**Pearson Edexcel Level 3 Certificate in Mathematics in Context**

**PRACTICE TASK: EARTHQUAKES**

**Data source A**

In Britain we are fortunate that we do not live in an earthquake zone. In some parts of the world, for example California or Japan, they are an intense object of study.

The size of an earthquake is measured with a seismometer which records the tremors in the Earth caused by an earthquake. The size of the earthquake can be described using, for example, the Richter scale (see Table 1).

**Table 1: The magnitude scale for earthquakes**

|  |  |  |  |
| --- | --- | --- | --- |
| **Magnitude**  ***m*** | **Approximate TNT equivalent  energy released** | **Energy released** | **Notes** |
| 0.0 | 15 g | 63 kJ |  |
| 1.0 | 480 g | 2.0 MJ |  |
| 1.2 | 1.1 kg | 4.9 MJ | Single stick of dynamite |
| 2.0 | 15 kg | 63 MJ |  |
| 3.0 | 480 kg | 2.0 GJ |  |
| 4.0 | 15 tons | 63 GJ |  |
| 5.0 | 480 tons | 2.0 TJ | [Lincolnshire earthquake (UK), 2008](http://en.wikipedia.org/wiki/2008_Lincolnshire_earthquake) |
| 5.6 | 3.8 kilotons | 16 TJ | [Pernik, Bulgaria, 2012](http://en.wikipedia.org/wiki/2012_Pernik_earthquake) - most recent in Europe |
| 6.0 | 15 kilotons | 63 TJ | [Little Boy](http://en.wikipedia.org/wiki/Little_Boy) - atomic bomb dropped on [Hiroshima](http://en.wikipedia.org/wiki/Hiroshima) |
| 7.0 | 480 kilotons | 2.0 PJ | [Haiti earthquake, 2010](http://en.wikipedia.org/wiki/2010_Haiti_earthquake) |
| 8.0 | 15 megatons | 63 PJ | [Sichuan earthquake (China), 2008](http://en.wikipedia.org/wiki/2008_Sichuan_earthquake) |
| 9.0 | 480 megatons | 2.0 EJ | [The Great East Japan earthquake, March 2011](http://en.wikipedia.org/wiki/2011_T%C5%8Dhoku_earthquake_and_tsunami) |
| 9.2 | 950 megatons | 4.0 EJ | [Sumatra earthquake and tsunami (Indonesia), 2004](http://en.wikipedia.org/wiki/2004_Indian_Ocean_earthquake) |
| 9.5 | 2.7 gigatons | 11 EJ | [Valdivia earthquake (Chile), 1960](http://en.wikipedia.org/wiki/1960_Valdivia_earthquake) |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Prefix** | k(ilo) | M(ega) | G(iga) | T(era) | P(eta) | E(xa) |
| **Power** | 103 | 106 | 109 | 1012 | 1015 | 1018 |

**Data source B**

Earthquakes release huge amounts of the energy that has been built up in the Earth’s crust.

The relationship between the magnitude, *m,* and the energy released, *E* joules, when an earthquake occurs is

*E* = 10(4.8 + 1.5*m*)

An earthquake produces P waves and S waves.



Seismometer

P waves

S waves

Focus

P waves travel at an average speed of about 7.5 km/s and S waves at about 4 km/s out from the focus.

It is possible to find how far an earthquake is by   
using the different times of arrival of the two  
types of wave at the seismometer (the detector) by using



Where *D* km is the distance to the focus and *T* seconds is the difference in the arrival times of the two types of wave.

An earthquake that occurs under the sea can generate a tsunami - a wave that can be hundreds of kilometres in extent, but in deep water just 1 metre high, becoming destructive only when it encounters shallow water. The speed in metres per second of a tsunami is given by

speed =  where *d* is the depth of the (deep) water in metres.

**Data source C**

The table shows information about the numbers of earthquakes from 2004 to 2013.

**Table** **2: The distribution of the magnitude of earthquakes 2004 - 2013**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Magnitude *m*** | 4 | 5 | 6 | 7 | 8 |
| **Number of earthquakes N(*m*) of magnitude ≥ *m*** | 187000 | 18909 | 1661 | 161 | 17 |

The number follows closely a rule of the form N(*m*) = 10*a - bm* , where *a* and *b* are constants.

The diagram shows a plot of how this power of 10 behaves with increasing *m*.

**Data source D**

Earthquakes can cause tremendous damage.

Here is a list of the most damaging in recent times.

**Table 3: The most damaging earthquakes of recent times**

| **Rank** | **Name** | **Magnitude** | **Property damage ($billions)** |
| --- | --- | --- | --- |
| 1 | 2011 Tōhoku, Japan | 9 | 235 |
| 2 | 1995 Great Hanshin, Japan | 6.9 | 100 |
| 3 | 2008 Sichuan, China | 8 | 75 |
| 4 | 2011 Christchurch, New Zealand | 6.3 | 40 |
| 5 | 2010 Chile, Chile | 8.8 | 22.5 |
| 6 | 1994 Northridge, USA | 6.7 | 20 |
| 7 | 2012 Emilia, Italy | 6.1 | 13.2 |
| 8 | 1989 Loma Prieta, USA | 7 | 11 |
| 9 | 1999 Taiwan | 7.6 | 10 |
| 10 | 1906 San Francisco, USA | 7.8 | 9.5 |

**1 Refer to data source A**

(a) Which has the larger energy – an earthquake releasing 3 × 1014 J or an earthquake releasing 40 terajoules (TJ)?

Give a reason for your answer.

**(2)**

(b)The largest man-made explosion was Tsar Bomba, a thermonuclear device detonated in 1961, which had a magnitude of 8.35.

(i) Work out the energy release of this explosion in joules.

(ii) Work out the energy release in tons of TNT.  
 Give a reason for your answer.

**(4)**

(c)Compare the energy releases from two earthquakes which differ in magnitude by 1.

**(3)**

**2 Refer to data source B**

An earthquake occurs 180 km away from a seismometer.

(a) (i) Work out the difference in the arrival times of the P wave and the S wave.

**(2)**

The first arrival of a P wave from a different earthquake is registered at 18:01:48 at the seismometer and the first arrival of the S wave at 18:02:16

(ii) Work out the distance of the focus of the earthquake from the seismometer.

**(3)**

The Japan earthquake of 2011 generated a tsunami which eventually reached Chile, 17 000 km away. The earthquake happened in Japan on 11th March at 14:46 (local time).

The local time in Chile is 12 hours behind the local time in Japan.

(b)Assuming the depth of the water to be 3 km, predict the local time of day in Chile at which the tsunami should have arrived.

**(5)**

**3 Refer to data source C**

The table and graph from data source C are reproducedbelow.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Magnitude *m*** | 4 | 5 | 6 | 7 | 8 |
| **Number of earthquakes N(*m*) of magnitude ≥ *m*** | 187000 | 18909 | 1661 | 161 | 17 |

2

4

6

2

4

6

8

10

0

Power of 10 (*y*)  
 *y*

magnitude *m*

1. (i)Use the graph and the law N(*m*) = 10*y* = 10*a – bm* to estimate the number of earthquakes with a magnitude of 4.5 or greater in the 10 year interval 2004‑2013.

**(2)**

(ii) For the frequency/magnitude law diagram, calculate the values of *a* and *b* in the law N(*m*) = 10*y* = 10*a - bm*

You can use any of the following summary figures.

Σ*m* = 30, Σ*y* = 16.21 Σ*m*2 = 190 Σ*y*2 = 62.84 Σ*my* = 87.08

**(4)**

(b)Use your results to predict

1. the number of earthquakes with magnitude of 3 or greater in a year

(ii) how often an earthquake with a magnitude of 9 or greater should occur.

Comment on the reliability of your answers.

**(6)**

**4 Refer to data source D**

Here is a graph to show damage costs and magnitudes for the 10 most destructive earthquakes of recent times.

(a) Make 2 comments about the scatter diagram.

**(2)**

(b) (i) Find the standard deviation of the costs.

Use Σcosts = 536.2, Σcosts2 = 73842 (where costs are in $billions)

1. Describe briefly the effect on the standard deviation of removing the largest cost.

**(3)**

**Total 36 marks**

**Source information**

Table 1 adapted from ‘Richter magnitude scale', http://en.wikipedia.org/wiki/Richter\_magnitude\_scale, granted under the GNU Free Documentation License (GFDL); Table 2 ' Number of Earthquakes by Year, 2012' adapted from <http://earthquake.usgs.gov/earthquakes/eqarchives/year/eqstats.php>, Source: U.S. Geological Survey Department of the Interior/USGS, <http://www.usgs.gov/>; and Table 3 adapted from ‘Lists of Earthquakes', http://en.wikipedia.org/wiki/Lists\_of\_earthquakes, granted under the GNU Free Documentation License (GFDL).