PHY 621

Newton's Law of Universal Gravitation

$= \frac{G M_1 M_2}{r^2}$

$F_g = mg$

$g_{new} = g_{surface} \left(\frac{R}{R + h} \right)^2$

r = distance between two centres of mass = mean orbit radius

h = altitude above surface

R = radius of body

r = R if object is on surface of celestial body

G = universal gravitation constant = $6.673 \times 10^{-11}\ Nm^2/kg^2$

g = acceleration due to gravity (value depends on location)

	mass	Body Radius
	kg	m
Moon	7.34×10^{22}	1.74×10^{6}
Earth	5.98×10^{24}	6.38×10^{6}
Mars	6.37×10^{23}	3.43×10^{6}

1. What is the force of attraction acting between a 68.4 kg woman and a 75.9 kg man standing 4.58 m apart?
2. What is the force of gravity pulling on an astronaut (with gear) of mass 105.8 kg standing on the surface of Mars?
3. What is the weight of a 59.4 kg woman flying in a jet 12.0 km above the surface of the Earth?
4. A man weighs 775.07 N while flying in a jet at an altitude of 15.0 km. What is the mass of the man?
5. Peter, having a mass of 69.36 kg, is standing 258.5 cm from the centre of mass of his beloved convertible. If the force of attraction between Peter and his convertible is 9.312×10^{-5} N, what is the mass of the convertible?
6. A woman weighs 766.85 N on the surface of the Earth. What would be her weight if she was standing on the moon?
7. The weight of the Mars' rover on the surface of mars is 379.2 N. What is the mass of the Mars' rover?
8. A woman of mass 62.30 kg experiences a force of gravity of 610.6 N. What is her elevation? (3 sig figs)

Answers:

1. 1.65×10^{-8} N [towards] 2. 382 N [down] 3. 5.80×10^{2} N [down] 4. 79.4 kg

5. 1.344×10^{5} kg 6. 127 N [down] 7. 105 kg 8. 824 m

Newton's Law of Uni. Gravity

#1) $m_1 = 68.4\ kg$
$m_2 = 75.9\ kg$
$r = 4.58\ m$
$F_G = ?$

$F_G = \frac{G m_1 m_2}{r^2}$

$= \frac{(6.673 \times 10^{-11}\ Nm^2/kg^2)(68.4\ kg)(75.9\ kg)}{(4.58\ m)^2}$

$= 1.6515 \times 10^{-8}\ N = \boxed{1.65 \times 10^{-8}\ N}$

#2) $m = 105.8\ kg$
$F_g = ?$
$R_M = 3.43 \times 10^6\ m$
$M_M = 6.37 \times 10^{23}\ kg$

$F_g = \frac{G m M_M}{R_M^2}$

$= \frac{(6.673 \times 10^{-11}\ Nm^2/kg^2)(105.8\ kg)(6.37 \times 10^{23}\ kg)}{(3.43 \times 10^6\ m)^2}$

$= 382.259\ N = \boxed{382\ N}$

#3) $m = 59.4\ kg$
$h = 12.0\ km$
$g = 9.81\ m/s^2$
$R_E = 6.38 \times 10^6\ m$

$g_{new} = \frac{R_E^2}{(R_E + h)^2} g$

$= \frac{(6.38 \times 10^6\ m)^2 (9.81\ m/s^2)}{(6.38 \times 10^6\ m + 12.0 \times 10^3\ m)^2}$

$= 9.77320\ m/s^2$

$F_g = m g_{new} = (59.4\ kg)(9.77320\ m/s^2) = 580.528\ N$

$= 581\ N$

using $F_g = \frac{G m M_E}{(R_E + h)^2}$ gives $580\ N$

#4) $F_g = 775.07\ N$
$h = 15.0\ km$
$M_E = 5.98 \times 10^{24}\ kg$
$R_E = 6.38 \times 10^6\ m$
$m = ?$

$$F_g = \frac{G m M_E}{(R_E + h)^2}$$

$$\therefore m = \frac{(R_E + h)^2 F_g}{G M_E}$$

$$= \frac{(6.38 \times 10^6\ m + 15.0 \times 10^3\ m)^2 (775.07\ N)}{(6.673 \times 10^{-11}\ N m^2/kg^2)(5.98 \times 10^{24}\ kg)} = 79.433\ kg$$

$$= \boxed{79.4\ kg}$$

#5) $m_p = 69.36\ kg$
$r = 258.5\ cm$
$F_g = 9.312 \times 10^{-5}\ N$
$m_c = ?$

$$F_g = \frac{G m_p m_c}{r^2}$$

$$\therefore m_c = \frac{F_g r^2}{G m_p}$$

$$= \frac{(9.312 \times 10^{-5}\ N)(258.5 \times 10^{-2}\ m)^2}{(6.673 \times 10^{-11}\ N m^2/kg^2)(69.36\ kg)} = 1.344417 \times 10^5\ kg$$

$$= \boxed{1.344 \times 10^5\ kg}$$

#6) $F_{gE} = 766.85\ N$
$F_{gM} = ?$
$M_E = 5.98 \times 10^{24}\ kg$
$R_E = 6.38 \times 10^6\ m$
$M_M = 7.34 \times 10^{22}\ kg$
$R_M = 1.74 \times 10^6\ m$

$$F_{gE} = \frac{G m M_E}{R_E^2} \rightarrow G m = \frac{F_{gE} R_E^2}{M_E}$$

$$F_{gM} = \frac{G m M_M}{R_M^2} \rightarrow G m = \frac{F_{gM} R_M^2}{M_M}$$

$$\therefore \frac{F_{gE} R_E^2}{M_E} = \frac{F_{gM} R_M^2}{M_M} \rightarrow F_{gM} = \left(\frac{M_M}{M_E}\right)\left(\frac{R_E^2}{R_M^2}\right) F_{gE}$$

$$= \left(\frac{7.34 \times 10^{22}\ kg}{5.98 \times 10^{24}\ kg}\right)\left(\frac{6.38 \times 10^6\ m}{1.74 \times 10^6\ m}\right)^2 (766.85\ N) = 126.546\ N$$

$$= \boxed{127\ N}$$

Newton's Law of Uni. Gravity

#7) $F_g = 379.2\ N$
$m = ?$
$R_M = 3.43 \times 10^6\ m$
$M_M = 6.37 \times 10^{23}\ kg$

$g_M = \frac{GM_M}{R_M^2}$

$= \frac{(6.673 \times 10^{-11}\ Nm^2/kg^2)(6.37 \times 10^{23}\ kg)}{(3.43 \times 10^6\ m)^2}$

$= 3.61304\ m/s^2$

$F_g = mg_M \rightarrow m = \frac{F_g}{g_M} = \frac{379.2\ N}{3.61304\ m/s^2} = 104.95\ kg$

$= \boxed{105\ kg}$

#8) $m = 62.30\ kg$
$F_g = 610.6\ N$
$h = ?$
$M_E = 5.98 \times 10^{24}\ kg$
$R_E = 6.38 \times 10^6\ m$

$F_g = \frac{GmM_E}{(R_E + h)^2}$

$(R_E + h)^2 = \frac{GmM_E}{F_g}$

$\therefore h = \sqrt{\frac{GmM_E}{F_g}} - R_E$

$= \sqrt{\frac{(6.673 \times 10^{-11}\ Nm^2/kg^2)(62.30\ kg)(5.98 \times 10^{24}\ kg)}{610.6\ N}} - 6.38 \times 10^6\ m$

$= 6.380824 \times 10^6\ m - 6.38 \times 10^6\ m = 824.17\ m$

$= \boxed{824\ m}$