Name: ______________

Learning Intentions

- Learn about the 4 fundamental forces.
- Learn how to calculate the force of gravity between two objects.

Notes

1. A force is a (vector / ~~scalar~~) that describes a push or a pull on an object.

2. There are 4 fundamental forces, a.k.a. (also known as) fundamental interactions.

Fundamental Force	Definition
strong interaction	Responsible for holding the positively-charged protons together in the nucleus of the atom.
weak interaction	The interaction that is responsible for the radioactive decay that occurs in nuclear fission.
gravity	The phenomenon by which all things with mass or momentum (including light) are drawn towards each other.
electromagnetic force	The push or pull experienced between electrically charged particles.

3. Electrostatic forces are much (stronger / ~~weaker~~) than gravitational forces.

3a. Forces are measured in Newtons (N), which are the same as $kg \cdot \frac{m}{s^2}$

See over →

4. The net force is the sum of all the external forces on an object.

$\vec{F}_{net} = \Sigma \vec{F}$ Σ: sigma, Greek for S, means sum

It is a concept, not a real force.

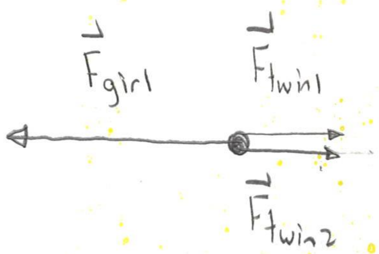
5. A free body diagram (FBD) is used to model force by replacing the object with a single dot, and using arrows to indicate all the forces that are acting on the object.

   a. In Physics 11, we will assume all forces act through the centre of mass of the object, so there is no rotation.

   b. In Physics 12, the location of application of the force matters, as it can cause a moment (or torque) that causes the object to rotate.

6. Draw a FBD of the following situations. Find the net force, including direction.

   a. A girl pushes a box to the left with a force of 45 N, while her twin brothers each push to the right with a force of 22 N. What is the net force on the box?



$\vec{F}_{net} = \Sigma \vec{F}$

$= \vec{F}_{girl} + \vec{F}_{twin1} + \vec{F}_{twin2}$

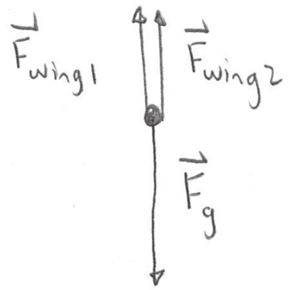
$= -45 N + 22 N + 22 N$

$= -1 N$

$\vec{F}_{net} = -1.0 N$ [right]

$= 1.0 N$ [left]

b. Gravity pulls down on a bird with a force of 53 N. Each wing provides an upwards force of 33 N. What is the net force on the bird?



$$\vec{F}_{net} = \Sigma\vec{F} = \vec{F}_g + \vec{F}_{wing1} + \vec{F}_{wing2}$$

$$= -53N + 33N + 33N$$

$$= 13N$$

$$\vec{F}_{net} = 13\,N\ [up]$$

7. Universal Law of Gravitation:

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

F_g: force of gravity (N)

G: gravitational constant $6.67 \times 10^{-11}\ \frac{m^3}{kg \cdot s^2}$

m: mass (kg)

r: distance between centres of objects (m)

a. Note: The law is not actually universal. It was superseded by Einstein's General Theory of Relativity.

Questions

1. If the Earth has a mass of 5.97×10^{24} kg and a radius of 6.37×10^6 m, what force does it exert on an object of mass 78 kg at the surface of the Earth?
2. What force does the Earth exert on an object of mass m_2 at the surface of the Earth?
3. What force does the Earth exert on an object of mass of 1.00 kg at the surface of the Earth?
4. Near the Earth's surface, the what is the force of gravity (**g**) in Newtons per kilogram (N/kg)?

5. If a 78 kg pilot in a turning plane experiences a force of 8 g's upwards, what is the force on the pilot in Newtons?

   Kid Takes 8Gs And Passes Out! https://www.youtube.com/watch?v=vxeBSmR1l7o

   Passenger passes out due to g force 8+g https://www.youtube.com/watch?v=Kt5dPtO7AeQ

6. What is the force of gravity between two 1.0 kg masses 1.0 m apart?

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

8. 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?

9. What will be the force of gravity, $\mathbf{g}_{moon}$, on a 1.0 kg mass at the moon's surface?

10. How does $\mathbf{g}_{moon}$ compare to $\mathbf{g}_{Earth}$?

11. Using the Universal Law of Gravitation, find the force of gravity on a 1.0 kg mass on the International Space Station, which is located 400 km above the Earth's surface.

12. How does the force of gravity on the mass at the ISS compare with the force of gravity at the Earth's surface?

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

1. $F_g = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\frac{m^3}{Kg\cdot s^2}\times5.97\times10^{24}\,Kg\times78\,Kg}{(6.37\times10^6\,m)^2}$

$F_g = 765.4\,\frac{Kg\cdot m}{s^2}$

$\vec{F}_g = 760\,N$ [towards Earth]

2. $F_g = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\frac{m^3}{Kg\cdot s^2}\times5.97\times10^{24}\,Kg\times m_2}{(6.37\times10^6\,m)^2} = 9.81\,m_2\cdot\frac{m}{s^2}$

$\vec{F}_g = 9.81\,\frac{m}{s^2}\cdot m_2$ [towards Earth]

3. $\vec{F}_g = 9.81\,m/s^2\cdot m_2$ [towards Earth]

$= 9.81\,m/s^2\cdot(1.00\,Kg)$ [towards Earth]

$= 9.81\,Kg\cdot\frac{m}{s^2}$ [towards Earth]

$\vec{F}_g = 9.81\,N$ [towards Earth]

4. $\vec{g} = 9.81\,\frac{N}{Kg}$ [towards Earth]

5. $\vec{F} = 8\cdot\vec{F}_g = 8\cdot m\cdot g = 8(78\,Kg)(9.81\,\frac{N}{Kg}) = 6121\,N$

$\vec{F} = 6000\,N$ [upwards]

6. $\vec{F}_g = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\frac{m^3}{kg\cdot s^2}(1.0\,kg)(1.0\,kg)}{(1.0\,m)^2} = 6.67\times10^{-11}\,N$

$\vec{F}_g = 6.7\times10^{-11}\,N$ [towards each other]

7. $\vec{F}_g = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\frac{m^3}{kg\cdot s^2}(1.0\,kg)(1.0\,kg)}{(0.0010\,m)^2} = 6.67\times10^{-5}\,N$

$\vec{F}_g = 6.7\times10^{-5}\,N$ [towards each other]

8. $F_g = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\frac{m^3}{kg\cdot s^2}(1.0\,kg)(1.0\,kg)}{(93\times10^9 \times 9.461\times10^{15}\,m)} = 8.616\times10^{-65}\,N$

93×10^9: 93 billion; $9.461\times10^{15}\,m$: light year (from Internet)

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

9. $\vec{F}_g = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\frac{m^3}{kg\cdot s^2}(7.35\times10^{22}\,kg)(1.0\,kg)}{(1.74\times10^6\,m)^2} = 1.619\,N$

$(1.74\times10^6\,m)$ ← From Internet

$\vec{F}_g = 1.6\,N$ [towards the moon]

10. $\frac{g_{moon}}{g_{earth}} = \frac{1.6\,N}{9.81\,N} = 0.16$

$\vec{g}_{moon} = 0.16\,\vec{g}_{earth}$ ∴ 16% as strong

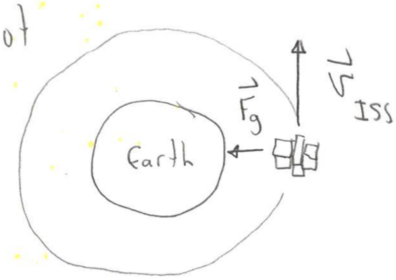
11. $$F_g = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\,\frac{m^3}{kg\cdot s^2}\,(5.97\times10^{24}\,kg)(1.0\,kg)}{(6.37\times10^{6}\,m + 4.0\times10^{5}\,m)^2} = 8.688\ kg\cdot m/s^2$$

$\vec{F}_g = 8.7\ N$ [towards Earth]

12. $$\frac{F_{g_{ISS}}}{F_{g_{Earth}}} = \frac{8.69\ N}{9.81\ N} = 0.8856$$

∴ 88% as strong

13. The ISS has a large velocity, so the force of gravity is only strong enough to keep the ISS in orbit, but not strong enough to pull the ISS back to Earth.



This sort of circular motion is analyzed in Physics 12.

Answers

1. $\mathbf{F_g}$ = 760 N [towards Earth]
2. $\mathbf{F_g}$ = m_2 x 9.81 m/s^2 [towards Earth]
3. $\mathbf{F_g}$ = 9.81 N [towards Earth]
4. **g** = 9.81 N/kg [towards Earth] = -9.81 N/kg [up]
5. **F** = 6,000 N [upwards]
6. $\mathbf{F_g}$ = 6.7 x 10^{-11} N [towards each other]
7. $\mathbf{F_g}$ = 6.7 x 10^{-5} N [towards each other]
8. $\mathbf{F_g}$ = 8.6 x 10^{-65} N [towards each other]
9. $\mathbf{g_{moon}}$ = 1.6 N [towards the moon]
10. $\mathbf{g_{moon}}$ = 0.16 $\mathbf{g_{Earth}}$
11. $\mathbf{F_g}$ = 8.7 N [towards Earth]
12. 89% of the force of gravity at the Earth's surface