Cambridge International Examinations
Cambridge Pre-U Certificate

PHYSICS (PRINCIPAL) **9792/02**

Paper 2 Written Paper **May/June 2017**

PRE-RELEASED MATERIAL

The question in Section 2 of Paper 2 will relate to the subject matter in these extracts. You should read through this booklet before the examination.

The extracts on the following pages are taken from a variety of sources.
Cambridge International Examinations does not necessarily endorse the reasoning expressed by the original authors, some of whom may use unconventional Physics terminology and non-SI units.

You are also encouraged to read around the topic, and to consider the issues raised, so that you can draw on all your knowledge of Physics when answering the questions.

You will be provided with a copy of this booklet in the examination.

This document consists of **6** printed pages and **2** blank pages.

DC (RW/SG) 128733/4

Extract 1: What are rechargeable batteries?

Rechargeable batteries, unlike single-use batteries, are designed to be used over and over again. One rechargeable battery can substitute for hundreds of single-use batteries, so using rechargeable batteries can reduce the amount of waste generated. Some products are designed to use only rechargeable batteries.

More and more people are enjoying the convenience of rechargeable batteries. They are found in mobile and cordless telephones, video cameras, portable power tools, small appliances, and laptop computers. Approximately 80% of rechargeable batteries are currently composed of nickel (Ni) and cadmium (Cd) and are referred to as nickel-cadmium cells, Ni-Cads.

According to the Environmental Protection Agency, nickel-cadmium batteries pose no real risks while the battery is in use. However, the environmental release of cadmium can be of concern when the batteries are discarded with ordinary municipal waste. Cadmium can accumulate in the environment by leaching into groundwater and surface water from landfills, and it can enter the atmosphere through incinerator smokestack emissions.

Recycling programs can prevent these adverse effects of disposal by diverting batteries from the municipal waste stream. In 1995, the battery industry set up the Rechargeable Battery Recycling Corporation (RBRC) to administer the collection and recycling of rechargeable batteries. Individual households can take advantage of the program by bringing their used batteries to household hazardous waste collection centres or participating retailers.

adapted from: http://www.informinc.org

Extract 2: How a battery charger works

Rechargeable batteries are produced and used extensively today for different applications. But without a battery charger, these batteries can become quite worthless.

Introduction

Whether it's your mobile phone, emergency light or the vehicle you own, the extensive use of batteries is evident everywhere. Rechargeable batteries can be used in inverters, where a d.c. voltage is converted into mains a.c. voltage and is used to power the household appliances during mains power failure.

The importance of a battery lies in the fact that it is electricity that you can carry. Moreover, when the power in a battery gets exhausted, it can be refilled and topped up or charged by a charger. This is achieved when the charger forces an electric current backwards through the rechargeable battery.

Car battery charger

- A battery charger is basically a d.c. power supply source. Here a transformer is used to step down the a.c. mains input voltage to the required level as per the rating of the transformer.
- This transformer is always a high-power type and is able to produce a high-current output as required by most lead-acid batteries.
- A bridge rectifier configuration is used to rectify the low voltage a.c. into d.c. and is further smoothed by a high-value electrolytic capacitor.
- This d.c. is fed to an electronic circuit which regulates the voltage into a constant level and is applied to the battery under charge, where the energy is stored through an internal process of chemical reaction.

How to calculate the charging or discharging time of a battery

- The capacity of a rechargeable battery is the total charge that the battery can pass through an external circuit as it discharges.
- The rated capacity of a rechargeable battery may vary according to its applications. Its capacity is usually expressed in ampere-hour (Ah) or milliampere-hour (mAh). (1 Ah = 3600 coulomb)
- If for example a 4 Ah fully charged battery is discharged at 4-ampere rate, then ideally it should take an hour for it to get fully discharged.
- Similarly if the same battery is charged at 4-ampere rate, then it should take an hour to get it fully charged. In practice the charging process is inefficient so it would take longer than an hour.
- It is never good practice to try to fully charge a battery by using a large current to charge it in just one hour.
- Ideally the charging and the discharging process should be carried out gradually for about 10 hours.

How to use a battery charger

- A commercial battery charger will consist of two output terminals coloured red and black.
- It should also consist of an ammeter to display the charging current and a voltage selector switch.
- Begin by selecting the appropriate charging voltage as per the battery used.
- Taking due care of the polarity, connect the red terminal to the positive and the black to the negative of the battery under charge.
- Switch on, and the ammeter will instantly indicate the charging current. The battery will now gradually get charged, the ammeter reading will go down.
- Once the ammeter reading reaches the zero mark, it will mean that the battery is fully charged and may be disconnected from the charger.

adapted from: http://www.brighthubengineering.com/diy-electronics-devices/68123-how-a-battery-charger-works/

Extract 3: Charging a nickel-cadmium cell

Charging nickel-cadmium

Battery manufacturers recommend that new batteries be slow-charged for 16 to 24 hours before use. A slow charge brings all cells in a battery pack to an equal charge level. This is important because each cell within the nickel-cadmium battery may have self-discharged at its own rate. Furthermore, during long storage the electrolyte tends to gravitate to the bottom of the cell and the initial trickle charge helps redistribute the electrolyte to eliminate dry spots on the separator.

Battery manufacturers do not fully format the batteries before shipment. The cells reach optimal performance after priming that involves several charge/discharge cycles. This is part of normal use and can also be done with a battery analyser. Quality cells are known to perform to full specifications after only 5–7 cycles; others may take 50–100 cycles. Peak capacity occurs between 100–300 cycles, after which the performance starts to drop gradually.

Most rechargeable cells include a safety vent that releases excess pressure if incorrectly charged. The vent on a NiCd cell opens at 1 000 kPa–1 400 kPa (150–200 psi). Pressure release through a re-sealable vent causes no damage; however, with each venting, some electrolyte escapes and the seal may begin leaking. The formation of a white powder at the vent opening makes this visible, and multiple venting will eventually result in a dry-out condition. A battery should never be stressed to the point of venting.

Full-charge detection by temperature

Full-charge detection of sealed nickel-based batteries is more complex than that of lead acid batteries. Low-cost chargers often use temperature sensing to end the fast-charge, but this can be inaccurate. The core of a cell is several degrees warmer than the skin where the temperature is measured, and the delay that occurs causes over-charge. Charger manufacturers use 50 °C as temperature cut-off. Although any prolonged temperature above 45 °C is harmful to the battery, a brief overshoot is acceptable as long as the battery temperature will drop quickly when the “ready” light appears.

Advanced chargers no longer rely on a fixed temperature threshold, but sense the rate of temperature increase over time. Rather than waiting for an absolute temperature to occur, this method uses the rapid temperature increase towards the end of charge to trigger the “ready” light. This method keeps the battery cooler than a fixed temperature cut-off, but the cells need to charge reasonably fast to trigger the temperature rise. Charge termination occurs when the temperature rises at 1 °C per minute. If the battery cannot achieve the pace of temperature rise, an absolute temperature cut-off set to 60 °C terminates the charge.

Full-charge detection by voltage signature

Advanced chargers terminate charging when a defined voltage signature occurs. This provides more precise full-charge detection of nickel-based batteries than temperature-based methods. The charger looks for a voltage drop that occurs when the battery has reached full charge. This method is called negative delta V (NDV).

NDV works best with fast charging. A fast charge also improves charge efficiency. For example, if we try to charge a standard NiCd cell in one hour the efficiency is 91%. If we try to charge it in 10 hours the efficiency is only 71%.

During the first 70% of charge, the efficiency of a NiCd is close to 100%; the battery absorbs almost all energy and the pack remains cool. NiCd batteries designed for fast charging can be charged with high currents without much heat build-up. Ultra-fast chargers use this quality and charge to 70% in minutes. The full charge must be done with a reduced current.

Charge characteristics of a NiCd cell

Figure E3.1 shows the relationship of cell voltage, pressure and temperature of charging a NiCd cell.

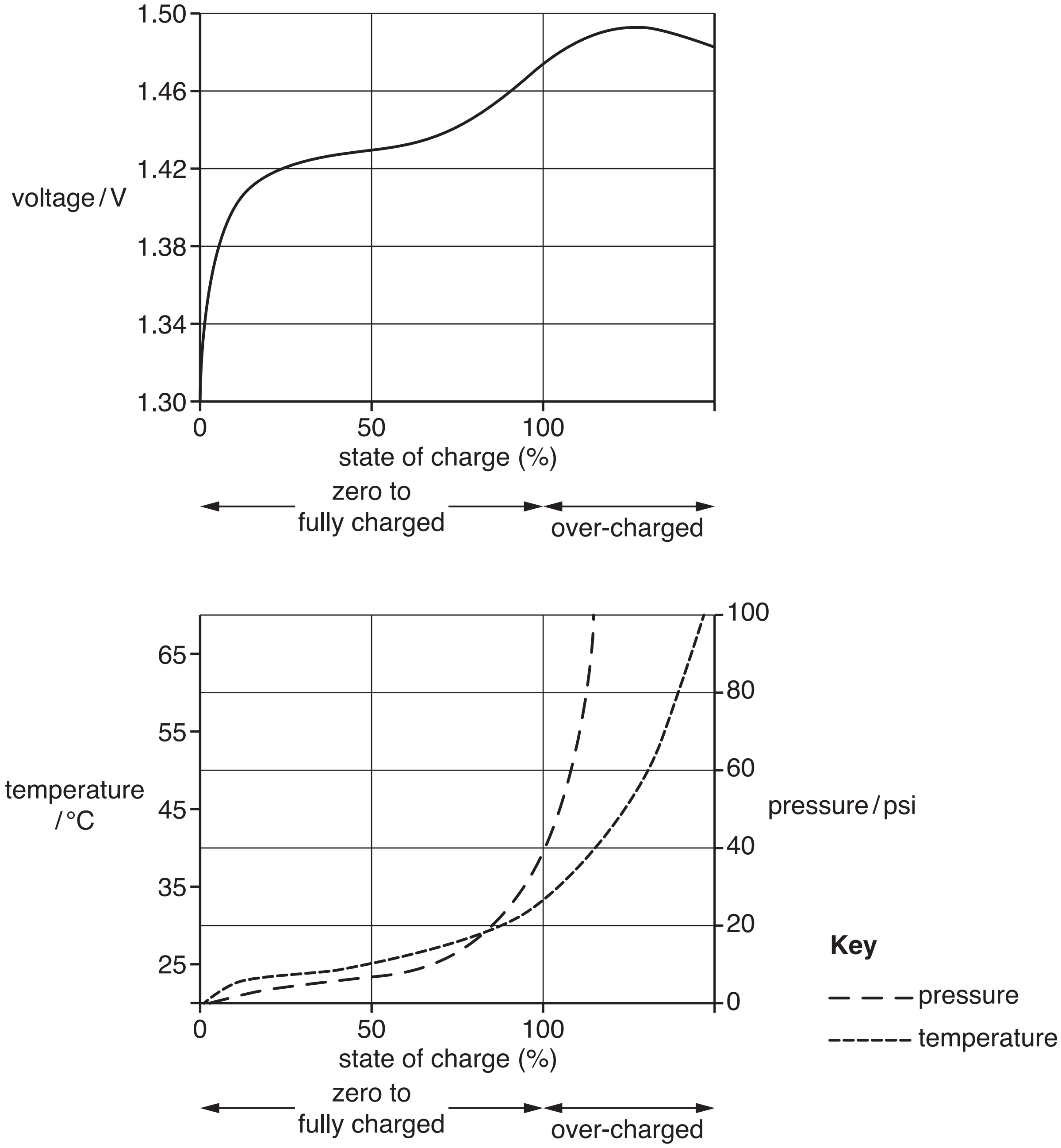

Fig. E3.1

adapted from: http://batteryuniversity.com/learn/article/charging_nickel_based_batteries

Extract 4: What is a diode?

A semiconductor diode consists of two pieces of semiconductor. When a potential difference is applied in one direction a current can flow across the boundary between these two pieces. When the potential difference is reversed, no current can flow.

A semiconductor diode is analogous to a valve in a heart or other mechanical pump. It allows one-way flow only. In electrical terms, it has low resistance when a potential difference is applied in the 'forward' direction, and very high resistance when a potential difference is applied in the 'reverse' direction.

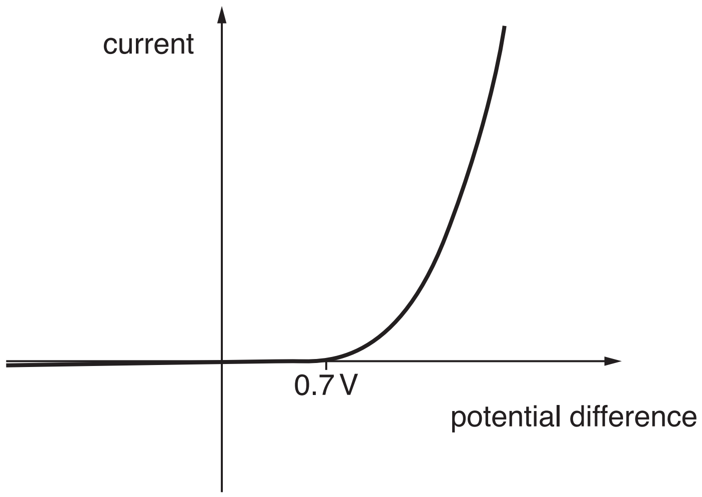

Fig. E4.1

The graph in Fig. E4.1 is the characteristic curve for a semiconductor diode. The graph shows that the diode does not conduct in the reverse direction but does conduct in the forward direction, once the potential difference reaches a certain value. This value is approximately 0.7 V.

Fig. E4.2 shows the circuit symbol for a diode.

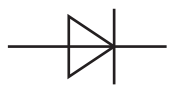

Fig. E4.2

The diode in Fig. E4.2 allows an electric current to flow from left to right but not from right to left.

adapted from: Advanced Physics, David Brodie

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