Grav Force and Field 9.27.20 [35 marks] – work with each other, submit individually.

1. *[1 mark]*

Satellite X orbits a planet with orbital radius *R*. Satellite Y orbits the same planet with orbital radius 2*R*. Satellites X and Y have the same mass.

What is the ratio $\frac{\text{centripetal acceleration of X}}{\text{centripetal acceleration of Y}}$?

A. $\frac{1}{4}$

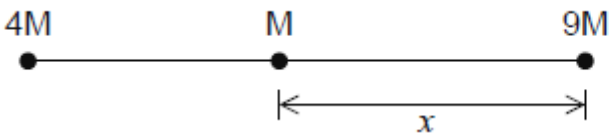
B. $\frac{1}{2}$

C. 2

D. 4

2. *[1 mark]*

Two isolated point particles of mass 4M and 9M are separated by a distance 1 m. A point particle of mass M is placed a distance from the particle of mass 9M. The net gravitational force on M is zero.



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What is ***x*** ?

A. $\frac{4}{13}$m

B. $\frac{2}{5}$m

C. $\frac{3}{5}$m

D. $\frac{9}{13}$m

3. *[1 mark]*

On Mars, the gravitational field strength is about $\frac{1}{4}$ of that on Earth. The mass of Earth is approximately ten times that of Mars.

What is $\frac{\text{radius of Earth}}{\text{radius of Mars}}$?

A. 0.4

B. 0.6

C. 1.6

D. 2.5

4. *[1 mark]*

What is the correct definition of gravitational field strength?

A. The mass per unit weight

B. The weight of a small test mass

C. The force acting on a small test mass

D. The force per unit mass acting on a small test mass

5. *[1 mark]*

The gravitational field strength at the surface of a certain planet is g. Which of the following is the gravitational field strength at the surface of a planet with twice the radius and twice the mass?

A. $\frac{g}{2}$

B. g

C. $2g$

D. $4g$

6. *[1 mark]*

A spacecraft travels away from Earth in a straight line with its motors shut down. At one instant the speed of the spacecraft is 5.4 km s^{-1}. After a time of 600 s, the speed is 5.1 km s^{-1}. The average gravitational field strength acting on the spacecraft during this time interval is

A. 5.0×10^{-4} N kg^{-1}
B. 3.0×10^{-2} N kg^{-1}
C. 5.0×10^{-1} N kg^{-1}
D. 30 N kg^{-1}

7a. *[2 marks]*

(i) Define *gravitational field strength.*

(ii) State the SI unit for gravitational field strength.

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7b. *[4 marks]*

A planet orbits the Sun in a circular orbit with orbital period T and orbital radius R. The mass of the Sun is M.

(i) Show that $T = \sqrt{\frac{4\pi^2 R^3}{GM}}$.

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(ii) The Earth's orbit around the Sun is almost circular with radius 1.5×10^{11} m. Estimate the mass of the Sun.

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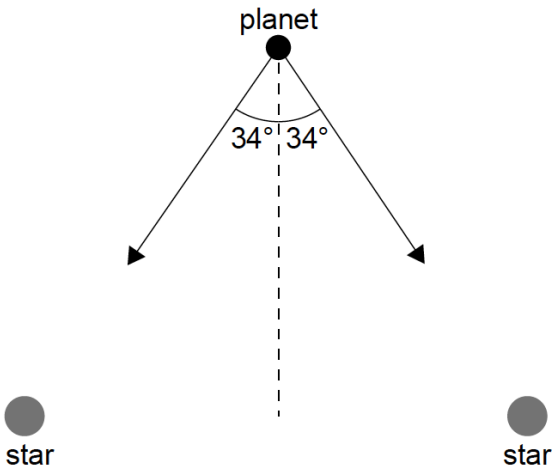
8a. *[1 mark]*

The two arrows in the diagram show the gravitational field strength vectors at the position of a planet due to each of two stars of equal mass *M*.



Each star has mass $M=2.0\times10^{30}$kg. The planet is at a distance of 6.0×10^{11}m from each star.

Show that the gravitational field strength at the position of the planet due to **one** of the stars is $g=3.7\times10^{-4}$Nkg^{-1}.

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8b. *[2 marks]*

Calculate the magnitude of the resultant gravitational field strength at the position of the planet.

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9a. *[2 marks]*

Part 2 Satellite

State, in words, Newton's universal law of gravitation.

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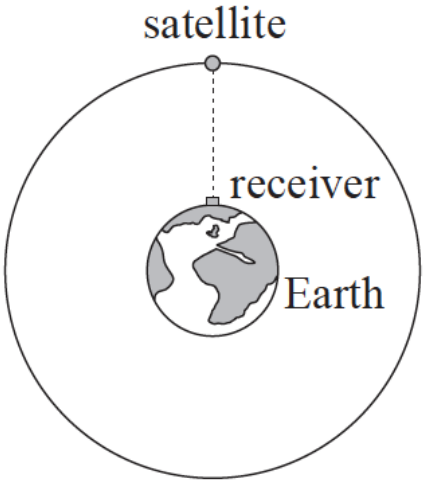
9b. *[3 marks]*

The diagram shows a satellite orbiting the Earth. The satellite is part of the network of global-positioning satellites (GPS) that transmit radio signals used to locate the position of receivers that are located on the Earth.



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When the satellite is directly overhead, the microwave signal reaches the receiver 67ms after it leaves the satellite.

(i) State the order of magnitude of the wavelength of microwaves.

(ii) Calculate the height of the satellite above the surface of the Earth

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9c. *[8 marks]*

(i) Explain why the satellite is accelerating towards the centre of the Earth even though its orbital speed is constant.

(ii) Calculate the gravitational field strength due to the Earth at the position of the satellite.

Mass of Earth = 6.0×10^{24}kg
Radius of Earth = 6.4×10^{6}m

(iii) Determine the orbital speed of the satellite.

(iv) Determine, in hours, the orbital period of the satellite.

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10a. *[2 marks]*

Deduce that the gravitational field strength g at the surface of a spherical planet of uniform density is given by

$$g = \frac{GM}{R^2}$$

where M is the mass of the planet, R is its radius and G is the gravitational constant. You can assume that spherical objects of uniform density act as point masses.

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10b. *[2 marks]*

The gravitational field strength at the surface of Mars g_M is related to the gravitational field strength at the surface of the Earth g_E by

$g_M = 0.38 \times g_E$.

The radius of Mars R_M is related to the radius of the Earth R_E by

$R_M = 0.53 \times R_E$.

Determine the mass of Mars M_M in terms of the mass of the Earth M_E.

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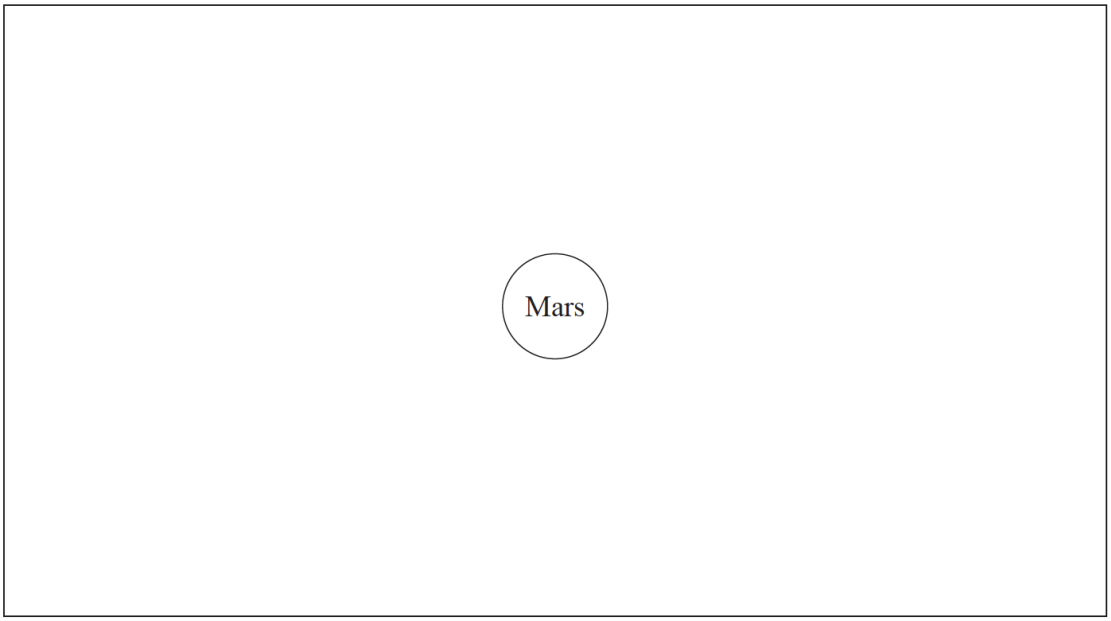
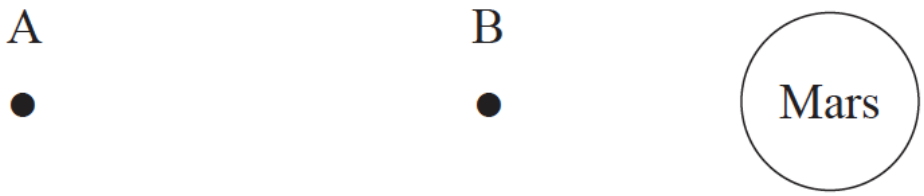
10c. *[3 marks]*

(i) On the diagram below, draw lines to represent the gravitational field around the planet Mars.



(ii) An object falls freely in a straight line from point A to point B in time t. The speed of the object at A is u and the speed at B is v. A student suggests using the equation $v=u+g_M t$ to calculate v. Suggest **two** reasons why it is not appropriate to use this equation.



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