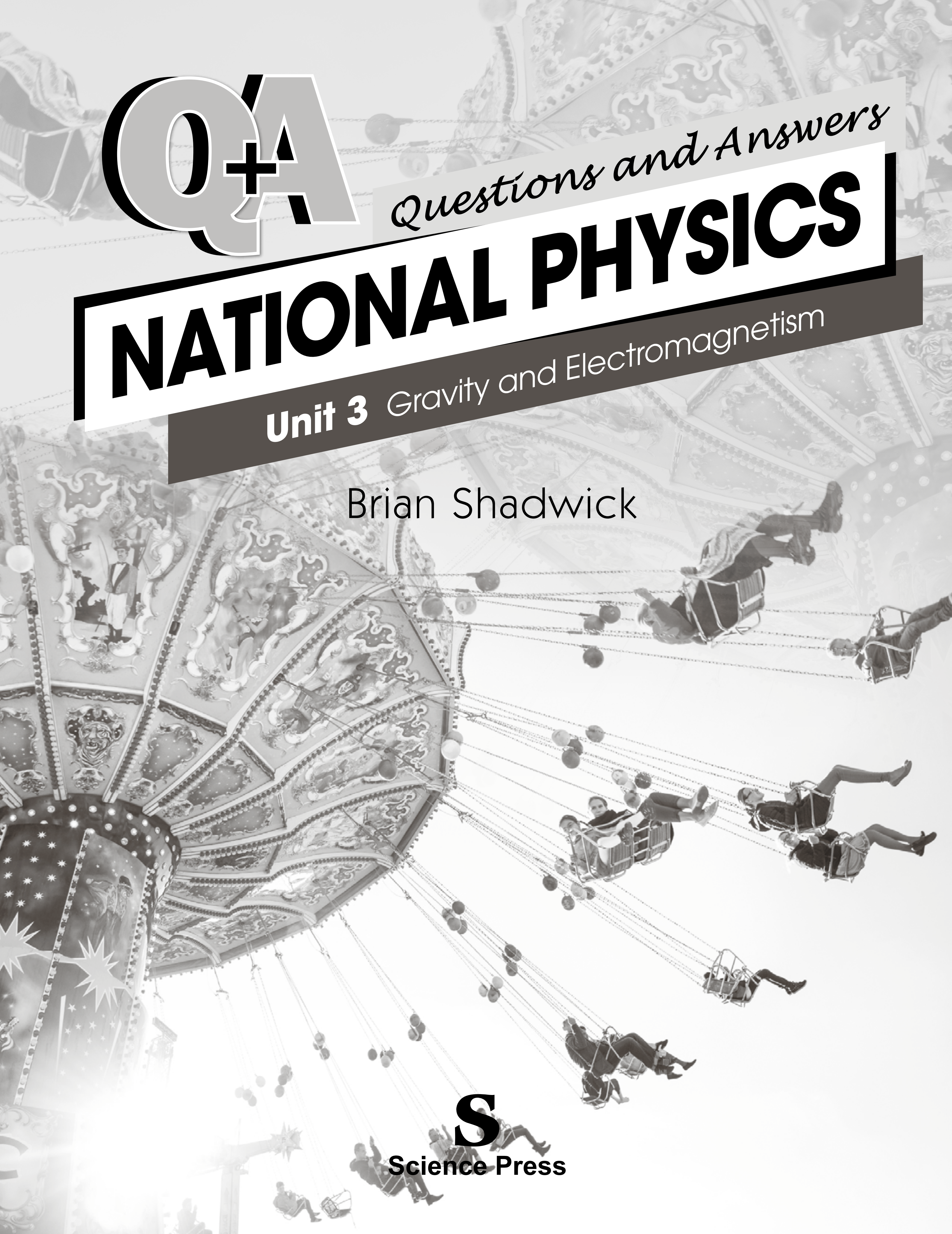

Q+A

Questions and Answers

NATIONAL PHYSICS

Unit 3 *Gravity and Electromagnetism*

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Contents

Words to Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

Questions and Answers

Gravity and Motion

Science Press

SET 1 Mass and Weight

1. (a) Define mass.

(b) How does the mass of an object change when it is moved from one position in the Universe to another position?

(c) Give three different units used to measure mass, and their symbols.

2. (a) What is weight?

(b) How does the weight of an object change when it is moved from one position in the Universe to another position?

(c) Give the unit used to measure weight, and its symbols.

(d) Write down the equation that connects mass and weight.

3. Convert to weight.

(a) 1 gram

(b) 85 g

(c) 0.55 kg

(d) 246 kg

(e) 2012 kg

(f) 1.6 tonnes

4. Convert to mass.

(a) 0.4 N

(b) 8 N

(c) 245 N

(d) 490 N

(e) 9800 N

(f) 65 kN

5. (a) Calculate the mass of a 60 kg person on the Moon. (Moon acceleration due to gravity is about 1.6 m s^{-2}.)

(b) Calculate this person's weight on the Moon.

(c) Predict his weight on Earth.

(d) Calculate the weight of a 70 kg astronaut on Earth.

(e) Calculate his mass on the Moon.

(f) Calculate his weight on the Moon.

6. List three essential differences between mass and weight.

7. Jupiter has a gravitational acceleration that is 2.53 times greater than that of Earth. An object on Jupiter weighs 506 N.

(a) What is the mass of the object?

(b) What will be its weight on Earth?

8. A 60 kg astronaut travels to a planet where acceleration due to gravity is 0.38 times that of Earth.

(a) What is the astronaut's weight on Earth?

(b) What is his mass on the planet?

(c) What is his weight on the planet?

9. On Earth an astronaut steps onto a set of scales. As she does, the surface of the scales moves down and compresses a spring in the workings. Gearing changes this movement into the horizontal swing of the pointer. The pointer becomes stationary at the 60 kg mark.

(a) Explain if the scales are measuring the astronaut's mass or weight.

(b) What would the scales read on the Moon? Justify your answer.

10. Calculate the weight of a 10 kg object at each of the following cities on Earth.

City	Gravitational field at this position (m s^{-2})
Sydney	9.7979
Hong Kong	9.8099
Toronto	9.8054
Helsinki	9.8189
Baghdad	9.7964
Seoul	9.7994
Manila	9.7844
New York	9.8024
Mexico City	9.7799

SET 2 Gravitational Field

For relevant questions in this set, take the radius of the Earth as 6380 km, and its mass as 6×10^{24} kg.

1. (a) What is a field?
(b) More specifically, what is a gravitational field?
(c) Where do we find gravitational fields?
(d) Define gravitational field strength.
(e) Give the mathematical equation for gravitational field strength.
(f) What are the units for gravitational field strength?
(g) What do we commonly refer to gravitational field as?

2. (a) What property of a mass changes if its position in a gravitational field changes?
(b) State the relationship between the work done on an object and its changing position in a gravitational field.

3. (a) Explain why the gravitational field strength at the surface of the Earth is not constant.
(b) Given that the gravitational force acting on an object gives it its weight force, by equating the two equations for gravitational force and weight force, derive another equation for gravitational field strength.
(c) Use this equation to explain why the gravitational field strength due to the Earth decreases as we go further away from the Earth.
(d) What does the 'r' (or perhaps you used R, or d) in your equation stand for?

4. (a) Recall the equation we used in earlier work to calculate the changes in the gravitational potential energy of masses close to the surface of the Earth.
(b) When calculating these changes, what does the 'h' or Δh stand for?
(c) Explain why we cannot use this equation to calculate the gravitational potential energy changes for objects which are not close to the Earth's surface.

5. (a) What does the work to cause the energy change when an object moves from a higher gravitational potential energy position to a lower gravitational potential energy position?
(b) What does the work to cause the energy change when an object moves from a lower gravitational potential energy position to a higher gravitational potential energy position?

6. An astronaut in his space suit weighs 882 N on Earth where the gravitational field strength is 9.8 N kg^{-1}.
(a) What would he weigh on a planet where the gravitational field strength was 2.2 N kg^{-1}?
(b) What would he weigh on a planet where the gravitational field strength was 12.2 N kg^{-1}?

7. Compare the gravitational field strength at sea level on Earth with the field strength on top of Mount Everest. Explain your answer.

8. (a) An 80 kg man moves from a place on Earth where the gravitational field strength is 9.82 N kg^{-1} to another place where the field strength is 9.77 N kg^{-1}. By how much does his mass change?
(b) Find his change in weight.

9. (a) Explain, in terms of gravitational field strength, why all objects, regardless of mass, will fall towards the Earth at the same rate when they are dropped from the same height.
(b) Will the rate at which they fall change if they are dropped from a significantly higher height? Justify your answer.

10. Planet X has a mass 6 times greater than that of the Earth and twice the Earth's diameter. What will be the strength of the gravitational field on its surface?

11. (a) Given the mass of our Sun as 2.00×10^{30} kg, and its diameter as 1 392 530 km, find the strength of its gravitational field on its surface.

(b) Estimate the gravitational field strength on the surface of a neutron star that has five times the mass of our Sun, and a radius of 10 km.

12. What is the acceleration due to gravity at an altitude of 2×10^5 m above the Earth's surface?

13. A hypothetical planet has a radius three times that of Earth, but has the same mass. What is the acceleration due to gravity near its surface?

14. Find the altitude above the Earth's surface where Earth's gravitational field strength would be two-thirds of its value at the surface.

15. The gravitational field intensity at the surface of a planet is 3.4 N kg^{-1}. If a planet's mass is 6.8×10^{22} kg, what is its radius?

16. Calculate the acceleration of an 85 kg astronaut on the International Space Station (ISS) when the ISS is at a height of 350 km above Earth's surface.

17. Compare the gravitational field strength if you were in a satellite in orbit 1000 km above the Earth to what it would be if you were in orbit 1000 km above Mars (take the mass of Mars as 6.42×10^{23} kg, and its radius as 3400 km).

18. At what distance from the Earth's surface is the gravitational field strength 7.33 N kg^{-1}?

19. On the surface of Planet X an object has a weight of 63.5 N and a mass of 22.5 kg. What is the gravitational field strength on the surface of Planet X?

20. On the surface of Planet Y, which has a mass of 4.83×10^{24} kg, an object has a weight of 50.0 N and a mass of 30.0 kg. What is the radius of this planet?

21. What is the gravitational field strength 1.27×10^7 m above the Earth's surface?

22. Planet B has a mass of 4.0×10^{22} kg and a radius of 5.0×10^5 m. What is the gravitational field strength on the surface of planet B?

23. (a) A receiver at sea level detects a signal from a satellite in a circular orbit when it is passing directly overhead. The microwave signal is received 75 ms after it was transmitted from the satellite. Calculate the altitude of the satellite. (Velocity of electromagnetic radiation = 3×10^8 m s^{-1}.)

(b) Determine the gravitational field strength of the Earth at the position of the satellite.

24. A 100 kg astronaut feels a gravitational force of 750 N when placed in the gravitational field of a planet.

(a) What is the gravitational field strength at the location of the astronaut?

(b) What is the mass of the planet if the astronaut is 2×10^6 m from its centre?

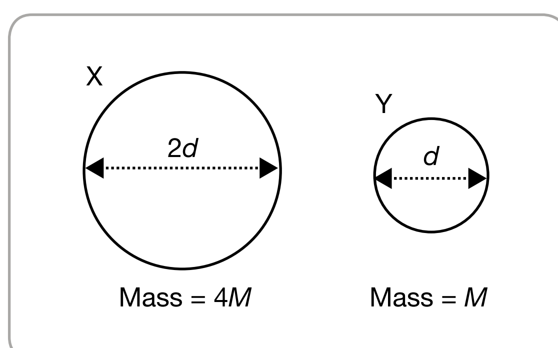
25. The gravitational field strength at the surface of a planet, X, is 18 N kg^{-1}.

(a) Calculate the minimum amount of energy required to lift a 7.0 kg rock a vertical distance of 20 m from the surface of X if the gravitational field can be considered to be uniform over such a small distance.

(b) State whether your answer to (a) would be different if the 7.0 kg mass were lifted a vertical distance of 20 m from a point near the top of the highest mountain on planet X. Explain your answer.

(c) Calculate the gravitational field strength at the surface of another planet, Y, that has the same mass as planet X, but twice the diameter of X.

26. Consider the two planets shown below. Their masses and diameters are given.



If the gravitational field on the surface of X is 8 m s^{-2}, what is it on the surface of Y?

SET 3 Newton's Law of Universal Gravitation

For relevant questions in this set, take the radius of the Earth as 6380 km, and its mass as 6×10^{24} kg.

1. Determine the gravitational force between two 10 kg masses 6 m apart.

2. Determine the gravitational force acting on a 500 kg satellite which is orbiting the Earth at an altitude of 300 km. The radius of Earth is 6380 km and its mass is 6×10^{24} kg.

3. Two objects have a gravitational force of F newtons acting between them. Predict what happens to this force if:

(a) The distance between the objects is doubled.

(b) The distance between the objects is halved.

(c) One of the objects is replaced by an object with twice the mass of the original object.

(d) Both objects are replaced by objects which each have three times the original mass.

(e) The distance between the objects is tripled *and* one of the objects is replaced by an object with four times the initial mass.

4. Two planets have masses M and $3M$, and radii R and $2R$ respectively.

(a) Compare the weight (as a ratio) of a 10 kg mass on the surface of each.

(b) How would this ratio change if the masses were 50 kg masses instead of 10 kg masses?

5. Given that the mass of the Moon is 7.34×10^{22} kg and that its average diameter is 3.48×10^{3} km, find:

(a) The gravitational force acting on a 50 kg mass on its surface.

(b) The gravitational force on a 500 kg satellite which orbits the Moon at an altitude of 300 km.

(c) The gravitational force on a 500 kg satellite orbiting the Moon with an orbital radius of 2000 km.

(d) The strength of the gravitational field at an altitude of 300 km above the surface of the Moon.

(e) The strength of the gravitational field in the orbital position of the satellite in (c).

6. Use the data in the table to answer this question.

Planet	Diameter (km)	Mass (kg)
Mars	$6. 79 \times 10^{3}$	6.42×10^{23}
Jupiter	1.43×10^{5}	1.90×10^{27}
Saturn	1.20×10^{5}	5.69×10^{26}
Uranus	5.18×10^{4}	8.68×10^{25}

(a) Find the gravitational force between Mars and a 50 kg mass on its surface.

(b) Find the gravitational force between Jupiter and a 50 kg mass on its surface.

(c) Find the weight of a 50 kg mass on the surface of Saturn.

(d) Find the weight of a 50 kg mass on the surface of Uranus.

(e) Find the weight of a 50 kg mass which is orbiting Mars at an altitude of 600 km.

(f) Find the weight of a 50 kg mass which is orbiting Jupiter at an altitude of 600 km.

(g) Find the gravitational force between Saturn and a 50 kg mass in orbit at an altitude of 400 km.

(h) Find the gravitational force between Uranus and a 50 kg mass in an orbit with an orbital radius of 2.70×10^{7} km.

(i) Find the gravitational field strength on the surface of Mars.

(j) Find the gravitational field strength 300 km above the surface of Jupiter.

(k) Compare the gravitational field strengths on the surfaces of Saturn and Uranus.

7. If the mass of Titan, one of Jupiter's moons, is 1.35×10^{23} kg and its radius is 2570 km determine:

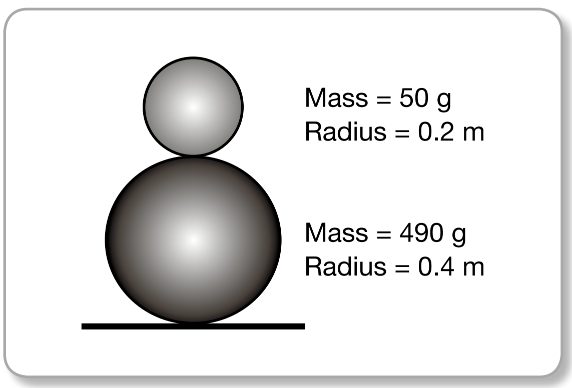
(a) The acceleration due to gravity at its surface.

(b) The force on a 750 kg rock which is on the surface of Titan.

8. (a) What force does Earth exert on an 80.0 kg astronaut at an altitude equivalent to 2.5 times Earth's radius?

(b) What is the gravitational field strength of the Earth at this position?

9. A 490 kg solid sphere with a radius of 0.40 m is on the surface of the Earth. Resting on top of this sphere is a second sphere, radius 0.2 m and mass 50 g as shown in the diagram.



(a) Find the net force the top sphere exerts on the bottom sphere.

(b) Find the magnitude of the gravitational force exerted by the bottom sphere on the top sphere.

10. If the mass of the Moon is 7.35×10^{22} kg and the orbital radius of the Moon about the Earth is 3.85×10^{5} km, determine the force of gravitational attraction between the Earth and the Moon.

11. A planet has two moons. The first is 3 times as far from the centre of the planet as the second and has a mass that is 4 times the mass of the second. What is the ratio of the gravitational force on the first planet to the gravitational force on the second?

12. Two spherical balls are placed so their centres are 3.72 m apart. The force between them is 2.45×10^{-8} N. If the mass of the smaller ball is 54.3 kg, what is the mass of the other ball?

13. How far (in km) from the centre of the Earth would a person with a weight of 470 N on the surface of the Earth have to be to have a weight of 56.2 N?

14. A mass of 20.0 kg is located 4.0 m to the right of a mass of 30.0 kg.

(a) What is the force on the 20.0 kg mass?

(b) What is the force on the 30.0 kg mass?

15. Christian and Mia have masses of 55 kg and 49 kg respectively. They sit 1.5 m apart in the front centre of Mr S's physics class. Determine the magnitude of the force of gravitational attraction between them.

16. The centres of two masses, X and Y, are separated by a distance *R*. The force of attraction between the two masses is *F*. How does this force change if the following changes are made?

(a) The mass of X is doubled.

(b) The distance between the masses was doubled.

(c) The mass of X was doubled and the mass of Y was tripled.

(d) Both the masses were halved, as was the distance between them.

(e) Mass X was halved, mass Y was tripled, and the distance between them increased by 50%.

17. Calculate the distance between two 150 kg masses that have a gravitational attraction of 8.34×10^{-7} N.

18. How far above the Earth's surface would you have to be for your weight to be only one fifth (0.2) times your weight on the surface of the Earth?

19. Compare your weight in a satellite in orbit 1000 km above the Earth to what it would be if you were in orbit 1000 km above Mars (take the mass of Mars as 6.42×10^{23} kg, and its radius as 3400 km).

20. The mass of Pluto is 1.3×10^{22} kg. Pluto is 5.76×10^{9} km from Earth. What is the force of gravity between Pluto and Earth?

SET 4 Gravitational Potential Energy

For relevant questions in this set, take the radius of the Earth as 6380 km, and its mass as 6×10^{24} kg.

1. Where would an object be if its gravitational potential energy was zero? Explain your answer.

2. Define gravitational potential energy for an object which is a significant distance above the surface of the Earth (or any other planet), giving the equation we use to find it, and the units we use to measure it.

3. Explain why we do not use the equation $E_P = mgh$ to calculate the gravitational potential energy of an object in space.

4. Explain, using appropriate laws of physics and mathematical equations if appropriate, why the gravitational potential energy of an object at a particular point in space is always a negative quantity.

5. Calculate the gravitational potential energy between two satellites, each with a mass of 500 kg, 5 km apart in space.

6. A 7 tonne satellite orbiting Earth has an orbital radius of 7100 km. What is its gravitational potential energy? Take the mass of the Earth as 6×10^{24} kg.

7. The Hubble telescope, mass 11 340 kg orbits Earth at an altitude of 595 km. What is its gravitational potential energy? Take the mass of the Earth as 5.974×10^{24} kg, and its diameter as 12 760 km.

8. (a) Find the gravitational potential energy of the Moon with respect to the Earth. The mass of the Moon is 7.34 × 1022 kilograms and the mass of the Earth is 5.974 × 1024 kilograms. The orbital radius of the Moon about the Earth is 384 400 kilometres.

(b) The orbital radius data in (a) includes the radius of the Earth and the radius of the Moon. However, in questions like 5, and 6 and 7 above, we did not include the size of the satellite in our deliberations. Why could the satellite's size be ignored?

9. Use the data in the table to answer this question.

Planet	Diameter (km)	Mass (kg)
Mercury	4.88×10^{3}	3.58×10^{23}
Venus	1.21×10^{4}	4.87×10^{24}
Earth	1.28×10^{4}	5.97×10^{24}
Neptune	4.93×10^{4}	1.02×10^{26}

(a) Find the gravitational potential energy of a 75 kg mass on the surface of Mercury.

(b) Find the gravitational potential energy of a 75 kg mass on the surface of Venus.

(c) Find the gravitational potential energy of a 150 kg mass 400 km above the surface of Earth.

(d) Find the gravitational potential energy of a 150 kg mass 800 km above the surface of Neptune.

(e) Find the gravitational potential energy of a 250 kg satellite in orbit at an altitude of 3000 km above the surface of Mercury.

(f) Find the gravitational potential energy of a 250 kg satellite orbiting Venus with an orbital radius of 6.5×10^{6} km.

ANSWERS

Set 1 Mass and Weight

1. (a) Mass is a measure of the amount of matter in a body.

(b) Mass, does not change regardless of where the object is. Mass is constant, not being changed by the object's position in a gravitational field.

(c) grams (g), kilograms (kg), tonnes (t)

2. (a) Weight is a measure of the force of gravity acting on a mass.

(b) Weight changes according to the strength of the gravitational field the object is in.

(c) Newton (N)

(d) $W_F = mg$

3. Convert mass to kg, and then multiply by 9.8 ($W = mg$).

(a) 9.8×10^{-3} N

(b) 0.83 N

(c) 5.39 N

(d) 2410.8 N

(e) 1.97×10^4 N

(f) 1580 N

4. Divide each figure by 9.8 (and convert to grams by dividing by 1000 if needed).

(a) 40.8 g

(b) 0.816 kg (816 g)

(c) 25 kg

(d) 50 kg

(e) 1000 kg

(f) 6632.7 kg

5. (a) 60 kg

(b) 96 N

(c) 588 N

(d) 686 N

(e) 70 kg

(f) 112 N

6. Mass is always constant regardless of its position in the Universe whereas weight changes according to the strength of the gravitational field it is in.

Mass is not a force, weight is a force.

Mass is measured in kilogram, weight in newtons.

(Mass is a scalar quantity – (does not require a direction) while weight is a vector quantity – (requires a direction).

7. (a) 20.4 kg

(b) 200 N

8. (a) 588 N

(b) 60 kg

(c) 223.4 N

9. (a) They work because the astronaut's weight force acts on them, but the scale has been calibrated in mass units rather than weight units, so they report her mass (as do all typical scales we use).

(b) They would read about 10 kg because the astronaut's weight on the Moon is about one sixth of that on Earth, so the spring mechanism inside the scales will only be compressed by one sixth its compression on Earth.

10.

City	Gravitational field at this position (m s^{-2})	Weight of 10 kg mass at this position (N)
Sydney	9.7979	97.979
Hong Kong	9.8099	98.099
Toronto	9.8054	98.054
Helsinki	9.8189	98.189
Baghdad	9.7964	97.964
Seoul	9.7994	97.994
Manila	9.7844	97.844
New York	9.8024	98.024
Mexico City	9.7799	97.799

Set 2 Gravitational Field

1. (a) A field is a region in which something experiences a force.
(b) A gravitational field is a region in which masses experience forces.
(c) Gravitational fields are found around all masses.
(d) Gravitational field strength is the force per unit mass an object experiences when placed in the field.
(e) $g = \frac{F}{m}$
(f) N kg^{-1} or m s^{-2}
(g) Acceleration due to gravity.

2. (a) Its gravitational potential energy.
(b) Work done equals the change in the gravitational potential energy.

3. (a) The Earth is not a perfect sphere, and gravitational field strength depends partly on the distance the object is from the centre (of mass) of the Earth.
(b) $mg = \frac{Gm_o m_E}{r^2}$
From which, on cancelling the m_o, and rearranging, $g = \frac{Gm_E}{r^2}$.
(c) This equation clearly shows the dependence of gravitational field on r^{-2}. As we go further from the Earth's centre, the gravitational field becomes exponentially smaller.
(d) r is the distance of the object from the Earth's centre. For an object in orbit, it represents the orbital radius of the orbit (it includes the radius of the Earth, and the altitude of the orbit).

4. (a) $GPE = mgh$ or $GPE = mg\Delta h$
(b) The height of the object above the surface of the Earth, or in the case of Δh, the change in the height of the object above the Earth's surface.
(c) This equation can be used as long as the value for the gravitational field at the positions involved are calculated. It is not used because it is easier to use a more appropriate equation (see later) Reason: The value of 'g' is 9.8 only at the surface so if 'h' is more than a few km the equation is unreliable.

5. (a) The gravitational field.
(b) Some external force, for example, the engine of a spacecraft, the motor of a car hoist.

6. (a) 198 N
(b) 1098 N

7. The gravitational field on top of Mount Everest would be less than that at sea level because the top of Mount Everest is further from the centre of mass of the Earth (taken as being at the centre of the Earth).

8. (a) Mass does not change = 80 kg
(b) 4 N

9. (a) The motion of an object in a gravitational field is described by Newton's three equations of motion, and the mass of an object is not one of the factors affecting that motion. However, in order to fall at the same rate, a larger object will need a larger force acting on if, so the gravitational force will be larger (equal to mass × gravitational field). This ensures that the rate of fall for all masses is the same.
(b) If the height is significant, then the value of the gravitational field (g) will be less, and therefore the initial rate of fall will also be less. As the object falls closer to the Earth, and gravitational field increases, the rate at which its downwards velocity increases will also increase (note that we are ignoring air resistance here).

10. 14.7 N kg^{-1} (or m s^{-2})

11. (a) 275.2 N kg^{-1} (or m s^{-2})
(b) 6.67×10^{12} N kg^{-1} (or m s^{-2})

12. 9.24 N kg^{-1} (or m s^{-2})

13. 1.09 N kg^{-1} (or m s^{-2})

14. 1447 km

15. 1155 km

16. 8.9 m s^{-1}

17. The gravitational field strength in the Earth orbit would 3.3 times greater than that in the Mars orbit.

18. 1.0×10^6 m

19. 2.82 N kg^{-1}

20. 1.4×10^7 m

21. 1.1 N kg^{-1}
22. 10.7 N kg^{-1}
23. (a) 22 500 km
(b) 0.45 N kg^{-1}
24. (a) 7.5 N kg^{-1}
(b) 4.5×10^{23} kg
25. (a) 2520 J
(b) Slightly less because the gravitational field strength would be slightly less at the higher altitude.
(c) 4.5 N kg^{-1}
26. From $g = \frac{GM}{r^2}$, with Y having one quarter the mass and half the radius, g = same as X = 8 m s^{-2}.

Set 3 Newton's Law of Universal Gravitation

1. 1.85×10^{-10} N
2. 4484 N
3. (a) Force will be four time less.
(b) Force will be four times greater.
(c) Force will be doubled.
(d) Force will be nine times greater.
(e) Force will be 9 times smaller because of the distance but 4 times larger because of the mass change, therefore overall it will be $\frac{4}{9}$ times smaller.
4. (a) Weight ratio is 4 : 3.
(b) It would still be the same, 4 : 3.
5. (a) 80.85 N
(b) 588.2 N
(c) 612 N
(d) 1.18 N kg^{-1} (or m s^{-2})
(e) 1.22 N kg^{-1} (or m s^{-2})
6. (a) 185.8 N
(b) 12 39.5 N
(c) 527 N
(d) 432 N
(e) 134.2 N
(f) 1218.9 N
(g) 520.2 N
(h) 3.97×10^{-4} N
(i) 3.72 N kg^{-1} (or m s^{-2})
(j) 24.58 N kg^{-1} (or m s^{-2})
(k) Saturn = 10.54 N kg^{-1} (or m s^{-2}). Uranus = 8.63 N kg^{-1} (or m s^{-2}). Saturn = 1.22 times greater than Uranus.
7. (a) 1.36 m s^{-2}
(b) 1022 N
8. (a) 125.8 N
(b) 1.057 N kg^{-1} (or m s^{-2})
9. (a) 0.49 N downwards
(b) 4.5×10^{-12} N upwards
10. 1.98×10^{20} N (attraction)
11. 4 : 9
12. 93.6 kg
13. 1.85×10^{4} km
14. (a) 2.5×10^{-9} N to the left
(b) 2.5×10^{-9} N to the right
15. 8.0×10^{-8} N

16. (a) Force will double to $2F$
(b) Force will be $0.25F$
(c) Force will become $6F$
(d) Force will be the same, F
(e) Force will be two thirds the original value, $\frac{2F}{3}$

17. 1.34 m

18. 3.8×10^4 km

19. Your weight in the Earth orbit would be 3.3 times greater than your weight in the Mars orbit.

20. 1.57×10^{11} N

Set 4 Gravitational Potential Energy

1. At infinity. It is only at infinity that an object is outside any gravitational field so that the force acting on it is zero. It therefore has no tendency to 'fall'.

2. The gravitational potential energy of an object at any point in space is equal to the work done in moving it from infinity to the point. $E_P = -\frac{GMm}{r}$, measured in joules (J).

3. We do not use this equation because the value of g is not constant, and because it refers only to objects close to the surface of Earth (or any other planet or moon) where the zero reference point is the surface of the planet or moon. The equation is more correctly given as $mg\Delta h$, and calculates the *change* in gravitational potential energy close to the surface.

4. The gravitational potential energy at infinity is zero so the only direction it can move is downwards, towards a planet. As it falls its gravitational potential energy will change to kinetic energy. Because the law of conservation of energy must be obeyed, and the object's kinetic energy will be positive, its gravitational potential energy must be negative.

5. -3.335×10^{-9} J

6. -3.95×10^{14} J

7. -6.48×10^{11} J

8. (a) -7.61×10^{28} J
(b) The radius of the satellite is insignificant compared to the other distances and can therefore be ignored.

9. (a) -7.34×10^8 J
(b) -4.03×10^9 J
(c) -8.72×10^9 J
(d) -4.01×10^{10} J
(e) -1.10×10^9 J
(f) -1.25×10^7 J

Set 5 Changes in Gravitational Potential Energy

1. (a) -5.34×10^{-8} J
(b) New gravitational potential energy will be -2.67×10^{-8} J. This represents an increase of 2.67×10^{-8} J.
(c) The gravitational force will decrease by a factor of 4 (inversely proportional to distance squared).
(d) If the objects are further apart, then there is a larger energy gap between them, so potential energy will increase whereas gravitational force decreases with increasing distance apart.

2. Gravitational potential energy at 10 000 km = -1.22×10^{10} J. At 20 000 km it will be -7.58×10^9 J. This represents an increase of 4.62×10^9 J, which is the amount of work that needs to be done on the satellite.

3. Gravitational potential energy at 6680 km = -1.5×10^{10} J. At 7680 km it will be -1.36×10^{10} J. This represents an increase of 1.4×10^9 J.

4. (a) 7303 km
(b) 923 km
(c) Gravitational potential energy at the new altitude would be -1.22×10^{10} J which represents a change of $+1.5 \times 10^{10}$ J (using rounded figures).

5. (a) $-0.5E$ J
(b) $-3E$ J
(c) Its gravitational potential energy will increase to $-1.5E$ J (increase by $+1.5E$ J).

6. (a) The satellite above Neptune. With all other variables constant, the determining factor is the mass of the planet.
(b) The satellite above Mercury. With all other variables constant, the determining factor is the mass of the planet.
(c) $13.6R$