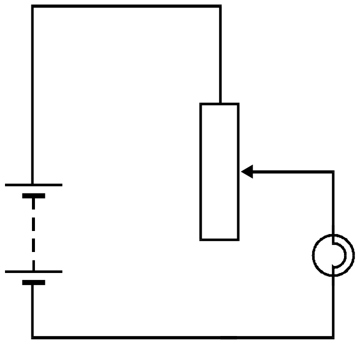


figure 2

(a) The current flowing through a torch bulb can be controlled by a variable resistor using either of the two circuit arrangements shown above. Figure 1 is called a potential divider arrangement and figure 2 may be called a rheostat arrangement. For each of these two methods explain **one** advantage and **one** disadvantage.

potential divider *(Figure 1)*

Advantage: The voltage across the bulb can be varied from zero to the full voltage of the supply. Therefore the current through the bulb can be varied from zero to its full operating voltage.

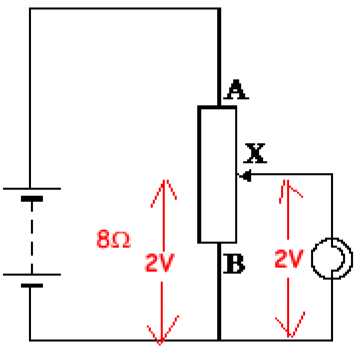
Disadvantage: There is a steady drain of power due to the current passing through the fixed resistor. This is the same no matter what voltage is across the bulb. It is therefore wasting energy.

Rheostat *(Figure 2)*

Advantage: It is simple to set up – a variable resistor in series with a bulb.

Disadvantage: When the variable resistor is set to maximum there is still a current passing through the bulb – it can never be zero.

(4)



(b) In figure 1, the variable resistor has a total resistance of 16 Ω. When the slider of the variable resistor is set at X, exactly mid-way along AB, the bulb works according to its specification of 2.0 V, 500 mW. Calculate

(i) the current through section XB of the variable resistance,

Pd across this section is 2.0 V because it is in parallel with the bulb and that has 2.0 V across it…

R = 8.0 Ω as it is halfway and total resistance is 16Ω.

V = IR so I = V/R = 2.0/8.0 = 0.25A **(1 mark)**

(ii) the current through section AX of the variable resistance.

Current through the bulb can be worked out from the power rating:

P = IV so I = P/V = 0.50/2 = 0.25A
Current through AX = sum of current through bulb and current through XB = 0.25 + 0.25 = 0.50A
(1 mark) (Care with sig figs here!)

(2)
(Total 6 marks)

7. (a) Some electrical components may be described as *non-ohmic.*

(i) Name an example, other than a diode, of a non-ohmic electrical component.

Filament lamp or thermistor (1 mark)

(ii) State how the current-voltage characteristic of your chosen component shows that it is non-ohmic.

You have to talk about the shape of the graph curve here – many of you spoke of proportionality but did not mention that a straight line indicated it – that might lose you marks – describe the graph line! If the question had said 'explain how' instead of 'state' you would have to talk of the line not being straight and therefore not showing prpotionality… but in this case what was wanted was….

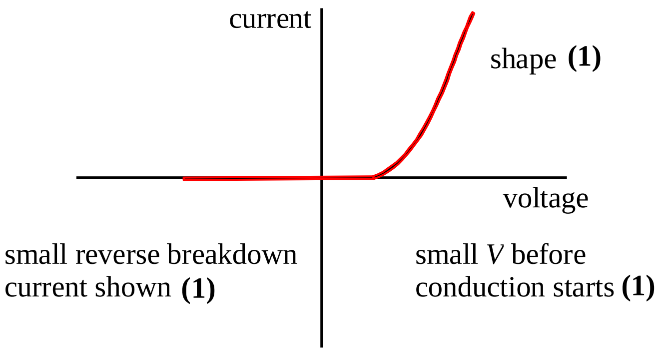
It does not produce a straight line graph. **(1 mark)**

(2)

(b) A semiconducting diode has special electrical properties that make it useful as an electrical component.

(i) Sketch on the grid the current-voltage characteristic of a diode.

(ii) State, with reference to the current-voltage characteristic you have drawn, how the resistance of the diode varies with the potential difference across its terminals for reverse bias and for forward bias.



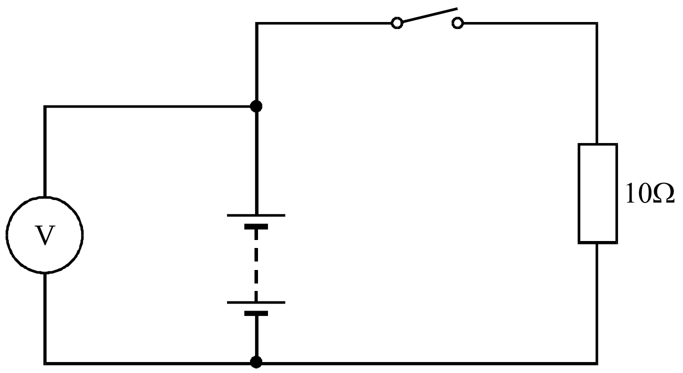
Many spoke of current or p.d. and not resistance – answer the question!!!!

reverse biased: high resistance (1 mark)

forward biased: low resistance (after the threshold voltage has been passed) (1 mark)

(4)
(Total 6 marks)

Q8.



A battery is connected to a 10Ω resistor as shown. The e.m.f. (electromotive force) of the battery is 12V.

(a) (i) Explain what is meant by the e.m.f. of a battery.

The EMF is the energy provided by a battery **(1 mark)** per unit charge **(1 mark)**

[OR when no current flows **(1 mark)** in an external circuit the EMF is the potential difference across the battery **(1 mark)**]

(ii) When the switch is open the voltmeter reads 12.0V and when it is closed it reads 11.5 V. Explain why the readings are different.

When a current flows in the external circuit a potential difference is developed across the internal resistance **(1)** of the battery.This voltage is called the 'lost volts' and corresponds to a reduction in the reading on a voltmeter across the terminals of the battery when the switch to an external circuit is closed.

(3)

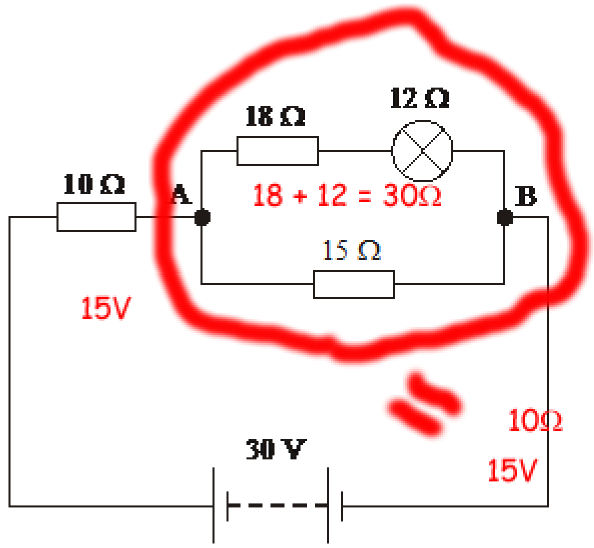
(b) Calculate the internal resistance of the battery.

ε = 12.0 V
V = 11.5 V
R = 10Ω

V = IR so I = V/R = 11.5/10 = 1.15A **(1 mark)**
ε = I(R+r) = IR + Ir = V + Ir
12.0 = 11.5 + 1.15 x r **(1 mark)**
R = 0.50/1.15 = 0.43Ω **(1 mark)**

(3)
(Total 6 mark)

Q9. In the circuit shown in the figure below, the battery, of negligible internal resistance, has an emf of 30 V. The pd across the lamp is 6.0 V and its resistance is 12 Ω.



(a) Show that the total resistance of the circuit is 20 Ω.

Parallel arrangement:
Top strand – in series so $R_{Tot} = R_1 + R_2$
= 18 + 12 = 30Ω (1 mark)
The two strands in parallel:
$1/R_{tot} = 1/R_1 + 1/R_2$
= 1/30 + 1/15 = 3/30
Rtot = 10Ω (1 mark)
This parallel arrangement is in series with a single resistor so overall resistance:
$R_{Tot} = R_1 + R_2$ = 10 + 10 = 20Ω **(1 mark)**

(3)

(b) Calculate

(i) the current supplied by the battery,

$\varepsilon = V = IR$ so $I = \varepsilon/R = 30/20 = 1.5$ A **(1 mark)**

(ii) the pd between the points A and B,

$pd_{AB} = 30 - (10 \times 1.5)$ **(1 mark)** = 15V **(1 mark)**

If you reason out a calculation – use words!

The resistance between AB is half the total resistance so it will get half of the voltage **(1 mark)** = 30/2 = 15V **(1 mark)**

(iii) the current in the lamp.

V = 6.0V R = 12W I = V/R = 6.0/12 = 0.50A **(1 mark)** (CARE with SF!!!)

(4)

(c) (i) What is the power of the lamp, in W?

Either $P = IV = 0.50 \times 6.0 = 3.0$ W

Or $P = I^2R = 0.50^2 \times 12 = 0.25 \times 12 = 3.0$W **(1 mark)**

(ii) What percentage of the power supplied by the battery is dissipated in the lamp?

power from battery = VI = 30 × 1.5 = 45W **(1 mark)**

3.0/45 × 100 = 6.7% **(1 mark)**

(3)
(Total 10 marks)

10. (a) For a conductor in the form of a wire of uniform cross-sectional area, give an equation which relates its resistance to the resistivity of the material of the conductor. Define the symbols used in the equation.

$R = \rho L/A$ **(1 mark)**

ρ is resistivity, L is the length of the wire, A is the cross-sectional area **(1mark)**

(2)

(b) (i) An electrical heating element, made from uniform nichrome wire, is required to dissipate 500 W when connected to the 230 V mains supply.

The cross-sectional area of the wire is 8.0×10^{-8} m^2. Calculate the length of nichrome wire required.

resistivity of nichrome = 1.1×10^{-6} Ω m

$P = \frac{V^2}{R}$ **(1 mark)**

$R = \frac{230^2}{500}$ = 106Ω **(1 mark)** (105.8 Ω)

$L = \left(\frac{RA}{\rho}\right) = \frac{105.8 \times 8.0 \times 10^{-8}}{1.1 \times 10^{-6}}$ = 7.7 m **(1 mark)** (7.69 m)

(ii) Two heating elements, each rated at 230 V, 500 W are connected to the 230 mains supply (A) in series, (B) in parallel.

Explain why only one of the circuits will provide an output of 1 kW.

In series the voltage across each element is less than 230 V because the pd is shared between them (they would only get 115V each **(1 mark)**

Therefore they will not be connected at the potential difference to give the power rating stamped on them. Power (= V^2/R) so it will be less than 500 W in each **(1 mark)**

In parallel the voltage across each element is the full 230 V **(1 mark)** they will both therefore be connected at the correct rating and each give out the 500W stamped on them. **(1 mark)**

[OR, **in series**, high resistance or combined resistance **(1 mark)** therefore they will run a low current **(1 mark)** in parallel, resistance is lower, therefore they will run a higher current **(1 mark)** and as Power = I^2R they will give out more power. **(1 mark)]**

(Max 6)

(Total 8 marks)