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Wednesday 15 May 2019 – Morning

Level 3 Certificate
Quantitative Problem Solving (MEI)

H867/01 Introduction to Quantitative Reasoning

Insert

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NOTES FOR GUIDANCE (CANDIDATES)

- This insert contains a copy of the pre-release material for use with the question paper.
- This document consists of **8** pages.

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A Making an investment

There are various ways of making an investment.

Investing in **precious metals** like gold or platinum can produce a good return, but their value can go down, and in that case some of the original investment is lost. Table A1 shows the annual average price of gold from 2000 to 2016 in £ per troy ounce. It also shows the indexed price.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Price (£/troy ounce)	183.7	190	215.7	232.5	226.9	298.8	322.9	418.8	604.9
Indexed price (2000 = 100)	100	103	117	127	124	163	176	228	329

Year	2009	2010	2011	2012	2013	2014	2015	2016
Price (£/troy ounce)	673.4	897.7	985.1	1019.7	727.2	773.4	719.2	927.4
Indexed price (2000 = 100)	367	489	536	555	396	421	392	505

Table A1

Premium Bonds are 100% safe because the money invested is never lost. There is the possibility of winning some money and actually increasing the investment; there is a draw each month. The amount of money given in prizes and the number of winning bonds depend on how many bonds are held at that time. At the time of writing, about £85 million in prizes is shared out each month to about 3 million winning bonds. Table A2 shows the frequency of the different prizes in a month when the prize fund is £83 829 075 and the number of premium bonds winning prizes is 2 932 798.

Prize	£1 million	£100 000	£50 000	£25 000	£10 000	£5000
Frequency	2	4	10	17	43	87

Prize	£1000	£500	£100	£50	£25
Frequency	1677	5031	22 984	22 984	2 879 959

Table A2

Savings accounts pay a guaranteed rate of compound interest, but the interest is greatly reduced if the money is taken out before the agreed time.

Another form of investment is to buy something that will **save money** in the long run. An example of this is double glazing. An important feature of this type of investment is the payback time. This is the length of time to get back the cost of making an investment, so for double glazing:

$$\text{Payback time in years} = \frac{\text{Total cost of installing and maintaining the double glazing}}{\text{Annual saving made to heating bill because of the double glazing}}.$$

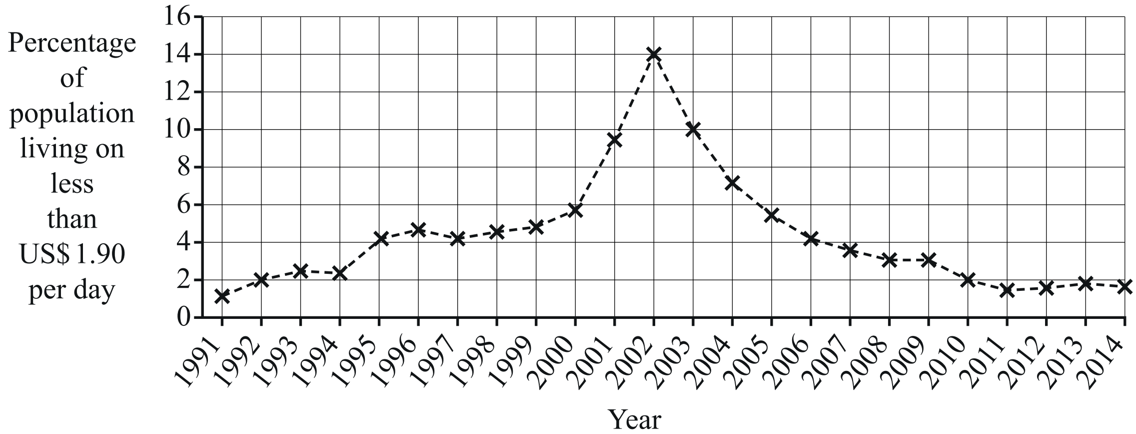
As a rough rule the shorter the payback time the better the investment.
If the payback time for some double glazing was 25 years, fuel prices may have risen over the 25 years, making the saving more than was originally thought. Other types of investment similar to double glazing are solar panels, solar water heating or underfloor heating.

B Measuring poverty

There are large differences in wealth and poverty between and within countries. This article outlines different approaches to measuring poverty.

Absolute poverty describes the situation of someone with an income below that which is considered to allow a person to just about manage. The World Bank recently set an income of US$ 1.90 a day as being this poverty line. Below this line people are considered to be poor.

Graph B1 shows the percentage of people in Argentina living below the poverty line of US$ 1.90 per day from 1991 to 2014. So in 2002 14% of Argentina's population (5.3 million out of 37.9 million) were living on less than US$ 1.90 a day.



Graph B1

Other methods of poverty measurement used by a number of countries and organisations to measure the poverty or wealth of a group or a whole country include the following.

- The proportion of people whose daily food intake is less than 2000 kcal.
  (Most people would agree that someone who is not getting sufficient nutrition must be poor.)
- The proportion of people who cannot buy a bundle of essential goods.
  (This can include fresh fruit, footwear, clothing, etc.)
- The proportion of people whose living conditions do not meet certain criteria.
  (These may include running water, electricity and protection from the rain.)
- The proportion of total income spent on food.
  (This involves calculating $\frac{\text{Amount spent on food}}{\text{Total income}}$ and is called **Engel's coefficient**.
  For example, for Japan in 2016 the average family had an income of 261 400 yen and spent 69 960 yen of this on food, giving an Engel's coefficient of $\frac{69\,960}{261\,400} \approx 0.27$. It will tend to be larger for poorer groups or countries. For the richest 20% in the US, 2004–2009, it had a value of 0.05, but a value of 0.35 for the poorest 20%.)

Relative poverty describes the situation of someone with an income which is a certain amount or proportion below the average income for that country or region. For example, the average income in the US a few years ago was $124 a day. Someone with an income of a tenth of this a day, $12.40, very much below the average, might be considered below the poverty line. However, in terms of the absolute poverty line of $1.90 a day, such a person would be well above it. Questionnaires can be used to find out how rich or poor people feel they are. Typical questions may include: 'When you think of your situation today, do you think of yourself as poor?'

C Cloudiness in rivers, lakes and the sea

Water absorbs light. Even in pure water it is difficult to see further than about 100 metres. At depths of more than several hundred metres the intensity of sunlight from the surface is reduced to almost zero. Particles present in river or seawater also tend to make the water cloudy. Cloudiness therefore indicates that pollution may be present.

One way to measure the cloudiness of water is to calculate the **extinction coefficient**.
An extinction coefficient is calculated as follows.

- The intensity of sunlight on the surface is set at 100 units.
- The depth, in metres, at which the sunlight intensity is reduced to 37 units is found.
- The reciprocal of this depth is the extinction coefficient.

An extinction coefficient is a number per metre of depth and so its unit is written as m^{-1}.

Extinction coefficients are used to measure pollution. As a rough guide, the greater the extinction coefficient, the greater the pollution.

Another measure of cloudiness is the **Secchi depth**. This is found using a **Secchi disc**. This disc is usually 20 cm diameter with black and white quadrants, as shown in Figure C1.

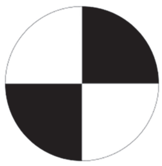


Figure C1

- The disc is lowered into the water until it can no longer be seen, as shown in Figure C2.

Figure C2

- This depth at which it can no longer be seen is recorded.
- The disc is then raised until it can just be seen again and this depth is recorded.
- The mean of the two depths is called the Secchi depth.

The smaller the Secchi depth the cloudier the water is.

D The transit method (for detecting exoplanets)

Humans have always wondered if there might be life elsewhere in the universe. A first step in addressing this question is to estimate how many stars are orbited by planets. Our star, the Sun, has eight major planets, including the Earth. The Sun and the planets are all part of the solar system.

Planets orbiting another star (other than the Sun) are called **exoplanets**. All stars are vast distances away and so it is very unlikely that any exoplanets will actually be seen by telescopes. However, there are now several methods which in certain circumstances can be used to detect the probable presence of an exoplanet.

The **transit method** detects an exoplanet by the small dip in a star's brightness when the exoplanet passes in front of it. This is called a transit. The distance from Earth to the star compared with the distance between the star and the exoplanet is so great that the star and exoplanet can both be modelled as circles, as shown in Figure D1.

Figure D1

The observed brightness of the star is directly proportional to the visible area of the star.
The area of the star, modelled as a circle facing the observer, is πR^2 and similarly the area of the planet is πr^2, where R is the radius of the star and r the radius of the planet.

So during transit the brightness of the star dips by the fraction $\frac{\pi r^2}{\pi R^2}$.

This leads to the formula $\frac{r}{R} = \sqrt{\frac{\text{Dip in brightness}}{\text{Normal brightness}}}$

So the brightness of the star before and during a transit allows the ratio of the exoplanet's radius to the star's radius to be calculated.

Most stars are so distant that their images are only a few pixels, as shown in Figure D2. Many readings have to be taken in order to detect a very small dip.

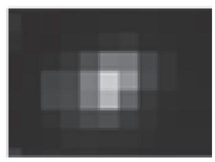
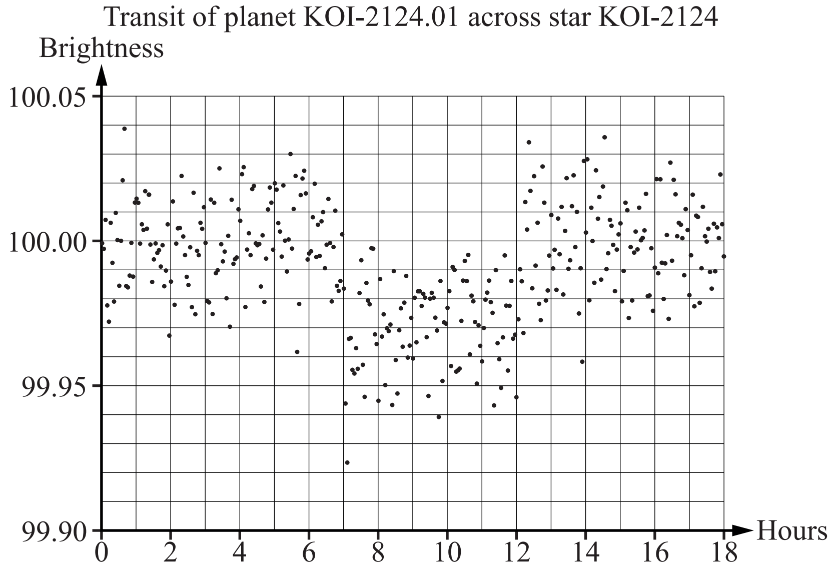


Figure D2

Graph D3 shows a typical set of brightness readings for the transit method. It is for one of the first exoplanets detected by the method.



Graph D3

The method has one serious disadvantage: transits can only be observed if the exoplanet passes directly between the star and the observer. The diagrams in Figure D4 illustrate one case when a transit can be seen (✓) and several where transits cannot be seen (✗). S represents the star and P the planet.

Figure D4

E Electrical energy

Electrical energy is measured in kilowatt hours, abbreviated to kWh. 1 kWh is also called '1 unit'. A 12-watt LED bulb left on for 3 hours uses $0.012 \times 3 = 0.036\,\text{kWh}$ of electrical energy. A 3 kW heater left on for 2 hours continuously uses 6 kWh (6 units) of electrical energy.

Electricity is sold by the kWh. In 2016 the average UK price for electricity was 14.05 p per kWh. At this rate a 12-watt LED bulb left on for 3 hours would cost $0.036 \times 14.05 = 0.5058\,\text{p}$.

A modern power station can, in a single day, produce 5000 MWh of energy. A MWh (megawatt hour) is one million or 10^6 watt hours or one thousand kWh.

Electrical power is the rate at which energy is being produced or used. It is measured in watts (W). When an electrical source produces 1000 watts for 1 hour, this amounts to 1 kilowatt hour or 1 kWh of energy.

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