Cambridge Pre-U

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
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Principal Subject

PHYSICS **9792/02**

Paper 2 Part A Written Paper **May/June 2012**

PRE-RELEASED MATERIAL

The question in Section B 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.
University of 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 **8** printed pages.

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UNIVERSITY of CAMBRIDGE
International Examinations

Extract 1: How Maglev Trains Work

If you've been to an airport lately, you've probably noticed that air travel is becoming more and more congested. Despite frequent delays, aeroplanes still provide the fastest way to travel hundreds or thousands of miles. Passenger air travel revolutionised the transport industry in the last century, letting people traverse great distances in a matter of hours instead of days or weeks.

Fig. E1.1 The first commercial maglev line made its debut in December of 2003.

The only alternatives to aeroplanes – feet, cars, buses, boats and conventional trains – are just too slow for today's fast-paced society. However, there is a new form of transport that could revolutionise transport in the 21st century the way aeroplanes did in the 20th century.

A few countries are using powerful electromagnets to develop high-speed trains, called maglev trains. Maglev is short for magnetic levitation, which means that these trains will float over a guideway using the basic principles of magnets to replace the old steel wheel and track trains. This is known as electromagnetic suspension.

Electromagnetic Suspension (EMS)

If you've ever played with magnets, you know that opposite poles attract and like poles repel each other. This is the basic principle behind electromagnetic propulsion. Electromagnets are similar to other magnets in that they attract other magnetic objects, but the magnetic pull is temporary.

There are three components to the maglev system:

- a large electrical power source
- metal coils lining a guideway or track
- large guidance magnets attached to the underside of the train

The big difference between a maglev train and a conventional train is that maglev trains do not have an engine – at least not the kind of engine used to pull typical train carriages along steel tracks. The engine for maglev trains is rather inconspicuous. Instead of using fossil fuels, the magnetic field created by the electrified coils in the guideway walls and the track combine to propel the train.

Fig. E1.2 An image of the guideway for the Yamanashi maglev test line in Japan

Adapted from: Bonsor, Kevin. “How Maglev Trains Work” 13 October 2000. HowStuffWorks.com. <http://science.howstuffworks.com/transport/engines-equipment/maglev-train.htm> 11 January 2011.

Extract 2: The Shanghai Airport Maglev

Fig. E2.1 Transrapid train emerges from the stylish station in Shanghai

Construction began in April 2001 of the first commercial Transrapid system. Despite the fact that the maglev was the first revenue-producing point-to-point high-speed maglev in the world, the system was up and running by 2004. The 30 km line runs between Pudong Shanghai International Airport and the Shanghai Lujiazui financial district. An end-to-end ride takes about eight minutes. A world record for commercial maglev systems was set on November 12, 2003. A five-section train achieved the top speed of 501 km/h (311 mph) while another vehicle passed at 430 km/h (267 mph) on the adjacent track. The Transrapid in Shanghai has a design speed of over 500 km/h and a regular service speed of 430 km/h. Shanghai Maglev is the fastest railway system in commercial operation in the world. Other maglev lines are under consideration in China.

Fig. E2.2 History-making maglev speeds between stations

Adapted from: http://www.monorails.org/tmspages/magshang.html

Extract 3: Trains without wheels or friction

Introduction

The principle of a magnet train is that it floats on a magnetic field and is propelled by a linear induction motor. The train follows guidance tracks with magnets. These trains are often referred to as *Magnetically Levitated* trains – abbreviated to *maglev*.

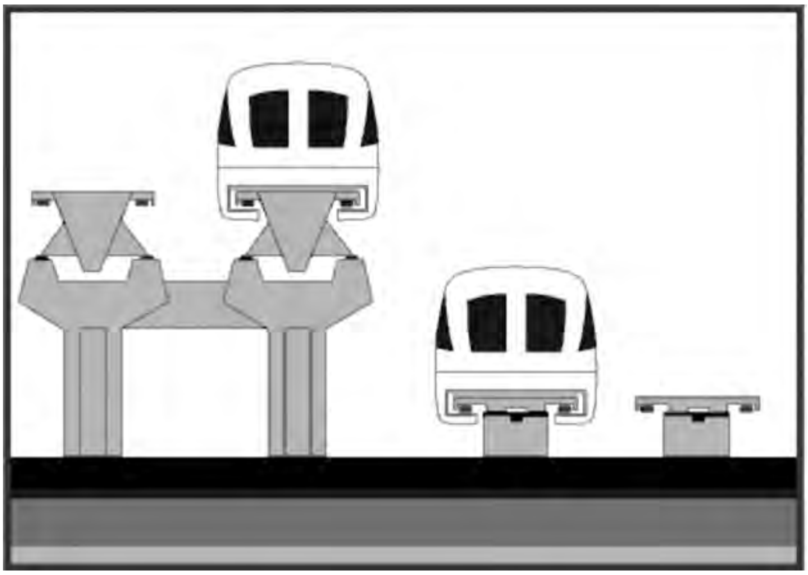

Fig. E3.1

How it works

A maglev train floats about 10 mm above the guideway on a magnetic field. It is propelled by the guideway itself, rather than an onboard engine, by changing magnetic fields (see below). Once the train is pulled into the next section the magnetism switches so that the train is pulled on again. The electromagnets run the length of the guideway.

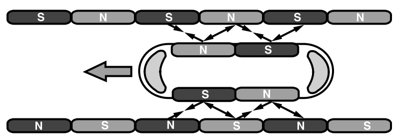

Fig. E3.2

What is the advantage of Maglev?

Well it sounds high-tech, a floating train, they do offer certain benefits over conventional wheel-on-rail railways. The primary advantage is maintenance. Because the train floats along there is no contact with the ground and therefore no need for any moving parts. As a result there are no components that would wear out. This means that *in theory* the trains and track would need no maintenance at all. The second advantage is that because maglev trains float, there is no friction. Note that there will still be air resistance. A third advantage is less noise; because there are no wheels running along there is no wheel noise. However noise due to air disturbance still occurs. The final advantage is the high speed. This last advantage is a consequence of the other three. It is possible for conventional trains to travel extremely fast, say 500 km/h or 300 mph, but it is not economically viable. Another advantage is that the guideway can be made a lot thicker in places, e.g. after stations and going uphill, which would mean a maglev could accelerate to 300 km/h (186 mph) in only 5 km where a conventional train takes 18 km. Furthermore, greater gradients would be manageable.

What are the disadvantages of Maglevs?

There are several disadvantages with maglev trains. Maglev guide paths are bound to be more costly than conventional steel railways. The other main disadvantage is the lack of existing infrastructure. For example, if a high speed line between two cities is built, then high speed trains can serve both cities but more importantly they can serve other nearby cities by running on normal railways that branch off the high speed line. The high speed trains could go for a fast run on the high speed line, then come off it for the rest of the journey. Maglev trains wouldn't be able to do that as they would be limited to where maglev lines run. This would mean it would be very difficult to make construction of maglev lines commercially viable unless there were two very large destinations being connected. Of the 5000 km that TGV trains serve in France, only about 1200 km is high speed line, meaning 75% of TGV services run on existing track. The fact that a maglev train will not be able to continue beyond its track may seriously hinder its usefulness.

Are maglevs really more environmentally friendly?

In terms of energy consumption, maglev trains are slightly better off than conventional trains. This is because there is no wheel-on-rail friction. That said, the vast majority of the resistive force at high speed is air resistance which means the energy efficiency of a maglev is only slightly better than a conventional train.

German engineers also claim that a maglev guideway takes up less room and because greater gradients are acceptable there need not be so many cuttings and embankments, meaning that a new guideway would be less disruptive to the countryside than a new high speed conventional railway.

Will maglevs replace conventional trains?

Provided maglev can be proved to be commercially viable (which has not yet been done) it should be a success. Most people have their eyes on Germany, where the first maglevs will run in commercial service. This may decide whether or not maglevs will be used across the world. Maglev may become the preferred path for new high-speed railway lines although it would depend whether or not services were needed to stretch beyond a high speed line. For example, if you have 300 km of conventional track between two cities cleared for over 200 km/h but there was a 60 km long section only cleared for 80 km/h then it would make sense to build a new high speed (300 km/h) line for the 60 km distance. If a maglev train were to be used a track 300 km long would have to be built.

Whether or not new railway lines stop being built in favour of maglevs, one thing is certain, with 31 932 km of track in the UK, 34 449 km in France and 40 726 km in Germany, no one is going to convert all of this into maglev track. Conventional trains are here to stay for a long time.

Adapted from: http://www.o-keating.com/hsr/maglev.htm

Extract 4: Linear induction motors

Linear motors are electric motors that produce motion in a straight line rather than rotational motion. In a traditional electric motor, the rotor (rotating part) spins inside the stator (static part); in a linear motor, the stator is unwrapped and laid out flat and the “rotor” moves past it in a straight line. Linear motors often use superconducting magnets, which are cooled to low temperatures to reduce power consumption.

Fig. E4.1 Photo: NASA tests a linear motor on a prototype Maglev railroad, 1999. Tracks like this could be used to launch vehicles into space in future.

The basic principle behind the linear motor was discovered in 1895, but practical devices were not developed until 1947. It was at this time that British electrical engineer Eric Laithwaite started to consider whether linear motors could be used in electric weaving machines. Laithwaite’s research at Imperial College, London attracted international recognition in the 1960s following a speech to the Royal Institution entitled “Electrical Machines of the Future.”

Linear motors are now used in all sorts of machines that require linear (as opposed to rotational) motion, including overhead travelling cranes and beltless conveyors for moving sheet metal. They are probably best known as the source of motive power in the latest generation of high-speed “maglev” (magnetic levitation) trains, which promise safe travel at very high speeds but are expensive and incompatible with existing railroads. Most research on maglev trains has been carried out in Japan and Germany.

Linear motors have a number of advantages over ordinary motors. Most obviously, there are no moving parts to go wrong. As the platform rides above the track on a cushion of air, there is no loss of energy to friction or vibration (but because the air-gap is greater in a linear motor, more power is required and the efficiency is lower). The lack of an intermediate gearbox to convert rotational motion into straight-line motion saves energy. Finally, as both acceleration and braking are achieved through electromagnetism, linear motors are much quieter than ordinary motors.

Superconducting magnets

The main problem with linear motors has been the cost and difficulty of developing suitable electromagnets. Enormously powerful electromagnets are required to levitate (lift) and move something as big as a train, and these typically consume substantial amounts of electric power. Linear motors often now use superconducting magnets to solve this problem.

If electromagnets are cooled to low temperatures using liquid helium or nitrogen their electrical resistance disappears almost entirely, which reduces power consumption considerably. This helpful effect, known as superconductivity, has been the subject of intense research since the mid 1980s and makes large-scale linear motors that much more viable.

Adapted from: http://www.explainthatstuff.com/linearmotor.html

Extract 5: Pros and cons of maglev and conventional trains

Due to the lack of physical contact between the track and the vehicle in a maglev system, there is no rolling friction. There is only air resistance and a very small amount of electromagnetic drag.

Maglevs can handle high volumes of passengers per hour (comparable to airports or eight-lane highways) and do it without introducing air pollution along the track. Of course, the electricity has to be generated somewhere, so the overall environmental impact of a maglev system is dependent on the nature of the grid power source.

The weight of the large electromagnets in maglev designs is a major issue. A very strong magnetic field is required to levitate a massive train. For this reason one research path is using superconductors to improve the efficiency of the electromagnets.

The high speed of some maglev trains translates to more sound due to air displacement, which gets louder as the trains go faster. A study found that high speed maglev trains are 5 dB noisier than traditional trains. At low speeds, however, maglev trains are nearly silent.

From: http://www.newworldencyclopedia.org/entry/Maglev_train