Edexcel AS Mathematics Kinematics

Section 1: Displacement and distance

Exercise level 3 (Extension)

1. *A **geostationary orbit** (**GEO**) is a circular **geosynchronous orbit** in the plane of the Earth's equator with a radius of approximately 42,164 km (26,199 mi) (measured from the center of the Earth). A satellite in such an **orbit** is at an altitude of approximately 35,786 km (22,236 miles) above mean sea level.* (Quoted from *Wikipedia*.)

   Such satellites are used for the transmission of television services, since they stay in relatively the same position with respect to the earth's surface. What is the velocity, in km h^{-1}) of such a satellite? (For this purpose, consider the earth's centre as fixed in space.)

2. According to NASA, the human body's maximum tolerance of acceleration for a rocket is 3.5g (g m s^{-2} is the acceleration due to gravity; $g \approx 10$) for 30 minutes.

   If you throw an object straight up, it will rise until the negative acceleration of gravity stops it, then returns it to Earth. Gravity's force diminishes as distance from the centre of the Earth increases, however. So if you can throw the object with enough initial upward velocity so that gravity's decreasing force can never quite slow it to a complete stop, its decreasing velocity can always be just high enough to overcome gravity's pull. The initial velocity needed to achieve that condition is called escape velocity. For the earth it is about 40 200 km h^{-1}.

   So can a human survive an attempt to reach escape velocity?

3. The table below is an extract from a 2015 Network Rail timetable. It shows the pattern of train service for part of a mid-week day between London Paddington and Reading; the first column is the line mileage from Paddington. "d" corresponds to departure time, and "a" to arrival.

London and Reading

18 May to 11 December

Miles													
0	London Paddington	d	11 00	11 06	11 15	10 42		11 18	11 20	10 57	11 30
5¾	Ealing Broadway	d				10 50				11 05	
18½	Slough	d				11 13			11 36	11 27	
24¼	Maidenhead	d				11 25				11 34	
31	Twyford	d				11 33				11 43	
36	Reading	a	11 25	11 30	11 40	11 43		11 47	11 51	11 52	11 56

   (i) Identify the train with the fastest average speed between London Paddington and Reading. What is that average speed?

   (ii) There are eight instances where one train passes another. Identify those, and for the latest pair of departures you found use a straight line model to estimate where and when the trains pass. Is this realistic?

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4. The Norman army is advancing with constant speed u towards the Saxon army, which is at rest. When the armies are d apart, a Saxon horseman rides from the Saxon army directly towards the Norman army at constant speed x. Simultaneously a Norman horseman rides from the Norman army directly towards the Saxon army at constant speed y, where $y > u$. The horsemen ride their horses so that $y - 2x < u < 2y - x$.
When each horseman reaches the opposing army, he immediately rides straight back to his own army without changing his speed. Represent this information on a displacement-time graph, and show that the two horsemen pass each other at distances

$$\frac{xd}{x+y} \text{ and } \frac{xd(2y-x-u)}{(u+x)(x+y)}$$

from the Saxon army.
Explain briefly what will happened in the case
(iii) $u > 2y - x$
(iv) $u < y - 2x$.
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