OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS B (ADVANCING PHYSICS) G495

Unit G495: Field and Particle Pictures

INSERT

Wednesday 2 February 2011
Afternoon

Duration: 2 hours

G410200111

INSTRUCTIONS TO CANDIDATES

- This insert contains the article required to answer the questions in Section C.

INFORMATION FOR CANDIDATES

- This document consists of **8** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER/INVIGILATOR

- Do not send this Insert for marking; it should be retained in the centre or destroyed.

Suited for Space

The astronomer Sir Fred Hoyle once remarked “Space isn’t remote at all. It’s only an hour’s drive away if your car could go straight upwards”. However one might get there, survival in space is not easy, for it is a hostile environment. Astronauts that have been for a “space walk” have done so dressed in carefully-designed suits that have developed over decades as mankind’s adventures have become increasingly daring. With hazards in mind, what are the important things to consider when designing a space suit?

To work in space, outside a spacecraft, astronauts must take their Earth-like environment with them in their suits. The suits must also protect the astronauts and allow them to move around as freely as possible to enable them to perform jobs.

Fig. 1: astronaut on a space walk

The Space Environment – a hazardous place

In space humans are deprived of essential things they have on Earth but they also have to cope with additional issues, largely based on the fact that space is a near-vacuum. Principal problems are:

- lack of air
- extreme temperatures (from +120 °C to –100 °C)
- micrometeoroids (fast-moving fragments of rock and dust)
- ionising radiation (primarily cosmic rays and the solar wind)
- working in a “weightless” environment

A successful space suit will cope with all of these problems; so, what does one consist of and how are these problems addressed?

The Structure of the Suit

The suit itself (known collectively as a Pressure Garment Assembly, PGA) has several basic components. There are many attachments added to enable things like radio communication and drinking (replacing fluids) to take place; the exact number of components will depend upon the nature of the mission, but some are common to all. The main components are:

The Liquid Cooling and Ventilation Garment (LCVG)

This is the first layer the astronaut puts on. It is tight-fitting and, among other things, keeps the astronaut cool. Water is circulated through a network of tubes in contact with the skin; the heated water flows to a back-pack (the Primary Life Support System) where it cools by radiating heat into space, before being circulated through the LCVG again. The system can typically lose heat at a rate of up to 600 W.

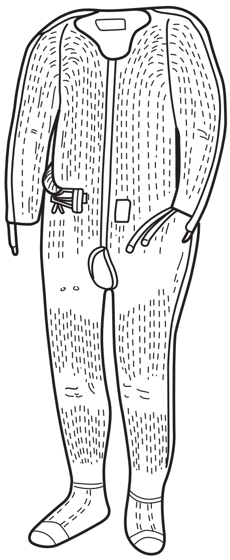

Fig. 2: the Liquid Cooling and Ventilation Garment

Nylon Bladder

This is a rubbery, airtight layer which covers the LCVG. Its function is primarily to contain the breathing air, rather like a balloon. It, in turn, is covered by an outer Nylon Restraint garment, a net-like structure which helps maintain the shape of the Nylon Bladder. Atmospheric pressure decreases roughly exponentially with altitude, as shown in Fig. 3. At altitudes greater than about 19 km, spacesuits with a contained atmosphere are required for breathing. These suits are maintained at a pressure which prevents body fluids from boiling. The pressure inside the suit is typically around 30 kPa, significantly less than atmospheric pressure. However, the gas in the suit is almost 100% oxygen, which allows the astronaut to breathe at this reduced pressure.

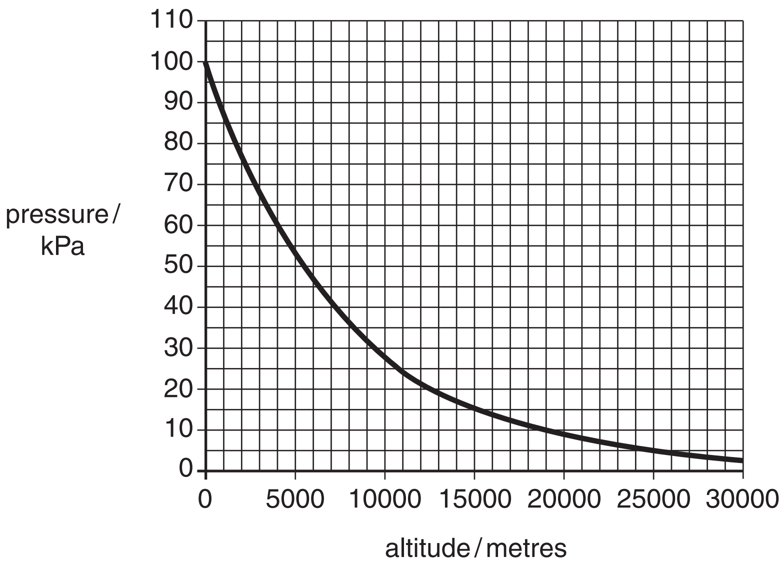

Fig. 3: variation of atmospheric pressure with altitude

The Thermal Micrometeoroid Garment (TMG)

This is the outer garment, the main part of the suit, put on in two sections (upper and lower torso), along with the arms and gloves. It acts as armour against impacting dust and micrometeoroids. It also provides thermal and cosmic ray protection. The TMG comprises several layers, some of which are composite materials. The three main layers, starting with the innermost, are:

- a synthetic rubber – a thermally-insulating, flexible and tear-resistant material of the sort used in wet suits
- PTFE-coated silica fibre – rather like a thin layer of fibre glass. It is fireproof and coated with extremely non-abrasive PTFE, which is used on non-stick cooking equipment.
- a polymer, thinly coated with aluminium – very high tensile strength, chemically very un-reactive and with a high reflectivity and very resistant to puncture. (This is the outermost layer of the garment.)

The suit is coloured white, maximising reflectivity to enable effective temperature control.

Fig. 4: the Thermal Micrometeoroid Garment

The Helmet and Sun Visor

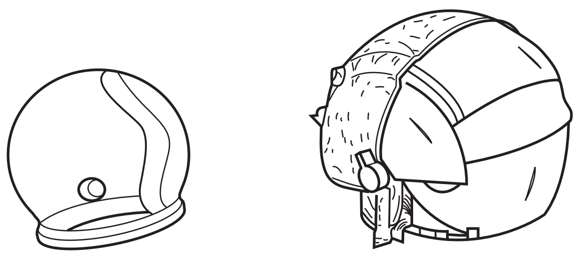

Fig. 5: the helmet and sun visor

These are the final parts of the suit to be put on. The helmet has similar layers to the TMG, whilst the visor is needed to protect the eyes from sunlight.

Protection

The space in which the Earth orbits is littered with tiny fragments of ancient dust (often from comets). Although such particles may be low in mass (less than 10^{-6} kg), their velocity relative to an astronaut on a space walk could be several tens of km s^{-1} and impact can potentially cause a great deal of damage. Some could penetrate the outer layers of the suit, but even if they don't, they can cause severe degradation of the suit as they vaporize on impact.
The solar wind is another hazard to protect against. This is the stream of charged particles moving at high speed, continuously emitted by the Sun at a typical rate of a million tonnes per second. At Earth's distance, this amounts to a solar wind flux (the number of particles passing perpendicularly through unit area every second) of more than 10^{12} m^{-2} s^{-1}.
There are also galactic cosmic rays to worry about, streams of sub-atomic particles from beyond the solar system, 90% of which are protons. The energies of these particles typically range from about 100 MeV to about 10 GeV, but some with energies as high as 10^{11} GeV have been detected, against which present suits offer little protection.

Mobility

Moving around dressed in a space suit is difficult, especially when in a state of constant freefall, with no planetary surface providing a reaction force. The suits have a mass of around 50 kg. An astronaut of 75 kg would therefore have a total mass of 125 kg. A Mobile Manoeuvring Unit (MMU) attached to the suit enables the astronaut to move by firing jets of gas in different directions. MMU thrusters can enable delicate movements to be made, but can also propel the astronaut to speeds of up to 20 m s^{-1}.
The arm and leg joints of the suit are designed to allow the astronaut as much limb mobility as possible. Another problem which needs to be overcome with these joint designs is the change in internal volume of the suit produced when a joint is flexed. If the pressure inside the suit is increased by decreasing the volume, the astronaut would need to work harder in order to move. The design of "constant volume" joints helps to remove this problem.

Future Considerations

The most sophisticated space suits of the current generation have been largely designed to be worn in "zero-gravity" conditions, for missions involving space walks to repair satellites. Future missions might well involve a return to the Moon, or even venture to Mars for the first time. The suits worn by the first Moon-walkers were very different from those of today and new suits to be worn on the Moon today would be much improved. Mars, meanwhile, will present even greater challenges.

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