Name: Answer Key
Block: ________________

Learning Intentions

- Learn how rolling resistance relates to the force of friction.
- Learn how to calculate the force of friction and the coefficient of friction.

Definitions and Formulas

1. Force of gravity:

$$\vec{F}_g = m\vec{g}$$

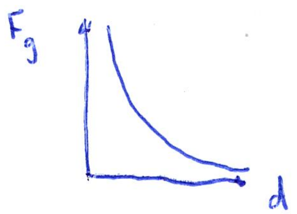
mass (Kg)

Force of gravity (Newtons)

Acceleration due to gravity

On Earth, $\vec{g} = 9.81\ m/s^2 = 9.81\ N/kg$ [down]

2. Universal Law of Gravitation:



$$F_g = \frac{Gm_1m_2}{d^2}$$

G = gravitational constant = $6.67\times10^{-11}\ \frac{m^3}{Kg\cdot s^2}$

m = mass of object (Kg)

d = distance between centres of objects (m)

a. The law is not actually universal. It was superseded by

Einstein's general theory of relativity

3. Gravity is a weak force.

a. What is the force of gravity between two 1.0 kg masses 1.0 metres apart?

$$F_g = \frac{Gm_1m_2}{d^2} = \frac{6.67\times10^{-11}\frac{m^3}{Kg\cdot s^2}\times1.0Kg\times1.0Kg}{(1.0m)^2} = 6.67\times10^{-11}\ \frac{Kg\cdot m}{s^2} = \cancel{6.67}$$

$= 6.67\times10^{-11}$ N [towards each other]

b. The masses are moved so that they are 1.0 mm apart. What is the force of gravity between the masses?

$$F_g = \frac{Gm_1m_2}{d^2} = \frac{6.67\times10^{-11}\frac{m^3}{Kg\cdot s^2}\cdot1.0Kg\cdot1.0Kg}{(0.0010m)^2} = 6.67\times10^{-5}\ N$$ [towards each other]

c. The masses are moved so that they are at opposite "ends" of the universe, 93 billion light years apart. What is the force of gravity between the masses?

$$d = 93\times10^9\ \text{light-years}\times\frac{9.461\times10^{15}\ m}{\text{light year}} = 8.80\times10^{26}\ m$$

$$F_g = \frac{Gm_1m_2}{d^2} = \frac{6.67\times10^{-11}\frac{m^3}{Kg\cdot s^2}\times1.0Kg\times1.0Kg}{(8.80\times10^{26}m)^2} = 0.086\times10^{-63}\ N$$

$= 8.6\times10^{-65}$ N [towards each other]

See over →

4. Using the Universal Law of Gravitation, find the force of gravity on a 1 kg mass at the Earth's surface.

$$F_g = \frac{Gm_1m_2}{d^2} = \frac{6.67\times10^{-11}\ \frac{m^3}{kg\cdot s^2} \times 1.0\ kg \times 5.972\times10^{24}\ kg}{(6\,371\,000\ m)^2} = 9.8\ N\ [down]$$

a. What will be the force of gravity on the 1 kg mass at the moon's surface? How does this compare to Earth's gravity?

$$F_g = \frac{Gm_1m_2}{d^2} = \frac{6.67\times10^{-11}\ \frac{m^3}{kg\cdot s^2} \times 1.0\ kg \times 7.35\times10^{22}\ kg}{(1\,737\,000\ m)^2} = 1.6\ N\ [down]$$

$$\frac{F_{g\ moon}}{F_{g\ Earth}} = \frac{1.6\ N}{9.8\ N} \approx 16\% \approx \frac{1}{6}$$

b. Using the Universal Law of Gravitation, find the force of gravity on a 1 kg mass on the International Space Station, which is located 400 km above the Earth's surface. How does this compare with the force of gravity at the surface?

$$F_g = \frac{Gm_1m_2}{d^2} = \frac{6.67\times10^{-11}\ \frac{m^3}{kg\cdot s^2} \times 1.0\ kg \times 5.972\times10^{24}\ kg}{(6371000\ m + 400000\ m)^2} = 8.7\ N\ [down]$$

$$\frac{F_{g\ ISS}}{F_{g\ Earth}} = \frac{8.7\ N}{9.8\ N} \approx 89\%$$

c. If there is still gravity at the ISS, why do astronauts float?