Gravitational Field Strength and Gravitational Acceleration

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Table 4.3 Masses and Radii for Celestial Bodies in the Solar System[a]

Celestial Body	Mass (kg)	Equatorial Radius (m)
Sun	1.99×10^{30}	6.96×10^{8}
Mercury	3.30×10^{23}	2.44×10^{6}
Venus	4.87×10^{24}	6.05×10^{6}
Earth	5.97×10^{24}	6.38×10^{6}
Earth's Moon	7.35×10^{22}	1.74×10^{6}
Mars	6.42×10^{23}	3.40×10^{6}
Jupiter	1.90×10^{27}	7.15×10^{7}
Saturn	5.69×10^{26}	6.03×10^{7}
Uranus	8.68×10^{25}	2.56×10^{7}
Neptune	1.02×10^{26}	2.48×10^{7}

Practice Problems

1. A satellite orbits Earth at a distance of $3r_{Earth}$ above Earth's surface. Use the data from Table 4.3 on page 117.
   (a) How many Earth radii is the satellite from Earth's centre?
   (b) What is the magnitude of the gravitational acceleration of the satellite?

2. An 80.0-kg astronaut is in orbit 3.20×10^4 km from Earth's centre.
   (a) Calculate the magnitude of the gravitational field strength at the location of the astronaut.
   (b) What would be the magnitude of the gravitational field strength if the astronaut is orbiting the Moon with the same separation distance?

3. The highest satellites orbit Earth at a distance of about $6.6r_{Earth}$ from Earth's centre. What would be the gravitational force on a 70-kg astronaut at this location?

Answers

1. (a) $4r_{Earth}$
   (b) 6.11×10^{-1} m/s^2
2. (a) 3.89×10^{-1} N/kg
   (b) 4.79×10^{-3} N/kg
3. 16 N [toward Earth's centre]

Questions from Page 123

6. Calculate the gravitational field strength at the location of a 70-kg astronaut $2.0r_{Earth}$ from Earth's centre. Use the data from Table 4.3 on page 117.

8. (a) Calculate the magnitude of the gravitational field strength at the surfaces of the celestial bodies listed in Table 4.3.
(b) Rank them from least to greatest.

14. If an 85-kg astronaut has a weight of 314 N, which planet is she standing on?

Gravitational Field Strength

Textbook questions:
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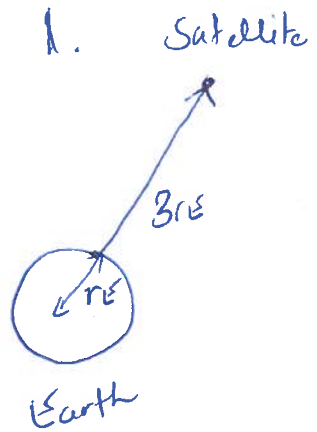
1. 

a) $r = 4r_E$

b) $G = 6.67\times10^{-11}\ \frac{Nm^2}{kg^2}$

$M_E = 5.98\times10^{24}$ kg

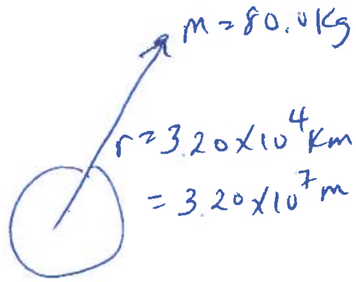
$r = 4r_E$
$= 4(6.38\times10^{6}\,m)$

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

$$= \frac{\left(6.67\times10^{-11}\ \frac{Nm^2}{kg^2}\right)\left(5.98\times10^{24}\ kg\right)}{\left((4)6.38\times10^{6}\,m\right)^2}$$

$$= 0.612\ N/kg$$

OR $g = \left(\frac{9.81\ N/kg}{16}\right) = 0.613\ \frac{N}{kg}$

2. 

$M_E = 5.98\times10^{24}$ kg

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

$$= \frac{\left(6.67\times10^{-11}\ \frac{Nm^2}{kg^2}\right)\left(5.98\times10^{24}\ kg\right)}{\left(3.20\times10^{7}\,m\right)^2}$$

$$= 0.390\ N/kg$$

b) $M_M = 7.35\times10^{23}$

$g = ?$

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

$$= \frac{\left(6.67\times10^{-11}\ \frac{Nm^2}{kg^2}\right)\left(7.35\times10^{23}\ kg\right)}{\left(3.20\times10^{7}\,m\right)^2}$$

$$= 4.79\times10^{-2}\ N/kg$$

3. $r = 6.6\,r_{Earth}$

$g_{surface} = 9.81\ N/kg$

$g = ?$

$m = 70$ kg

$F_g = ?$

$$g = \frac{GM_E}{(6.6r_E)^2} = \frac{GM_E}{(6.6)^2 r_E^2}$$

$$= \frac{9.81\ N/kg}{(6.6)^2}$$

$$= 0.2252\ N/kg$$

$F_g = mg$
$= (70\,kg)(0.2252\ \frac{N}{kg})$
$= 15.76$ N
~ 16 N

Pg 123 Questions

6) $g_{surface} = 9.81$ N/kg
$r = 2.0\, r_{Earth}$
$g = ?$

$$g = \frac{GM_E}{r^2} = \frac{g\, M_E}{(2)^2\, r_E^2} = \frac{9.81 \text{ N/kg}}{4} = 2.45 \text{ N/kg}.$$

8. Sun - $g = \frac{GM_s}{r_s^2} = \frac{(6.67\times10^{-11}\ \frac{Nm^2}{kg^2})(1.99\times10^{30}\ kg)}{(6.96\times10^{8}\ m)^2} = 274$ N/kg

Mercury - $g_{Merc} = 3.697 \sim 3.70$ N/kg

Venus - $g_v = 8.87$ N/kg

Earth - $g_E = 9.81$ N/kg

Moon - $g_{moon} = 1.62$ N/kg

Mars - $g_{mars} = 3.704$ N/kg

Jupiter - $g_{jup} = 24.8$ N/kg

Saturn - $g_{sat} = 10.44$ N/kg

Uranus - $g_{uran} = 3.75$ N/kg

Neptune - $g_{nept} = 11.06$ N/kg

ranking.
g_{moon} - 1.62 N/kg
g_{merc} - 3.697 N/kg
g_{mars} - 3.704 N/kg
g_{uranus} - 3.75 N/kg
g_{venus} - 8.87 N/kg
g_{earth} - 9.81 N/kg
g_{sat} - 10.44 N/kg
$g_{Neptune}$ - 11.06 N/kg

14) $m = 85$ kg
$F_g = 314$ N
$g = ?$

$$g = \frac{F_g}{m} = \frac{314\text{ N}}{85\text{ kg}} = 3.69 \text{ N/kg}$$

Very close to value for mars or mercury!