1.3 Mass and weight

Name: _____ Class: _____ Date: _____ **Total: 28 marks**

0 Vocabulary

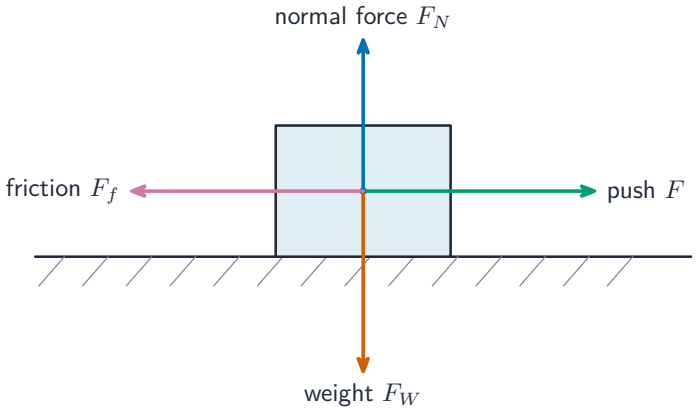
Word	Example
mass /mæs/ 质量	The **mass** of this bag of rice is 5 kg. 这袋大米的**质量**是 5 kg。
velocity /vəˈlɒsɪti/ 速度	The ball's **velocity** is 5 m/s to the left. 球的**速度**为 5 m/s，方向向左。
acceleration /əkˌseləˈreɪʃn/ 加速度	The car speeds up quickly, so its **acceleration** is large. 汽车加速很快，所以它的**加速度**很大。
electric field strength 电场强度 /ɪˈlektrɪk fiːld streŋθ/	Near the charged ball, the **electric field strength** is 500 N/C. 带电小球附近的**电场强度**为 500 N/C。
gravitational field strength 重力场强度 /ˌgrævɪˈteɪʃənl fiːld streŋθ/	The **gravitational field strength** on Earth is 9.81 N/kg. 地球上的**重力场强度**为 9.81 N/kg。
speed /spiːd/ 速率	The bus moves at a **speed** of 15 m/s. 公共汽车以 15 m/s 的**速率**行驶。
acceleration of free fall 自由落体加速度 /əkˌseləˈreɪʃn ɒv friː fɔːl/	The **acceleration of free fall** on Earth is 9.81 m/s^2. 地球上的**自由落体加速度**是 9.81 m/s^2。
matter /ˈmætə/ 物质	All **matter** is made of tiny particles. 所有**物质**都由微小的粒子组成。
balance /ˈbæləns/ 天平	Weigh the solid on a **balance**. 用**天平**称量固体。
extension /ekˈstenʃn/ 伸长量	The **extension** of the spring is 4 cm. 弹簧的**伸长量**是 4 cm。

1 Key knowledge and worked examples

Study these first. Each one shows the method for a question type used later: follow the steps and you can do the Practice and Exam-style questions yourself.

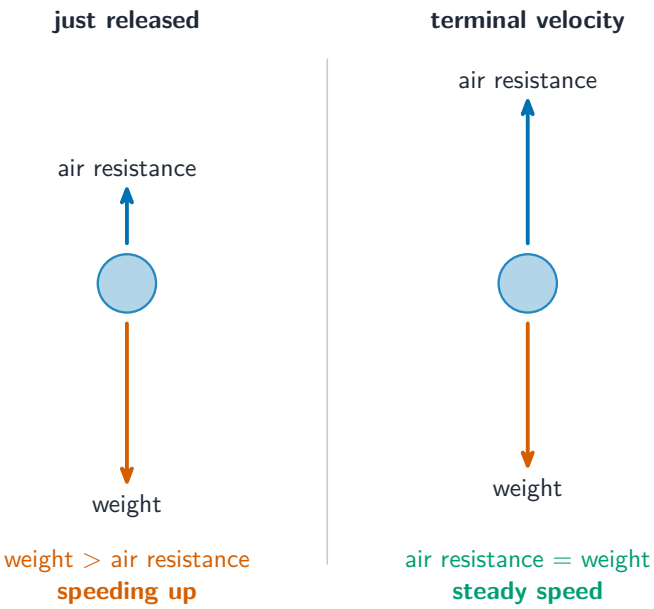
■ Mass and weight

	mass m	**weight** F_W
what it is	the quantity of matter	the force of gravity on a mass
unit	kilogram (kg)	newton (N)
measured with	a balance (compares masses)	a spring balance (a force meter)
on the Moon	the same	smaller



Weight is the downward force of gravity on a mass: $F_W = mg$

- **Gravitational field strength** g is the force per unit mass: $g = \dfrac{F_W}{m}$, in N/kg. Earth: $g = 9.8$ N/kg.
- With only its weight acting, an object falls with acceleration $a = \dfrac{F_W}{m} = g$, so g is also the **acceleration of free fall** 自由落体加速度: 9.8 N/kg $= 9.8\ \dfrac{\text{m}}{\text{s}^2}$. Papers use either name.



Weight is the downward force, balanced by drag at terminal velocity

■ Worked example 1: weight from mass

A bag of rice has a mass of 1.2 kg. Find its weight on Earth, where $g = 9.8$ N/kg.

1. Known: $m = 1.2$ kg, $g = 9.8$ N/kg; weight is the gravitational force on a mass, so use $F_W = mg$.
2. $$F_W = mg = (1.2 \text{ kg})(9.8 \text{ N/kg}) = \mathbf{12} \text{ N}$$

■ Worked example 2: weight on another planet

An object weighs 30 N on Earth ($g = 9.8$ N/kg). Find its weight on the Moon ($g = 1.6$ N/kg).

1. The mass does not change, so find it first from the Earth weight: $F_W = mg$ gives $m = \dfrac{F_W}{g}$.
$$m = \frac{F_W}{g} = \frac{30 \text{ N}}{9.8 \text{ N/kg}} = 3.06 \text{ kg}$$
2. Use the same mass with the Moon's field strength:
$$F_W = mg = (3.06 \text{ kg})(1.6 \text{ N/kg}) = \mathbf{4.9} \text{ N}$$

Check: the Moon's g is about $\frac{1}{6}$ of Earth's, so the weight should be about $\frac{1}{6}$ of 30 N.

■ Worked example 3: a planet's volume from its mass and density

The Moon has a mass of 7.3×10^{22} kg and an average **density** 密度 of 3300 kg/m^3. Find its volume.

1. Density is mass per unit volume, $\rho = \dfrac{m}{V}$, so $V = \dfrac{m}{\rho}$.
2. $$V = \frac{m}{\rho} = \frac{7.3 \times 10^{22}\ \text{kg}}{3300\ \text{kg/m}^3} = \mathbf{2.2 \times 10^{19}}\ \text{m}^3$$

■ **Watch out**

- A mass in kg is never a weight: "it weighs 5 kg" in everyday speech means a **mass** of 5 kg.
- A balance compares masses, and gravity pulls equally on both pans, so it reads the same anywhere. A spring balance measures the pull of gravity, so it reads less on the Moon.

2 Practice

2.1 State the unit of weight and the unit of mass. [1]

weight mass

2.2 Find the weight of a 6.0 kg bag on Earth ($g = 10$ N/kg). [2]

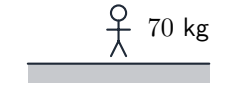


$g = 10$ N/kg

2.3 Define **gravitational field strength**. [1]

gravitational field strength

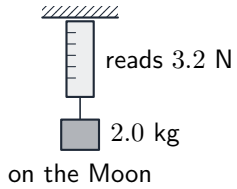
2.4 Find the weight of a 70 kg astronaut on Mars, where $g = 3.7$ N/kg. [2]



Mars, $g = 3.7$ N/kg

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2.5 On the Moon, a 2.0 kg mass hangs from a spring balance. The spring balance reads 3.2 N. Calculate the gravitational field strength on the Moon. [2]



3 Exam-style questions

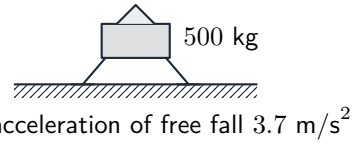
3.1 When an astronaut goes to the Moon, their: [1]

☐ **A** mass and weight both decrease
B mass stays the same but weight decreases
C mass decreases but weight stays the same
D mass and weight both stay the same



3.2 A lander of mass 500 kg rests on Mars. The acceleration of free fall on Mars is 3.7 $\frac{\text{m}}{\text{s}^2}$. What is the weight of the lander on Mars? [1]

☐ **A** 135 N
B 504 N
C 1850 N
D 5000 N



3.3 An object has a weight of 48 N on Earth, where $g = 10$ N/kg.

(a) Calculate its mass. [2]



Earth: $g = 10$ N/kg
Moon: $g = 1.6$ N/kg

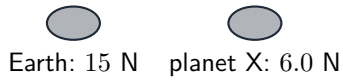
(b) Calculate its weight on the Moon, where $g = 1.6$ N/kg. [2]

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3.4 A rock has a weight of 15 N on Earth, where $g = 10$ N/kg. On planet X the same rock has a weight of 6.0 N.

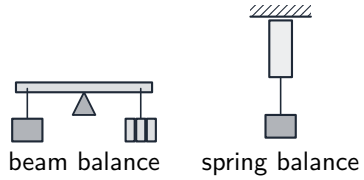
(a) Calculate the mass of the rock. [1]

(b) Calculate the gravitational field strength on planet X. [2]



(c) Calculate the weight on planet X of a 4.0 kg toolbox. [2]

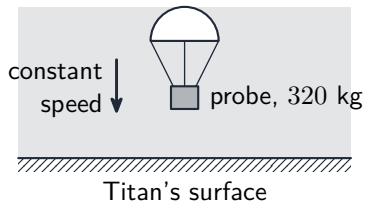
3.5 A beam balance compares an object with standard masses; a spring balance measures the pull of gravity on the object. Explain why only the beam balance gives the same reading on the Moon as on Earth. [2]



3.6 Table 3.7 contains information about Titan, the largest moon of Saturn.

quantity	**value**
mass	1.35×10^{23} kg
gravitational field strength at surface	1.35 N/kg
average density	1900 kg/m^3

(a) An object has a weight of 50 N at the surface of the Earth, where $g = 10$ N/kg. Calculate the weight of the object at the surface of Titan. [2]



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(b) Calculate the volume of Titan. [2]

(c) A probe of mass 320 kg falls through Titan's atmosphere at a constant speed.

(i) Calculate the weight of the probe on Titan. [1]

(ii) State the size of the air resistance on the probe, and explain your answer. [2]

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Solutions

Each answer shows the steps, then the **result**.

2.1

- weight in newtons (N); mass in kilograms (kg)

2.2

- known: $m = 6.0$ kg, $g = 10$ N/kg; weight is $F_W = mg$

$$F_W = mg = (6.0\text{ kg})(10\text{ N/kg}) = \mathbf{60}\text{ N}$$

2.3

- the force per unit mass (the weight of each kilogram), in N/kg

2.4

- known: $m = 70$ kg, $g = 3.7$ N/kg; weight is $F_W = mg$

$$F_W = mg = (70\text{ kg})(3.7\text{ N/kg}) = \mathbf{260}\text{ N}$$

2.5

- the spring balance reads the weight, $F_W = 3.2$ N; g is force per unit mass, $g = \dfrac{F_W}{m}$

$$g = \frac{F_W}{m} = \frac{3.2\text{ N}}{2.0\text{ kg}} = \mathbf{1.6}\text{ N/kg}$$

3.1 B

- mass is unchanged; weight is less because the Moon's gravitational field is weaker

3.2 C

- $F_W = mg$ with $g = 3.7\ \dfrac{\text{m}}{\text{s}^2} = 3.7$ N/kg:

$$F_W = mg = (500\text{ kg})(3.7\text{ N/kg}) = 1850\text{ N}$$

- A divides instead of multiplying; B adds; D uses Earth's $g = 10$ N/kg

3.3

(a)

- the weight is known on Earth; $F_W = mg$, so $m = \dfrac{F_W}{g}$

$$m = \frac{F_W}{g} = \frac{48\text{ N}}{10\text{ N/kg}} = \mathbf{4.8}\text{ kg}$$

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(b)

- the mass is the same on the Moon; $F_W = mg$

$$F_W = mg = (4.8\text{ kg})(1.6\text{ N/kg}) = \mathbf{7.7}\text{ N}$$

3.4

(a)

- $F_W = mg$, so $m = \dfrac{F_W}{g}$:

$$m = \frac{F_W}{g} = \frac{15\text{ N}}{10\text{ N/kg}} = \mathbf{1.5}\text{ kg}$$

(b)

- the mass is the same on planet X; rearrange $F_W = mg$ to $g = \dfrac{F_W}{m}$

$$g = \frac{F_W}{m} = \frac{6.0\text{ N}}{1.5\text{ kg}} = \mathbf{4.0}\text{ N/kg}$$

(c)

- $F_W = mg$ with $g = 4.0$ N/kg from (b)

$$F_W = mg = (4.0\text{ kg})(4.0\text{ N/kg}) = \mathbf{16}\text{ N}$$

3.5

- gravity on the Moon is weaker, so the spring balance, which measures weight, reads less
- the beam balance compares masses: gravity is weaker on both sides equally, so it still balances and reads the same

3.6

(a)

- mass from the Earth weight: $m = \dfrac{F_W}{g}$

$$m = \frac{F_W}{g} = \frac{50\text{ N}}{10\text{ N/kg}} = 5.0\text{ kg}$$

- the same mass on Titan: $F_W = mg$

$$F_W = mg = (5.0\text{ kg})(1.35\text{ N/kg}) = \mathbf{6.8}\text{ N}$$

(b)

- density $\rho = \dfrac{m}{V}$, so $V = \dfrac{m}{\rho}$

$$V = \frac{m}{\rho} = \frac{1.35 \times 10^{23}\text{ kg}}{1900\text{ kg/m}^3} = \mathbf{7.1 \times 10^{19}}\text{ m}^3$$

(c)

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(i)

- $F_W = mg$:

$$F_W = mg = (320 \text{ kg})(1.35 \text{ N/kg}) = \mathbf{430} \text{ N}$$

(ii)

- 430 N (upwards)
- the speed is constant, so the resultant force is zero and the air resistance balances the weight

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