Unit 2 Part 2: Forces

Note 1: **Newton`s Universal Law of Gravitation**

Gravity…

Newton`s Law of Universal Gravitation states:

Where:

G =

=

M =

m =

r =

Ex 1: What is the force of gravity exerted on a 70.0 kg astronaut that is standing on Earth's surface?

Radius of Earth = 6.38×10^6 m

Mass of Earth = 5.98×10^{24} kg

Ex 2: What is the force of gravity acting on a 70.0 kg astronaut who is at an ***altitude*** of 6.38×10^6 m?

Ex 3: Two physics lab partners sit side by side. One has a mass of 55 kg and the other a mass of 65 kg. If they sit 50.0 cm apart, what is the irresistible force of attraction between them?

A typical problem type…

An astronaut weighs 800 N on Planet X. How much would she weigh if she was at an altitude equal to the radius of Planet X?

A spaceship orbits a planet at radius, r and weighs 10 000N. How much would it weigh if it orbits a planet twice as massive at half the radius?

Unit 2 Part 2: Forces

Note 2: Gravitation field strength (g)

To help explain how two bodies that are not in contact can exert a force on one another (i.e. gravitational, magnetic or electrostatic) we use the concept of _____.

Fields are spheres of influence. They are _____ and _____; they simply demonstrate how strong a characteristic is at a certain distance.

Consider a campfire. We can think of it as having a _____ *field*. The _____ we get to the fire, the _____ the field becomes.

Likewise, the _____ the fire is, the _____ _____ we will notice its field of effects.

To represent this force field around earth, we draw vectors of force pointing towards earth's centre. Their _____ indicate that the field becomes _____ as the distance from earth's centre _____.

Gravitational fields are defined as:

Notice that its units are in N/kg or m/s^2

Ex 1

The Earth is not actually a perfect sphere. Just like a spinning basketball, it is an ***oblate spheroid*** … or kinda bulgy in the middle.

Calculate the acceleration due to gravity:

a) At the North Pole ($r = 6.370 \times 10^6$ m)
b) At the Equator ($r = 6.386 \times 10^6$ m)

Ex 2

The moon is 385 000 km away from the Earth's surface. What is the Earth's gravitational field strength at this distance?

Unit 2 Part 2: Forces

Note 3: Force of Friction

Friction is created whenever…

On the microscopic level…

Friction is given by the equation:

Where:

F_N =

=

μ =

=

=

Static Friction:

Kinetic Friction:

$Friction_{static}$ **$Friction_{kinetic}$**

μ_{static} **$\mu_{kinetic}$**

Ex 1: A 3.75 kg block is pushed along a tabletop with a force of 45.0N. The coefficient of friction is 0.65.

a) Find the force of friction.

b) Find the acceleration.

Ex 2: A 0.200 kg puck is pushed along a sheet of ice with a force of 0.240 N. If it moves at a constant velocity, find the coefficient of friction.

Ex 3: A 1.1 kg textbook is held against a vertical wall with a force of 45 N. What is the coefficient of friction between the book and the wall?

Unit 2 Part 2: Forces

Note 4 **Hooke's Law**

$F_{Elastic}$;

Examples:

Hooke's Law:

Where:

k (N/m) =

Δx (m) =

Ex:

A student stretches an elastic band with a spring constant of 50.0 N/m by 15 cm. How much force are they applying?

Ex:

Al McInnis uses a wooden stick with a spring constant of 850 N/m. What is the distortion on the stick if he exerts 525 N while taking a slapshot?

Ex:

A 65 kg girl sits in a redneck sling shot that has a spring constant of 10.5 N/m. If the sling is stretched by 45 m, what is her *initial* acceleration when released?

Unit 2 Part 2: Forces

Note 5 Tension

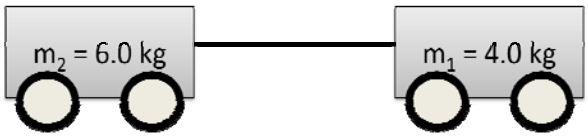
Tension occurs within a material that is being…

It is an internal force that acts ___ ___ _____ along a rope (string, chain, etc) in _____ _____.

Consider two carts attached by a rope being pulled along a flat surface. (Friction is negligible.)

If m_1 is pulled to the right by a force of 40.0 N find:

a) The acceleration of the carts.



NOTE: tension…

b) The tension in the string connecting them.

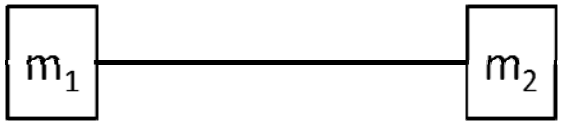
NOTE: Since it cancels out of the total F_{net} equation, we will only consider the forces acting...

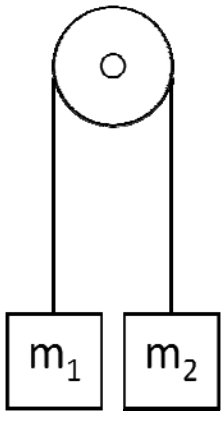
NOTE: Since tension acts on both masses equally we can use…

Consider two equal masses hanging from a pulley.

Diagram the forces acting on the entire system.

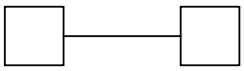
With pulley problems it is sometime easier to "*unfold*" the rope as shown.



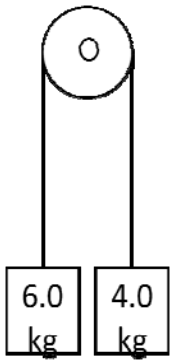


Ex: The two masses shown hanging from a frictionless pulley are released at rest. Find

a) The acceleration of the system.



b) The tension in the string.

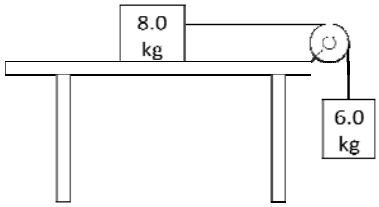


NOTES: 1. When solving for acceleration of the whole system we consider _____

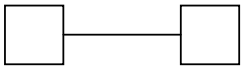
2. When finding T we only use _____ _____.

Ex: A mass on a frictionless table is attached to a hanging mass over a frictionless pulley as shown. Find:

a) The acceleration of the masses.

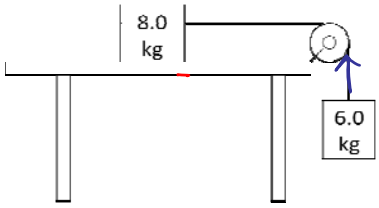


b) The tension in the rope.

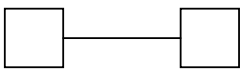


Ex2: If the same system has a friction force of 25 N acting on the 8.0 kg mass find:

a) The acceleration of the masses.



b) The tension in the rope.



Unit 2 Part 2: Newton's Laws

Note 6 - Elevators and Apparent Weight

When a person is accelerating upwards or downwards they can sometimes *feel* heavier or lighter than they actually are. Although their _____ weight (force of gravity) is the same, their _____ weight differs. Apparent weight (how heavy we *feel*) is equal to the _____force supporting us.

Mass + Spring Scale = Elevator

Describe **2 times** when the mass appears *heavier* than normal.

1)

2)

What can you summarize about the acceleration of the mass?

Describe **2 times** when the mass appears *lighter* than normal.

1)

2)

What can you summarize about the acceleration of the mass?

Describe **3 times** when the mass' apparent and actual weights are equal.

1)

2)

3)

What can you summarize about the acceleration of the mass?

Ex 1: A 65 kg person in an elevator is traveling upwards at 5.0 m/s. What is their apparent weight?

Ex 2: The same 65 kg person is in an elevator that accelerates upwards at 4.9 m/s^2. What is their apparent weight?

Ex 3: The elevator reaches the top floor and decelerates at 4.9 m/s^2. What is their apparent weight?

An 85.0 kg person in an elevator goes from the top to the bottom floor. Find their apparent weight when they:

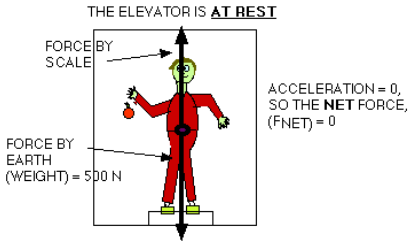
a) accelerate downwards at 3.00m/s^2?

b) continue downward at a velocity of 12.0 m/s?

c) accelerate upwards at 3.00 m/s^2?

The Elevator Problem

Imagine that you are standing on a bathroom scale in an elevator. You are holding an apple. (Yes, people *are* staring at you...). You weigh **500 N**, so your mass is about 50 kg.

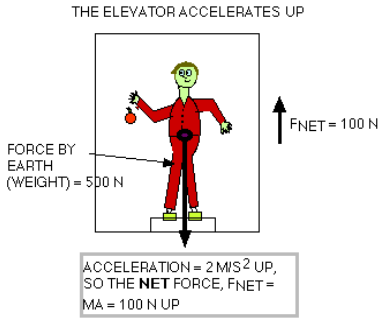


Part A: Elevator Is At Rest.

You have just boarded the elevator, so it (with you inside) is at rest...

Question 1: What does the scale read?

Question 2: If you let go of the apple, what does it do?



Part B: The Elevator Accelerates Upward.

The elevator, (with you inside) begins to accelerate upward from rest at 2 m/s^2.

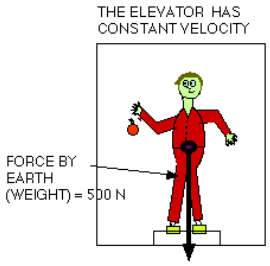
Complete the FBD!

Question 3: What will the scale read now?

Question 4: If you let go of the apple now, what does it do?

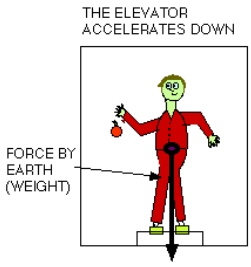
Part C: The Elevator Moves Up With Constant Velocity

The elevator (and you) accelerated for 5 seconds, so it is moving upward with a velocity of 10 m/s. It now moves with this constant upward velocity of 10 m/s.



Question 5: What does the scale read now?

Question 6: If you let go of the apple, what does it do?



Part D: The Elevator Slows Down (While Going Up)

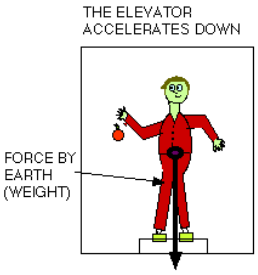
The elevator, (with you inside) begins to slow down as it approaches its destination. Its acceleration (or deceleration) is 2 m/s^2 downward.

Question 7: What does the scale read now?

Question #8: If you let go of the apple now, what does it do?

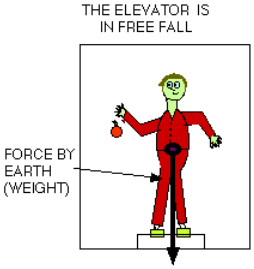
Part E: The Elevator Speeds Up (While Going Down)

The elevator, (with you inside) reaches its floor, stops for a while, and then begins to accelerate downward. Its acceleration is 2 m/s^2 downward.



Question 9: What does the scale read now?

Question #10: If you let go of the apple now, what does it do?



Part F: Oh, No!

The elevator cable snaps, and the elevator (with you inside!) begins to fall! Perhaps you have time for one last Physics observation!

Question 11: What does the scale read as the elevator falls?

Question 12: If you let go of the apple now, what does it do?

Worksheet 5.1 - Newton's Law of Universal Gravitation

1) Two students are sitting 1.50 m apart. One student has a mass of 70.0 kg and the other has a mass of 52.0 kg. What is the gravitational force between them?

2) What gravitational force does the moon produce on the Earth is their centers are 3.88×10^{8} m apart and the moon has a mass of 7.34×10^{22} kg?

3) If the gravitational force between objects of equal mass is 2.30×10^{-8} N when the objects are 10.0 m apart, what is the mass of each object?

4) Calculate the gravitational force on a 6.50×10^{2} kg that is 4.15×10^{6} m above the surface of the Earth?

5) The gravitational force between two objects that are 2.1×10^{-1} m apart is 3.2×10^{-6} N. If the mass of one object is 55 kg what is the mass of the other object?

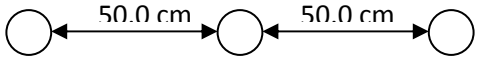
6) If two objects, each with a mass of 2.0×10^{2} kg, produce a gravitational force between them of 3.7×10^{-6} N. What is the distance between them?

7) What is the gravitational force acting on a 70.0 kg object standing on the Earth's surface?

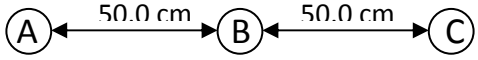
8) What is the gravitational force on a 35.0 kg object standing on the Earth's surface?
(You can use your answer from #7 to reduce your calculations)

9) What is the gravitational force on a 70.0 kg that is 6.38×10^6 m **above** the Earth's surface?
(You can use your answer from #7 to reduce your calculations)

10) Three objects each with a mass of 10.0 kg are placed in a straight line 50.0 cm apart. What is the net gravitational force on the center object due to the other two?



11) Three objects A, B, C are placed 50.0 cm apart along a straight line. A and B have a mass of 10.0 kg, while C has a mass of 15.0 kg. What is the net force on B due to A and C?



1) 1.08×10^{-7} N 2) 1.94×10^{20} N 3) 186 kg 4) 2340 N 5) 38 kg 6) 0.85 m 7) 686 N 8) 343 N 9) 172 N 10) 0 N 11) 1.33×10^{-8} N

Worksheet 5.2 - Gravitational Field Strength

1) What is the weight of a 25.0 kg object near the surface of the earth?

2) What is the mass of an object if it has a weight of 80.0 N near the earth's surface?

3) What is the acceleration due to gravity near the surface of the moon if an object that has a mass of 22.0 kg has a weight of 36.0 N near the moon's surface?

4) What is the weight of a 72.0 kg object near the surface of the Moon?

5) What is the mass of an object if it has a weight of 127 N near the earth's surface?

6) What is the gravitational field strength at a point 6.38×10^6 m above earth's surface?

7) What is the acceleration due to gravity on the surface of the sun?

$r_{sun} = 6.96 \times 10^8$ m
$m_{sun} = 1.99 \times 10^{30}$ kg

8) The Earth orbits the Sun at a distance of 1.46×10^{10} m from center to center. What is the strength of the Sun's gravitational field at this distance?

1) 245 N 2) 8.16 kg 3) 1.64 m/s^2 4) 118 N 5) 13.0 kg 6) 2.45 m/s^2 7) 274 m/s^2 8) 0.622 m/s^2

Worksheet 5.3 - Force of Friction

1) A 7.6 kg object is resting on a horizontal surface. What is the normal force on the object?

2) A 7.6 kg object is pulled along a horizontal surface. If the coefficient of friction is 0.20, what is the force of friction?

4) A 9.6 kg object is pulled along a horizontal surface. If the coefficient of friction is 0.11 what is the force of friction?

5) A 20.0 N object is pulled along a horizontal surface at a constant velocity by a 3.0 N force, what is the coefficient of friction?

6) A 16.2 kg object is pulled along a frictionless surface by an applied force of 10.2 N, what is the normal force acting on it?

7) A 6.2 kg object is pulled along a horizontal surface by a force of 22.0 N. If its acceleration is 1.1 m/s^2, what is the coefficient of friction between the two surfaces?

8) A 1250 kg car traveling at 60.0 km/h comes to a sudden stop in 35 m. What is the coefficient of friction acting on the brakes?

9) A 950 kg car traveling at a constant velocity of 28 m/s, has a coefficient of friction of 0.125 acting on its axle. How much force is required by the engine to maintain its speed?

10) A 1425 kg dragster exerts 13900 N of force and accelerates from 0 to 100.0 km/h in 3.25 s. What is the coefficient of friction acting on the car?

1) 74 N 2) 15 N 3) 137 N 4) 10. N 5) 0.15 6) 159 N 7) 0.25 8) 0.40 9) 1200 N 10) 0.123

Worksheet 4 -Hooke's Law: Springs & Things

1. How much force would it take to stretch a steel bar with a spring constant of 21×10^6 N/m until it is 1.0mm longer?

2. What is the spring constant of a car spring if a 2500N force compresses it from a length of 50.cm to a length of 40.cm?

3. a) What force would be required to compress a 20.cm long spring to 15cm if the spring constant is 30.N/m?

b) What mass, when placed on top of the vertical spring, would cause the same compression?

4. A spring is compressed 10m when a force of 5N is applied. How far does it compress when 10N is applied?

5. Peter (from Peter and the Wolf fame) is out hunting a possum with his spring loaded rock thrower. He pulls back on the spring with a force of 350 N and it stretches 10 cm.

a) Determine the spring's constant.

b) Peter puts a 50 g rock in the thrower and releases it. Calculate the rock's initial acceleration.

6. Pedro Martinez is standing on the planet Baseball (r = 5000 km, m = 7.0×10^{24} kg) with his favorite spring (k = 100 N/m… it is spring training time after all) in his hand. If he puts a 1.2 kg mass on the end of the spring, how far does it stretch? If he then slowly removes 300 g, how far up does the remaining mass move? What mass would be required to stretch the spring 35 cm?

Answers: 1) 2.1×10^4N 2)25000N/m 3)a)1.5N b)0.15kg 4) 20m 5) a) 3.5×10^3 N/m b) 7.0×10^3m/s^2
6). 0.22 m, 5.6×10^{-2} m, 1.9 kg

Worksheet 5.5 - Tension Worksheet

1) Two masses are connected by a rope over a pulley as shown:
$m_1 = 7.0$ kg and $m_2 = 13.0$ kg

a) What is the acceleration of m_1?
b) What is the acceleration of m_2?
c) What is the tension in the rope on m_1?
d) What is the tension in the rope on m_2?

2) Two masses are attached by a string as shown:

If $m_1 = 20.0$ kg and $m_2 = 10.0$ kg,

a) Determine the acceleration of m_2 assuming that the table is frictionless.
b) Find the tension in the rope (no friction).
c) Determine the acceleration there is a force of friction of 40.0 N.
d) Find the tension on the rope (yes friction).

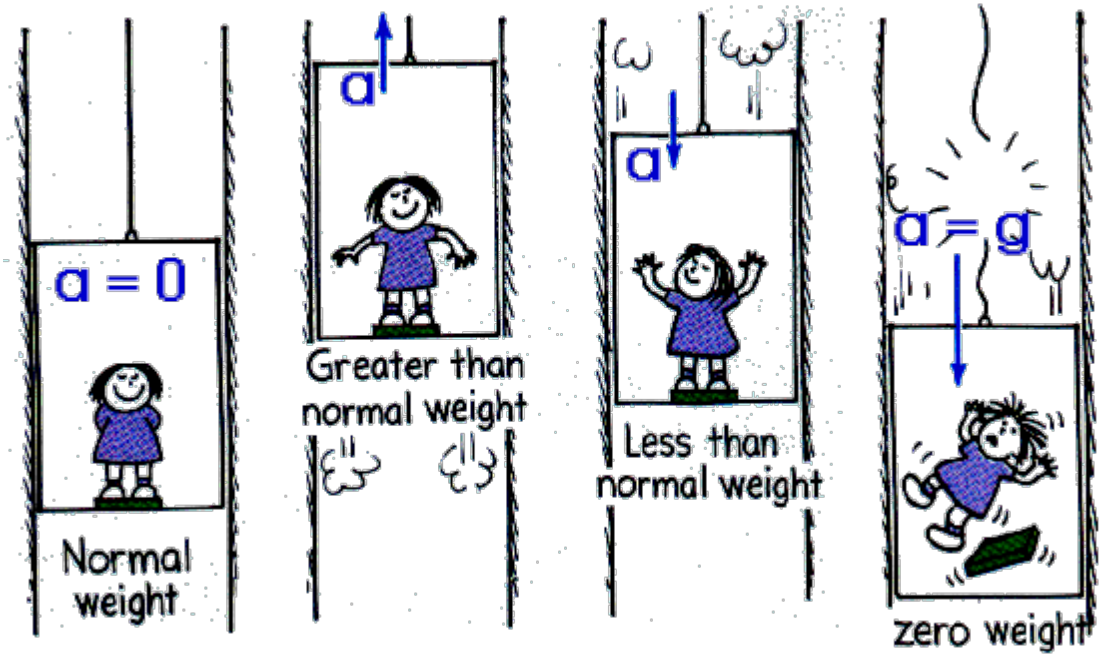
3) Three masses are attached as follows,
assuming no friction force:
$m_1 = 19.0$ kg, $m_2 = 11.0$ kg, $m_3 = 5.0$ kg

a) What is the acceleration of the blocks?
b) What is the tension in the string at point A?
c) What is the tension in the string at point B?

4) Look at the diagram from question 3.
If the F_f on m_2 is 35 N and the F_f on m_3 is 18 N, find their acceleration.

Worksheet 6 **Apparent Weight: Person on Scale in Elevator**

A pictorial summary of apparent weight:



1. Tom is in an elevator that is accelerating upward at 0.55 m/s2 . His mass is 75 kg. What is his weight and apparent weight?

2. Jerry is in an elevator that is accelerating upward at 2.5 m/s2 . His mass is 82 kg. What is his weight and apparent weight?

3. Jean is in an elevator that is accelerating downward at 1.25 m/s2 . Her mass is 65 kg. What is her weight and apparent weight?

4. Lucy is in an elevator that is accelerating downward at 3.75 m/s2 . Her mass is 55 kg. What is her weight and apparent weight?

5. Roy is in an elevator that is moving upward at a constant velocity of 2.5 m/s. His mass is 87.5 kg. What is his weight and apparent weight?

6. Larry is in an elevator that is moving downward at a constant velocity of 4.2 m/s. His mass is 105kg. What is his weight and apparent weight?

7. Alice is in an elevator when the cable snaps and the elevator plummets in free fall. Her mass is 52.5 kg. What is her weight and apparent weight just before the elevator crashes to the ground?

Answer (apparent weight only): 780N, 2) 1009N, 3) 556.4N, 4) 360N 5) 858N, 6) 1030N 7) 0N