Topic 6 Review Packet *[40 marks]*

1. A small sphere X of mass M is placed a distance d from a point mass. The gravitational force on sphere X is 90 N. Sphere X is removed and a second sphere Y of mass $4M$ is placed a distance $3d$ from the same point mass. The gravitational force on sphere Y is *[1 mark]*

   A. 480 N.

   B. 160 N.

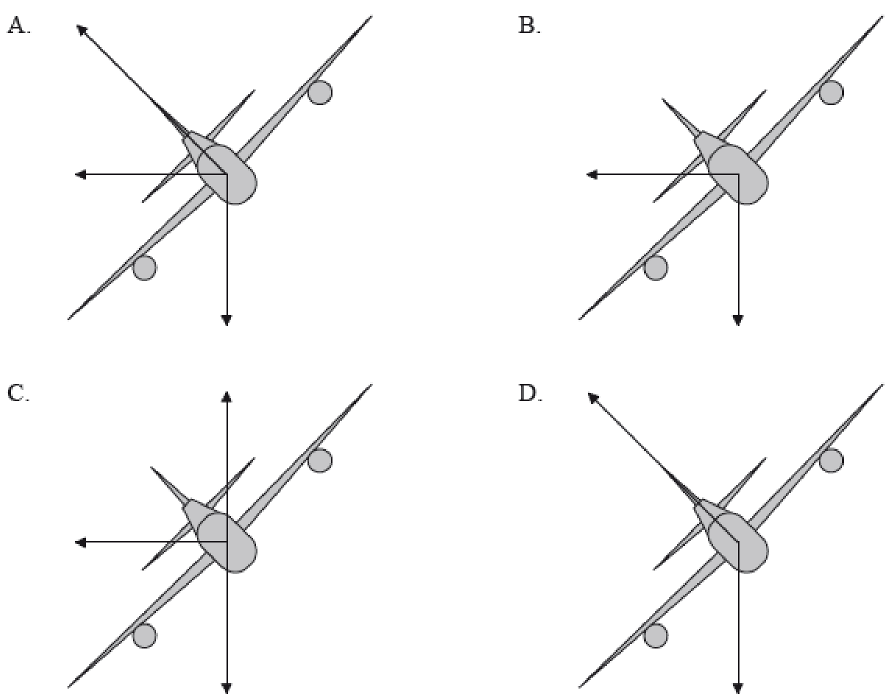
   C. 120 N.

   D. 40 N.

   ## Markscheme

   D

2. An aircraft is flying at constant speed in a horizontal circle. Which of the following diagrams best illustrates the forces acting on the aircraft in the vertical plane? *[1 mark]*



Markscheme

D

3. For a particle moving at constant speed in a horizontal circle, the work done by the centripetal force is *[1 mark]*

A. zero.

B. directly proportional to the particle mass.

C. directly proportional to the particle speed.

D. directly proportional to the (particle speed)^2.

Markscheme

A

4. The mass of Earth is M_{E}, its radius is R_{E} and the magnitude of the gravitational field strength at the surface of Earth is g. The universal gravitational constant is G. The ratio $\frac{g}{G}$ is equal to *[1 mark]*

A. $\frac{M_{\mathrm{E}}}{R_{\mathrm{E}}^2}$

B. $\frac{R_{\mathrm{E}}^2}{M_{\mathrm{E}}}$

C. $M_{\mathrm{E}}R_{\mathrm{E}}$

D. 1

Markscheme

A

5. A communications satellite is moving at a constant speed in a circular orbit around Earth. At any given instant in time, the resultant force on the satellite is *[1 mark]*

A. zero.

B. equal to the gravitational force on the satellite.

C. equal to the vector sum of the gravitational force on the satellite and the centripetal force.

D. equal to the force exerted by the satellite’s rockets.

Markscheme

B

6. The mass of a planet is twice that of Earth. Its radius is half that of the radius of Earth. The gravitational field strength at the surface of Earth is g. The gravitational field strength at the surface of the planet is *[1 mark]*

A. $\frac{1}{2}g$.

B. g.

C. $2g$.

D. $8g$.

Markscheme

D

7. The weight of an object of mass 1 kg at the surface of Mars is about 4 N. The radius of Mars is about half the radius of Earth. Which of the following is the best estimate of the ratio below? *[1 mark]*

$$\frac{\text{mass of Mars}}{\text{mass of Earth}}$$

A. 0.1

B. 0.2

C. 5

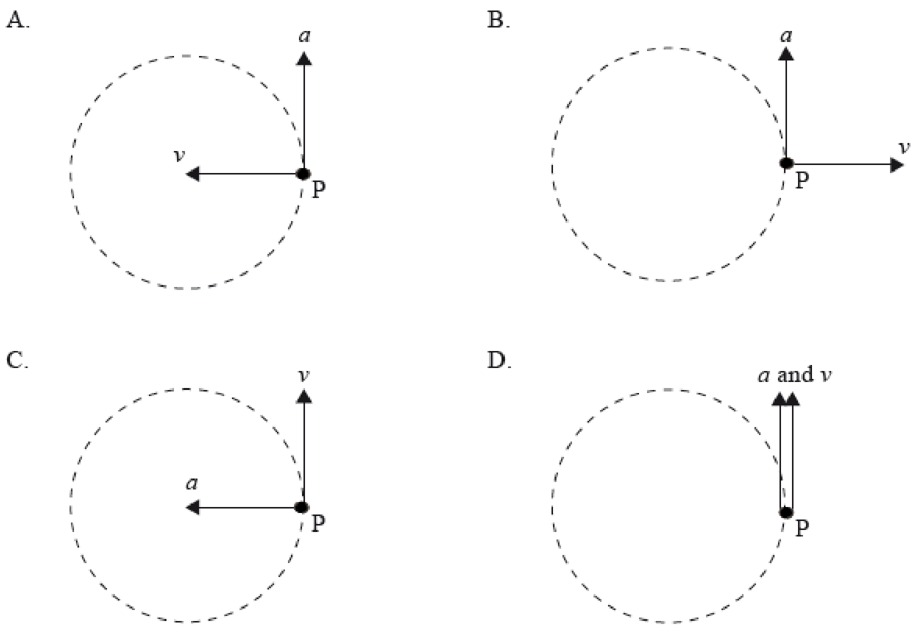
D. 10

Markscheme

A

8. A particle P is moving anti-clockwise with constant speed in a horizontal circle. *[1 mark]*

Which diagram correctly shows the direction of the velocity v and acceleration a of the particle P in the position shown?



Markscheme

C

9. A spherical planet of uniform density has three times the mass of the Earth and twice the average radius. The magnitude of the gravitational field strength at the surface of the Earth is g. What is the gravitational field strength at the surface of the planet? *[1 mark]*

A. 6 g

B. $\frac{2}{3}g$

C. $\frac{3}{4}g$

D. $\frac{3}{2}g$

Markscheme

C

10. A cyclist rides around a circular track at a uniform speed. Which of the following correctly gives the net horizontal force on the cyclist at any given instant of time? *[1 mark]*

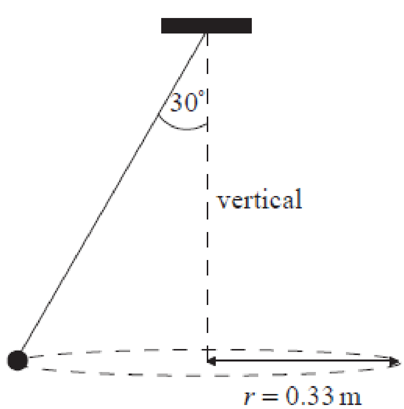
	Net horizontal force along direction of motion	Net horizontal force normal to direction of motion
A.	zero	zero
B.	zero	non zero
C.	non zero	zero
D.	non zero	non zero

Markscheme

B

This question is about circular motion.

A ball of mass 0.25 kg is attached to a string and is made to rotate with constant speed v along a horizontal circle of radius r = 0.33m. The string is attached to the ceiling and makes an angle of 30° with the vertical.

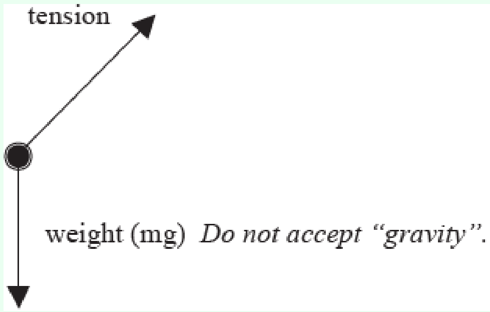


11a. (i) On the diagram above, draw and label arrows to represent the forces on the ball in the position shown. *[4 marks]*

(ii) State and explain whether the ball is in equilibrium.

Markscheme

(i) ***[1]*** each for correct arrow and (any reasonable) labelling;



*Award **[1 max]** for arrows in correct direction but not starting at the ball.*

(ii) no;
because the two forces on the ball can never cancel out / there is a net force on
the ball / the ball moves in a circle / the ball has acceleration/it is changing direction;
*Award **[0]** for correct answer with no or wrong argument.*

11b. Determine the speed of rotation of the ball. *[3 marks]*

Markscheme

$T\left(=\frac{mg}{\cos 30^\circ}\right) = 2.832\text{N};$

$\frac{mv^2}{r} = T\sin 30^\circ;$

$v = \left(\sqrt{\frac{Tr\sin 30^\circ}{m}} = \sqrt{\frac{2.832\times 0.33\times \sin 30^\circ}{0.25}}\right) = 1.4\text{ms}^{-1};$

or

$T\cos 30^\circ = mg;$

$T\sin 30^\circ = \frac{mv^2}{r};$

$v = \left(\sqrt{gr\tan 30^\circ} = \sqrt{9.81\times 0.33\times \tan 30^\circ}\right) = 1.4\text{ms}^{-1};$

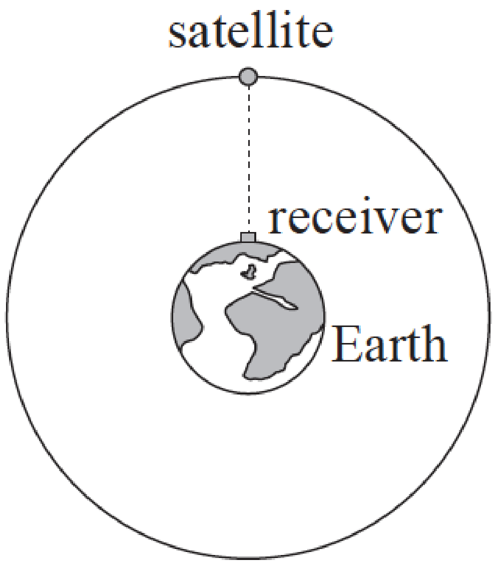
Part 2 Satellite

12a. State, in words, Newton's universal law of gravitation. *[2 marks]*

Markscheme

force is proportional to product of masses and inversely proportional to square of distance apart;
reference to point masses;

12b. 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. *[3 marks]*



(not to scale)

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

Markscheme

(i) order of 1 cm;

(ii) $3\times10^{8}\times67\times10^{-3}$;
2.0×10^{7}m;

12c. (i) Explain why the satellite is accelerating towards the centre of the Earth even though its orbital speed is constant. *[8 marks]*

(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.

Markscheme

(i) force required towards centre of Earth to maintain orbit;
force means that there is an acceleration / *OWTTE*;

or

direction changes;
a change in velocity therefore acceleration;

(ii) uses= $\frac{GM}{r^2}$ ***or*** $\frac{6.7 \times 10^{-11} \times 6.0 \times 10^{24}}{\left[2.6 \times 10^{7}\right]^{2}}$;

0.57Nkg^{-1}; (allow ms^{-2})

(iii) $v = \sqrt{0.57 \times \left(2.0 \times 10^{7} + 6.4 \times 10^{6}\right)}$ by equating $\frac{v^2}{r}$ and g;

3900ms^{-1};

(iv) $T = 2\pi \frac{2.6 \times 10^{7}}{3900}$;

11.9 hours;

Part 2 Gravitational fields

13a. State Newton's universal law of gravitation. *[3 marks]*

Markscheme

there is an attractive force;
between any two point/small masses;
proportional to the product of their masses;
and inversely proportional to the square of their separation;
Accept formula with all terms defined.

13b. Deduce that the gravitational field strength g at the surface of a spherical planet of uniform density is given by *[2 marks]*

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

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.

Markscheme

use of $g = \frac{F}{m}$ and $F = \frac{GmM}{R^2}$;
evidence of substitution/manipulation;
to get $g = \frac{GM}{R^2}$

13c. 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 *[2 marks]*

$g_M = 0.38 \times g_E$.

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

$R_M = 0.53 \times R_E$.

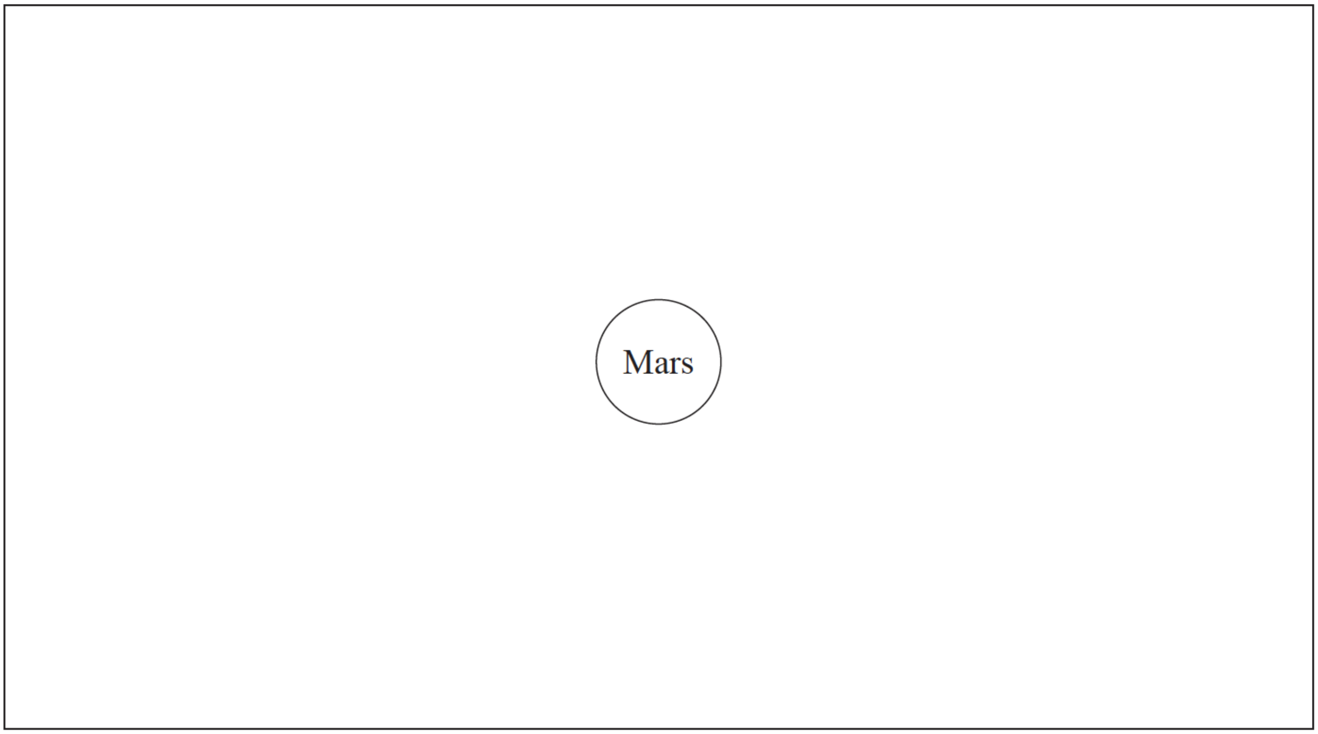
Determine the mass of Mars M_M in terms of the mass of the Earth M_E.

Markscheme

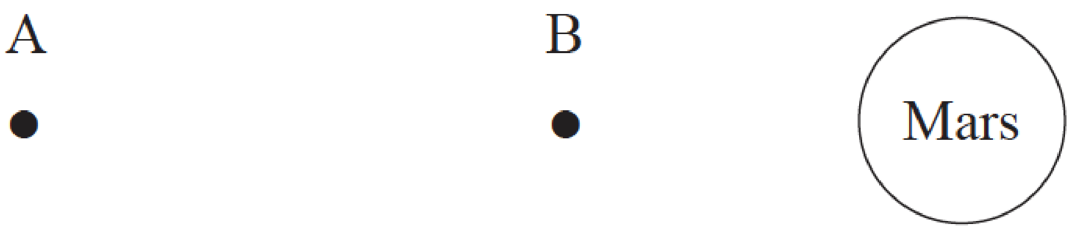
$$\frac{g_M}{g_E} = \frac{\frac{M_M}{R_M^2}}{\frac{M_E}{R_E^2}} \Rightarrow \frac{M_M}{M_E} = \frac{g_M}{g_E} \times \left[\frac{R_M}{R_E}\right]^2;$$

$$M_{\mathrm{M}} \left(= 0.38 \times 0.53^2 M_{\mathrm{E}}\right) = 0.11 M_{\mathrm{E}};$$

13d. (i) On the diagram below, draw lines to represent the gravitational field around the planet Mars. *[3 marks]*

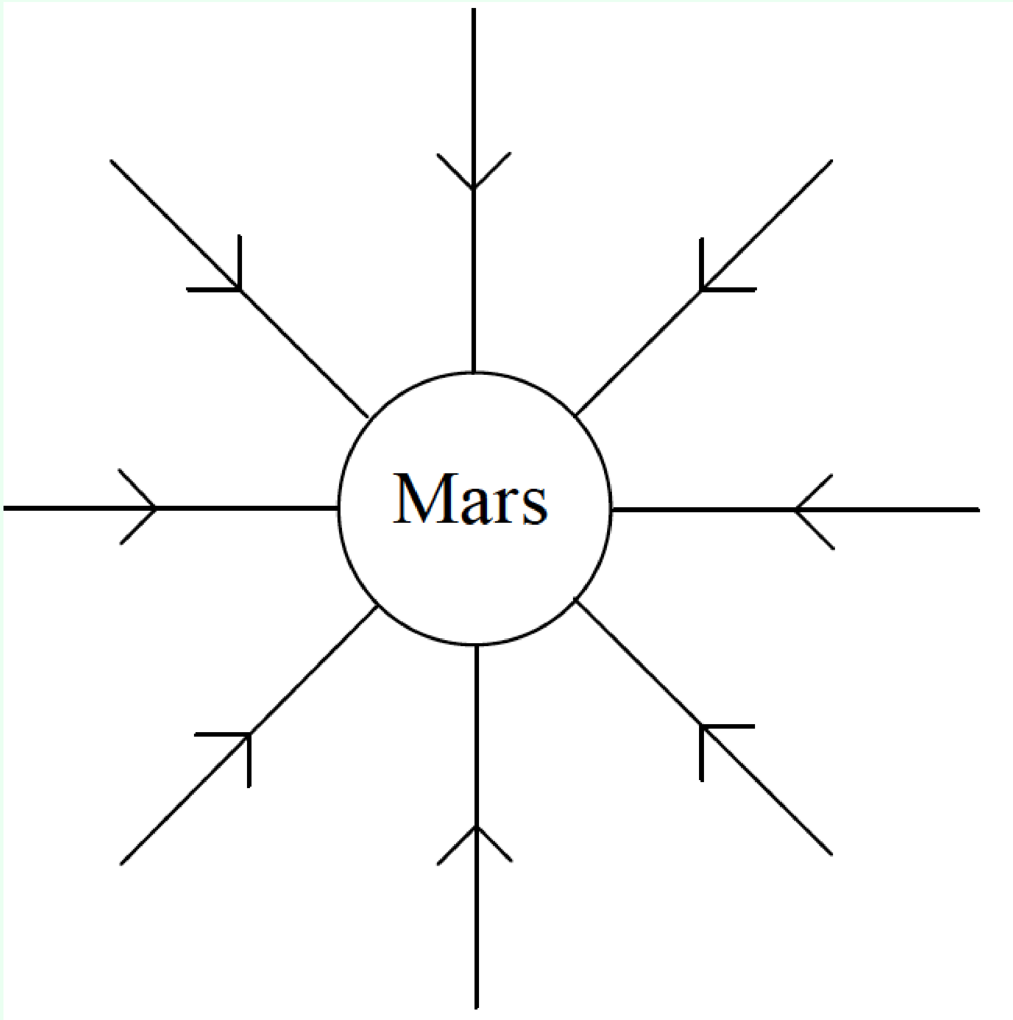


(ii) An object falls freely in a straight line from point A to point B in time t. The speed of the object at A is u and the speed at B is v. A student suggests using the equation $v = u + g_M t$ to calculate v. Suggest **two** reasons why it is not appropriate to use this equation.



Markscheme

(i) radial field with arrows pointing inwards;



(ii) field between A and B is not equal to field at surface;
acceleration is not constant between these two points;