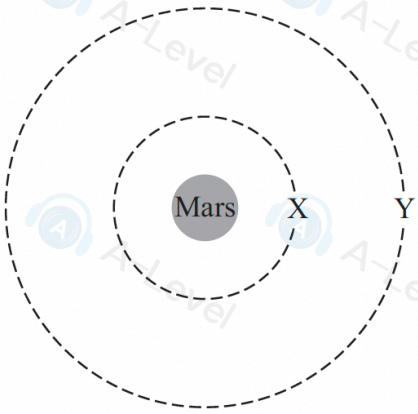
5 The dashed circles on the diagram represent gravitational equipotentials about the planet Mars.

The gravitational potential at X is $-5.5\,\text{MJ kg}^{-1}$.

The gravitational potential at Y is $-3.7\,\text{MJ kg}^{-1}$.



A meteor of mass 250 kg falls from Y to X.

Which of the following is the change in gravitational potential energy of the meteor as it falls?

- ☒ **A** 450 MJ
- ☒ **B** 920 MJ
- ☒ **C** –450 MJ
- ☒ **D** –920 MJ

(Total for Question 5 = 1 mark)

8 Mars has approximately 8 times the mass of the Moon.

Mars has twice the diameter of the Moon.

The value of g on the surface of the Moon is $1.6\,\text{N kg}^{-1}$.

What is the value of g on the surface of Mars?

- ☒ **A** $0.8\,\text{N kg}^{-1}$
- ☒ **B** $1.6\,\text{N kg}^{-1}$
- ☒ **C** $3.2\,\text{N kg}^{-1}$
- ☒ **D** $6.4\,\text{N kg}^{-1}$

(Total for Question 8 = 1 mark)

1: Which of the following statements applies to both electric fields and gravitational fields?

- ☒ **A** Each field causes a force on all particles.
- ☒ **B** Each field can cause an attractive or repulsive force.
- ☒ **C** Field strength is proportional to the square of the distance from a point source.
- ☒ **D** Field strength is inversely proportional to the square of the distance from a point source.

(Total for Question 1 = 1 mark)

DO NOT WRITE IN THIS AREA

4 A satellite of mass m is on the Earth's surface.

The satellite is moved into a circular orbit of height h above the Earth.

The mass of the Earth is M and the radius of the Earth is R.

Which of the following gives the change in gravitational potential energy of the satellite?

☒ **A** $\frac{GM}{(R+h)} - \frac{GM}{R}$

☒ **B** $\frac{GMm}{R} - \frac{GMm}{(R+h)}$

☒ **C** $\frac{GM}{(R+h)^2} - \frac{GM}{R^2}$

☒ **D** $\frac{GMm}{R^2} - \frac{GMm}{(R+h)^2}$

(Total for Question 4 = 1 mark)

DO NOT WRITE IN THIS AREA

10 The Earth has 10 times the mass of Mars and twice the radius of Mars.

The gravitational field strength at the surface of the Earth is g_E.
The gravitational field strength at the surface of Mars is g_M.

Which of the following gives the relationship between g_E and g_M?

☒ **A** $g_E = 2.5 g_M$

☒ **B** $g_E = 5 g_M$

☒ **C** $g_M = 2.5 g_E$

☒ **D** $g_M = 5 g_E$

(Total for Question 10 = 1 mark)

DO NOT WRITE IN THIS AREA

6 The Moon is gradually moving away from the Earth.

The gravitational potential at the Earth due to the Moon, and the gravitational force between the Earth and the Moon, are both changing.

Which row of the table is correct?

	Gravitational potential	Gravitational force
☒ **A**	decreases	decreases
☒ **B**	increases	decreases
☒ **C**	decreases	increases
☒ **D**	increases	increases

(Total for Question 6 = 1 mark)

3 There is an electric field around a point charge and a gravitational field around a point mass.

Which of the following is **not** correct?

- ☒ **A** Both fields are radial.
- ☒ **B** Both fields can produce attractive forces.
- ☒ **C** Both fields can produce repulsive forces.
- ☒ **D** Both fields produce forces that obey an inverse square law.

(Total for Question 3 = 1 mark)

DO NOT WRITE IN THIS AREA

6 The planet Mercury orbits the Sun in an elliptical orbit. As a result, the speed of Mercury varies as it orbits the Sun.

Which row of the table shows how the speed and gravitational potential energy of Mercury change as Mercury approaches the Sun?

	Gravitational potential energy	Speed
☒ **A**	decreases	decreases
☒ **B**	decreases	increases
☒ **C**	increases	decreases
☒ **D**	increases	increases

(Total for Question 6 = 1 mark)

DO NOT WRITE IN THIS AREA

9 Due to tidal action, the Moon is slowly moving away from the Earth.

As the Moon moves away from the Earth, the gravitational force between the Earth and the Moon changes. The gravitational potential energy of the Moon also changes.

Which row of the table correctly shows these changes?

	Gravitational force between the Earth and the Moon	Gravitational potential energy of the Moon
☒ **A**	decreases	decreases
☒ **B**	decreases	increases
☒ **C**	increases	decreases
☒ **D**	increases	increases

(Total for Question 9 = 1 mark)

DO NOT WRITE IN THIS AREA

7 A small satellite of mass 122 kg is orbiting the Earth. The satellite is orbiting at a height above the surface of the Earth equal to the radius of the Earth.

Which of the following is the approximate weight of the satellite in its orbit?

- ☒ **A** zero
- ☒ **B** 300 N
- ☒ **C** 600 N
- ☒ **D** 1200 N

(Total for Question 7 = 1 mark)

14 The Earth takes 365 days to make one complete orbit of the Sun.

(a) Show that the mass of the Sun is about 2×10^{30} kg.

radius of Earth's orbit about Sun = 1.49×10^{11} m
1 year = 3.15×10^{7} s

(3)

(b) A television programme claimed that the gravitational field strength at the surface of the Sun is 28 times the gravitational field strength at the surface of the Earth.

Deduce whether this claim is correct.

diameter of Sun = 1.39×10^{9} m

(3)

(Total for Question 14 = 6 marks)

DO NOT WRITE IN THIS AREA

17 Makemake is a dwarf planet in the solar system. Makemake has a mass of 3.1×10^{21} kg and a radius of 715 km.

(a) Calculate the gravitational field strength at the surface of Makemake.

(2)

Gravitational field strength at surface = ...

(b) The average distance of Makemake from the Sun is similar to the average distance of the dwarf planet Pluto from the Sun.

A website states:

"The time taken by Makemake to complete one orbit of the Sun is 20% greater than the time taken by Pluto to complete one orbit of the Sun."

Assess the accuracy of the website statement.

mass of Sun = 1.99×10^{30} kg
orbit radius of Makemake = 6.80×10^{12} m
orbit time of Pluto = 248 years
1 year = 3.15×10^{7} s

(6)

(Total for Question 17 = 8 marks)

18 In January 2023, the asteroid 2023 BU came close to the Earth. The closest distance of the asteroid from the surface of the Earth was 3590 km.

(a) Calculate the force between the asteroid and the Earth at the closest distance. You may assume the asteroid is a sphere.

asteroid diameter = 5.65 m
asteroid density = 1950 kg m^{-3}
mass of Earth = 5.98×10^{24} kg
radius of Earth = 6380 km

(4)

Force between asteroid and Earth = ...

(b) Calculate the change in gravitational potential energy of the asteroid if it had fallen to the surface of the Earth from a height of 3590 km.

Assume that the mass of the asteroid remains constant.

(3)

Change in gravitational potential energy = ...

DO NOT WRITE IN THIS AREA

(c) Explain why the mass of the asteroid would **not** remain constant as the asteroid fell to the surface of the Earth.

(2)

(Total for Question 18 = 9 marks)