Gravitational Field Strength

Gravitational field: region of space where a mass experiences a force

Sketch the gravitational field of the Earth

Gravitational Force

$F_g = \frac{GmM}{r^2}$

$F_g = mg$

Gravitational Field Strength

$g = \frac{Gm}{r^2}$

Variable	Fg	G	g
Quantity	• Weight • Force of gravity • Gravitational Force of Attraction	universal gravitational constant	• gravitational field strength • acceleration due to gravity
Units	N	Nm^2/kg^2	m/s^2
Type	vector	scalar	vector
Property	varies	same/constant	varies

1. Calculate the Earth's gravitational field strength:

a) at the surface of Earth.

$M_E = 5.97 \times 10^{24} kg$

$r = 6.37 \times 10^6 m$

$g = \frac{GM_E}{r^2}$

$g = \frac{(6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(5.97 \times 10^{24} kg)}{(6.37 \times 10^6 m)^2} = 9.81 \frac{m}{s^2}$

b) at an altitude equal to one Earth radius.

$g = \frac{1}{(2r)^2} = \frac{1}{4}(9.81 \frac{m}{s^2})$

$= 2.45 \frac{m}{s^2}$

2. The International Space Station (ISS) orbits at an average altitude of 340 kilometers. How strong is the Earth's gravitational field at this altitude?

refer to ISS problem part "c"

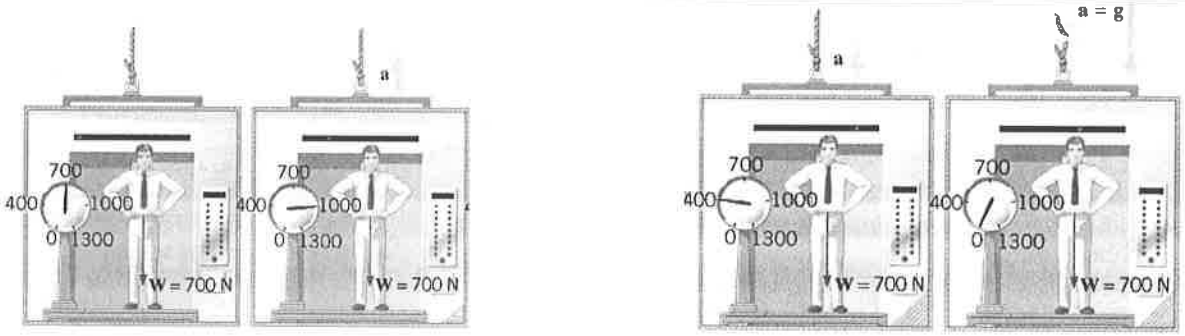
$8.8 \frac{m}{s^2}$

3. Planet X has the same mass as Earth but only half the diameter. What is the gravitational field strength on the surface of this planet?

$F_g = \frac{G m M_x}{r^2}$ $\quad \vec{g} = \frac{GM_x}{r^2}$ $\quad \frac{GM_x}{\left(\frac{1}{2}r\right)^2} =$ 4x gravitational field strength of Earth

$M_x = M_E$

Weight and Weightlessness - Riding in an Elevator



(a) No acceleration (v = constant) (b) Upward acceleration (c) Downward acceleration (d) Free-fall

1. When does the scale read the normal weight of the person?

At rest or at constant speed

2. When does the scale read higher than the normal weight of the person?

when $\vec{a}$ is upward

3. When does the scale read less than the normal weight of the person?

when $\vec{a}$ is downward

4. What does a scale reading actually measure?

normal force or F_N

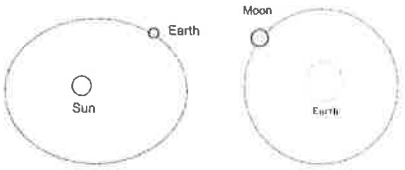
5. ~~Determine the acceleration of the elevator in cases (b) and (c).~~

Satellites

IB 11

Satellite: an object that orbits another object

Natural Satellites



Artificial Satellites

1. How can an object become a satellite?

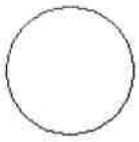
Satellite moves fast enough with an initial escape velocity so that it constantly misses what it is falling toward.

2. What keeps a satellite up?

Enough horizontal velocity to keep missing the Earth.

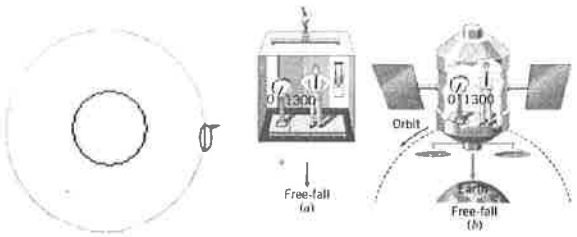
3. Why doesn't the Moon fall into the Earth as an apple does?

Real weightlessness



$\Sigma F_{NET} = 0N$

Apparent weightlessness



4. Why did the Apollo astronauts feel weightless?

No normal force

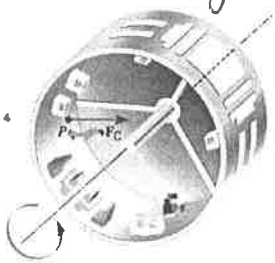
5. Why do the space shuttle astronauts feel weightless?

Falling toward the Earth at an acceleration = "g".

Artificial Gravity

6. How can gravity be simulated in a space station?

By using circular motion, F_N is the inward force.



7. How fast would this 20. meter diameter space station have to spin to simulate Earth's gravity?

$\Sigma F_{in} = \frac{mv^2}{r}$

$F_N = F_g = mg$

$mg = \frac{mv^2}{r}$

$v = \sqrt{rg}$

$v = \sqrt{(10.\text{m})(9.8\frac{\text{m}}{\text{s}^2})} = \boxed{9.9\frac{\text{m}}{\text{s}}}$