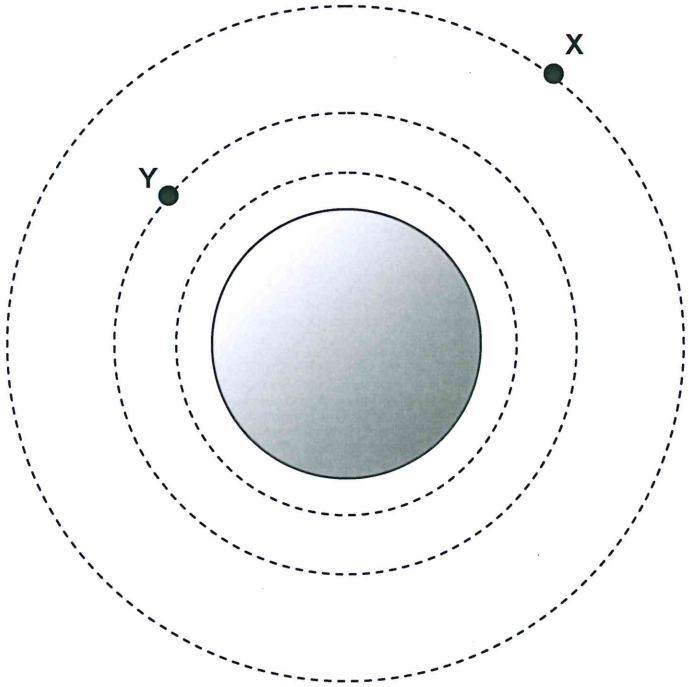
Exam Questions
Chapter 2·1 & 2·2 - Gravitational Fields & Forces

Question 1 2010:1:8

(5 marks)

This question is about the gravitational field around an asteroid. The asteroid is spherical and of uniform density. The diagram below shows lines of equal gravitational field strength as dashed lines. There is a constant difference in the value of the field strength between each line.



(a) Describe what the diagram shows about the gravitational field strength as the distance from the asteroid increases. (1 mark)

(b) Draw the gravitational field at points X and Y. (2 marks)

(c) The asteroid has a radius of 1.25×10^5 m. If the gravitational field strength on its surface is 0.194 N kg^{-1}, calculate the mass of the asteroid. (2 marks)

Question 2 2011:1:5

(4 marks)

Bathroom scales measure weight (a force) but give the reading in kilograms (mass). A particular scale shows a person's mass as being 70 kg at the Earth's equator. The spinning of the Earth contributes to the scale's reading. What would the scale read at the South Pole, with the same person standing on it? (Circle the correct answer.)

the same less than 70 kg more than 70 kg

Explain your reasoning: _____

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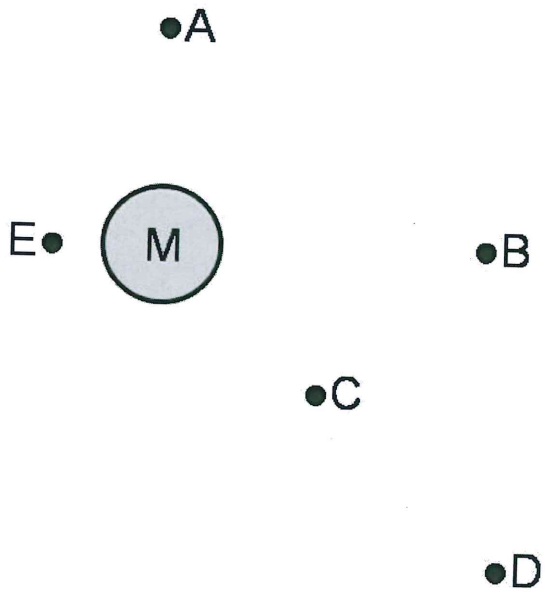
Question 3 2011:1:2

(4 marks)

The diagram below shows five points, labelled 'A' to 'E', in free space around a large mass M. You may wish to use a ruler to help you answer this question.



Which two points have the same magnitude of gravitational field strength due to M?

Point _____ and Point _____

Which two points experience the same direction of gravitational field due to M (as viewed in this diagram)?

Point _____ and Point _____

What is the ratio of the gravitational field strength at E to the gravitational field strength at B?

Point E _____ : Point B _____

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Question 4 2013:1:12

(7 marks)

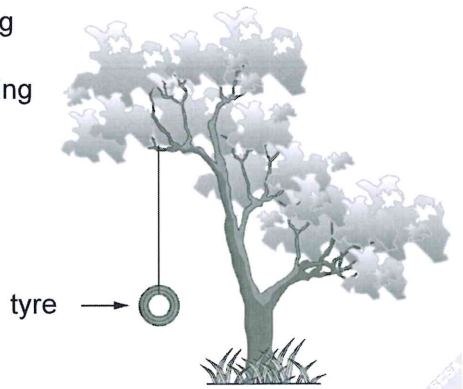
A satellite orbits 4.22×10^7 m above the Earth's centre. At a certain point in its orbit around the Earth, the satellite and the Moon line up as shown in the diagram below. Show that in this position the influence of the Moon on the satellite is negligible, compared with the influence of the Earth.

Question 5 2013:2:15

(18 marks)

Andrew and Sarah were at the park and noticed a tyre-swing hanging in a tree. They realised that it would behave as a pendulum and would complete one swing (return to its starting point for one complete cycle) with a period (T) in seconds. They had previously discussed pendulums in class and been given the equation:

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$



[Where ℓ = length in metres]

(a) The tyre swung with a period of 3.84 s. Determine the length of the rope in metres. (2 marks)

(b) Andrew and Sarah decided to conduct an investigation to determine the relationship between the length of a pendulum and its period.

(i) Complete the above table. (2 marks)

(ii) Use the data from the table to plot a straight line graph on the grid provided to demonstrate the relationship between the length of the pendulum and the square of the period (plot ℓ on the x-axis). (4 marks)

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Question 5: continued

An incomplete table of results for this investigation is shown below:

Length of pendulum ℓ (m)	Time for ten swings (s)	Time for one swing T (s)	Period squared T^2 (s^2)
0.10	5.5		
0.20	6.9		
0.30	10.9		
0.40	12.5		
0.50	15.0		
0.60	18.5		

(b) (iii) Use your graph to determine the pendulum length that gives a period of 1.0 s. (3 marks)

(iv) Determine the gradient of your graph using a line of best fit. (4 marks)

(v) Use your gradient to determine the experimental value of g. (3 marks)

Question 6 2014:3:21

(18 marks)

It is generally accepted that around 65 million years ago the Earth was struck by a fast-moving object approximately 10 km in diameter. This impact is believed to have left a scar on the Earth in the form of the Chicxulub Crater and to have been responsible for the extinction of the dinosaurs.

In 2013 the 'Chelyabinsk meteor' entered the Earth's atmosphere over Russia. This meteor had a mass of approximately 12 kilotonnes, measured about 20 metres in diameter and released about 1.8×10^{15} J, causing extensive damage, though mostly to arable land and not populated cities.

Events such as this have sparked interest in cataloguing such Near Earth Objects (NEOs) and then determining if they have an orbit that might put them on a collision course with the Earth. If a NEO is deemed to have an orbit that puts it on a collision course with the Earth then various possibilities exist for preventing the collision. These methods of prevention fall into two categories, either deflection or destruction of the NEO. With either method, early intervention is desirable. The Earth is orbiting the Sun at 30.0 km s^{-1} and to avoid an impact scientists have to ensure that the NEO and the Earth are not in the same position in space at the same time. The section of the Earth's orbit in which a collision is possible is known as the 'impact window'.

Essentially deflection strategies seek to alter the velocity of the NEO so that it intersects the Earth's orbit before or after the Earth is in that position. It is estimated that a velocity change of a NEO of $\frac{3.5 \times 10^{-2}}{t}$ m s^{-1} is sufficient to avoid a collision where 't' is the time in years to impact.

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Question 6: continued

One possible method of deflecting a NEO is to use a 'gravity tractor'. A gravity tractor is a massive spacecraft that is brought near to the NEO. Gravity will act between the spacecraft and the NEO and both objects will mutually attract each other. In time the NEO will gradually change the direction of its orbit. Once the NEO moves out of its normal path and comes close to the spacecraft, thrusters fire, moving the spacecraft further away from the NEO and allowing the spacecraft to continue to act as a gravity tractor. The gravity tractor method requires the earliest of interventions.

(a) Estimate the velocity of the of the Chelyabinsk meteor. Give your answer to an appropriate number of significant figures. Show **all** workings. (4 marks)

(b) (i) The width, in Earth diameters, of the impact window is (circle your answer): (1 mark)

less than one one more than one

(ii) Calculate the length of time that an 'impact window' has for any collision of an object with the Earth to occur. Ignore the size of the object. Show **all** workings. (3 marks)

(c) The NEO Apophis is on an orbit that will bring it close to the Earth in 2036. It has an assumed mass of 4.00×10^{10} kg and diameter of 325 m.

(i) Suppose that a spacecraft arrives and begins interacting with Apophis in 2016. Determine the change in velocity required to avoid a collision with the Earth. (3 marks)

(ii) If a gravity tractor type of intervention is decided upon, and does not begin interacting until 2021, then Apophis will require a change in velocity of 2.33×10^{-3} m s^{-1}. Determine the mass of the gravity tractor spacecraft needed, given that the centres of mass will be 175 m apart. (4 marks)

(d) When using a gravity tractor, explain why 'the earliest of interventions' is desirable if an asteroid is to be deflected sufficiently to avoid collision with the Earth. (3 marks)