

Newton's Laws

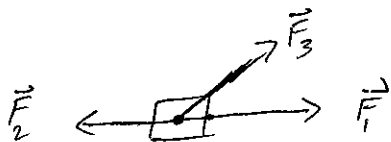
New Vector Quantity

Force - any kind of push or pull on an object.

Ask for Examples: pushing a car,
lifting a bag
hammer hitting a nail.
Gravity.

 What does this tell you about force.
(components, too)

Force has magnitude and direction.



Any direction is possible. Or all three!
(we can add them up! they're vectors).

Newton's First Law (kinda stolen from Galileo.)

- pushing a heavy object on surfaces w/ decreasing friction.

"Every object continues in a state of rest, or of uniform velocity in a straight line, as long as no net force acts on it."

"Law of inertia" - object in motion stays in motion; object at rest stays at rest unless acted upon by another force.

What does No NET Force mean? The vector sum of the forces!

Look at box drawing above!

Conceptual Example: 4-1

Newton's 2nd Law

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To first understand, we must understand what mass is.

mass - "quantity of matter"

- "measure of inertia"

- "how resistant it is to changes in its motion"

mass: m units kilograms (kg)

Mass is not Weight!

2nd Law:

What happens if a ~~force does~~ net force does act on an object?

It accelerates!

2nd law is the relationship between force and acceleration.

Law pg. 75 in book.

$$\vec{a} = \frac{\sum \vec{F}}{m}$$

or

$$\boxed{\sum \vec{F} = m \vec{a}}$$

Note: direction of acceleration follows direction of Net force.

Vector components:

~~Equation~~ $\sum F_x = m a_x$, $\sum F_y = m a_y$

Note: units: 1 Newton = $1 \text{ kg} \cdot \frac{\text{m}}{\text{s}^2}$

Ex:

Net force needed to accelerate (a) 1000 kg car at $\frac{1}{2}g$

(b.) 200 g apple at $\frac{1}{2}g$

Newton's Third Law

When one object exerts a force on a second object, the second exerts an equal force in the opposite direction on the first.

"Equal and opposite reaction."

Example: pushing hand on corner of desk. You can feel (and see) the desk push back.

Example: ice skater pushing on wall.

- Rocket taking off. exerts a strong force on the gases.

~~Question~~

Concept: 4-4 p. 79: What makes a car go forward?

Exercise A: p. 80

Questions: 1, 2, 3, 4, 5, 7

Problems: 1, 2, 3

Cliff Problem:

Part I: Rock falls

$$t = t_I + t_{II}$$

$$V_s = 340 \text{ m/s}$$

$$A.) \quad V_y = V_{y0} - g t$$

$$B.) \quad y = y_0 + V_{y0} t - \frac{1}{2} g t^2$$

$$C.) \quad V_y^2 = V_{y0}^2 - 2g(y - y_0)$$

$$A.) \quad V_y = V_{y0} - g t \Rightarrow \boxed{V_y = -g t}$$

$$B.) \quad y = y_0 + V_{y0} t - \frac{1}{2} g t^2 \Rightarrow 0 = y_0 - \frac{1}{2} g t^2 \Rightarrow \boxed{y_0 = \frac{1}{2} g t^2}$$

$$C.) \quad V_y^2 = V_{y0}^2 - 2g(y - y_0) \Rightarrow \boxed{V_y^2 = 2g y_0}$$

Part II: Sound goes up

$$V_s = \frac{\Delta y}{\Delta t} = \frac{y_0 - y}{t_{II}} = \frac{y_0}{(t - t_I)} \Rightarrow \boxed{V_s = \frac{y_0}{t - t_I}}$$

$$\Rightarrow \boxed{y_0 = V_s (t - t_I)}$$

SKIP

Now, look at our equations and see what we can combine.

$$A + C: \quad V_y = -g t_I \Rightarrow V_y^2 = g^2 t_I^2$$

$$V_y^2 = 2g y_0$$

$$g^2 t_I^2 = 2g y_0 \Rightarrow g t_I^2 = 2 y_0 \Rightarrow \boxed{y_0 = \frac{1}{2} g t_I^2}$$

Same as B.

From B. and II

$$y_0 = V_s(t - t_I) = \frac{1}{2}gt_I^2$$

$$\Rightarrow V_s t - V_s t_I = \frac{1}{2}gt_I^2$$

$$\Rightarrow \frac{1}{2}gt_I^2 + V_s t_I - V_s t = 0$$

Quadratic to find t_I .

Then plug t_I into B again: $y_0 = \frac{1}{2}gt_I^2$

Ch. 4) Gravity + Normal Force

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If: $\Sigma \vec{F} = m \vec{a}$

And: $\vec{a}$ due to gravity (near earth) is $\vec{g}$.

Then: Force of gravity:

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

~~The force due to gravity on an~~

The force on an object due to gravity is its Weight.

Weight has units of Newtons!

Mass has units of Kilograms!

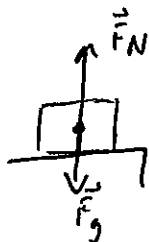
If an object isn't falling, but is sitting still on a table,
is gravity still acting on it?

- Net force is zero!

+ Opposite/Opposite

- Must be another force.

Normal Force - force acting perpendicular to a common surface.



$$\Sigma \vec{F} = \vec{F}_N + \vec{F}_g = 0 \quad \text{No acceleration/movement.}$$

Note: $\vec{F}_N$ is not always equal to $\vec{F}_g$

$\vec{F}_N$ is not always vertical!

F_N cannot be less than zero.

Ch. 4.] Note: Newton's Second Law on one object at a time! [2.]

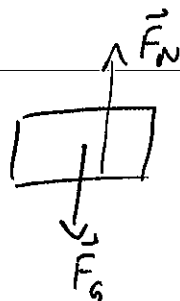
Ex 4-6: $m = 10.0 \text{ kg}$.

a.) Determine weight of box and normal force exerted by table.

$$\Sigma \vec{F} = m \vec{a}$$

$$\Sigma F_y = m a_y = 0$$

$$\Sigma F_y = F_N - F_g$$



$$\cancel{F_N = F_g}$$

$$\boxed{\vec{F}_g = m g = 98.0 \text{ N down}}$$

$$\Sigma F_y = 0 = F_N - F_g$$

$$\Rightarrow \boxed{F_N = F_g = 98.0 \text{ N upward}}$$

b.) Push down with 40.0 N . What is F_N ?

$$\Sigma F_y = m a_y = 0$$

$$\Sigma F_y = F_N - m g - 40.0 \text{ N} = 0$$

$$\Rightarrow \boxed{F_N = m g + 40.0 \text{ N} = 138.0 \text{ N upward}}$$

Note: F_g is still just 98.0 N !

c.) Pulls up with 40.0 N

$$\Sigma F_y = m a_y = 0$$

$$\Sigma F_y = F_N + 40.0 \text{ N} - m g = 0$$

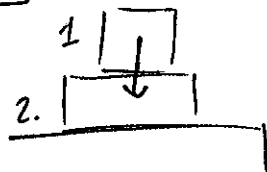
$$\boxed{F_N = m g - 40.0 \text{ N} = 58.0 \text{ N}}$$

Ch. 4.] Problems + Questions

Q: 10, 13, 14

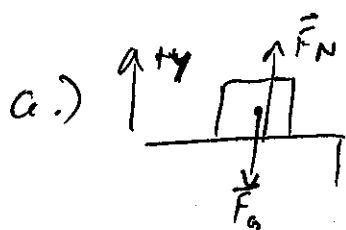
Problems: 5, 7, 8 ; note on 7: avg $\rightarrow$ net

5.]



$$m = 10.0 \text{ kg}$$

$$M = 20.0 \text{ kg}$$



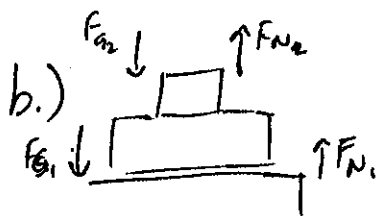
$$\Sigma F_y = ma_y = 0$$

$$\Sigma F_y = F_N - F_g$$

$$\boxed{F_g = mg \approx 200 \text{ N}}$$

$$\Sigma F_y = 0 = F_N - F_g$$

$$\boxed{F_N = F_g = mg \approx 200 \text{ N}}$$



~~On~~ On 20.0 kg box:

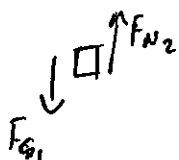


$$\Sigma F_y = ma_y = 0$$

$$\Sigma F_y = F_{N1} - F_{g1} - F_{g2} = 0$$

$$\boxed{F_{N1} = F_{g1} + F_{g2} \approx 300 \text{ N}}$$

On 10.0 kg box:



$$\Sigma F_y = ma_y = 0$$

$$\Sigma F_y = F_{N2} - F_{g1} = 0$$

$$\boxed{F_{N2} = F_{g1} = 100 \text{ N}}$$

Ch. 4 | Problem 7. average $\rightarrow$ net

$$\Sigma F = ma$$

$$m = .007 \text{ kg}$$

$$a = ?$$

$$F = ?$$

$$V_0 = 0$$

$$V = 125 \text{ m/s}$$

$$x_0 = 0$$

$$x = 0.800 \text{ m}$$

$$V^2 = V_0^2 + 2a(x - x_0)$$

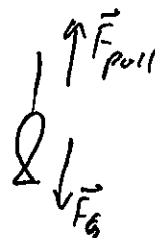
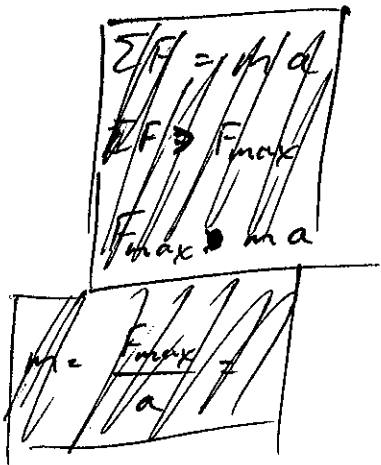
$$V^2 = 2ax$$

$$a = \frac{V^2}{2x}$$

$$\Sigma F = ma = m \frac{V^2}{2x} = 68.4 \text{ N}$$

p. | $a = 2.5 \text{ m/s}^2$

$$F_{\text{pull}} = 22 \text{ N}$$



$$\Sigma F_y = m a_y$$

$$\Sigma F_y = F_{\text{pull}} - F_g$$

$$F_{\text{pull}} - F_g = m a_y$$

$$F_{\text{pull}} - m g = m a_y$$

$$F_{\text{pull}} = m a_y + m g$$

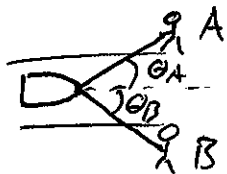
$$m = \frac{F_{\text{pull}}}{(a_y + g)}$$

FREE BODY DIAGRAMS

FORCES AS VECTORS

When solving a force problem, it is often useful to draw a free body diagram of the forces on that object.

Example: Two workers pulling on a boat. Find resultant force.

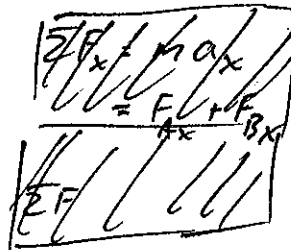
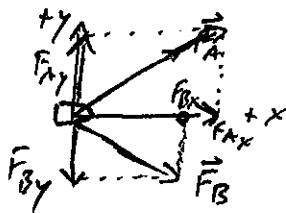


$$F_A = 40.0 \text{ N} \quad F_B = 30.0 \text{ N}$$

$$\theta_A = 45.0^\circ \quad \theta_B = 37.0^\circ$$

FREE Body Diagram

DRAW
BIG



Component:

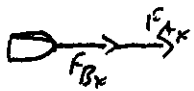
Recall component equations:

$$F_{Ax} = F_A \cos \theta_A$$

$$F_{Ay} = F_A \sin \theta_A$$

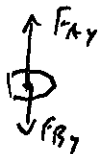
$$\theta_A = \tan^{-1} \left(\frac{F_{Ay}}{F_{Ax}} \right)$$

Do Newton's 2nd Law for each direction (x and y)



$$\Sigma F_x = m a_x = F_{Ax} + F_{Bx}$$

$$= F_A \cos \theta_A + F_B \cos \theta_B = 28.3 \text{ N} + 24.0 \text{ N} = 52.3 \text{ N}$$



$$\Sigma F_y = m a_y = F_{Ay} - F_{By}$$

$$= F_A \sin \theta_A - F_B \sin \theta_B = 28.3 \text{ N} - 18.1 \text{ N} = 10.2 \text{ N}$$

$$F = \sqrt{F_x^2 + F_y^2} = \boxed{53.3 \text{ N}}$$

$$\theta = \tan^{-1} \left(\frac{F_y}{F_x} \right) = \boxed{11.0^\circ}$$

Note:

FREE BODY DIAGRAMS ONLY WORK ON ONE object at a time!

STEPS:

~~1. Draw picture~~

1.) Check to see if there is an acceleration.

If so, draw your axes so that one axis aligns with the acceleration. Otherwise, you're free to choose their position.

2.) Draw simple picture of object at origin.

3.) Draw an arrow for each force acting ON the object.

Label each arrow with its appropriate force.

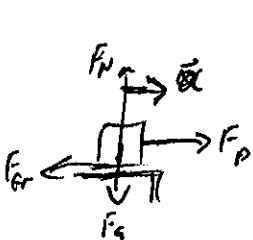
Label the angle each force makes with each axis.

Do this for each object.

FRICTION

Two Types: Kinetic + Static

- Kinetic friction opposes motion.



$$F_{fr} = \mu_k F_N$$

where μ_k is coefficient of kinetic friction.

F_N is normal force.

F_{fr} is perpendicular to F_N

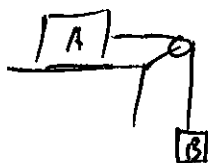
- STATIC friction opposes forces acting on stationary object to make net force zero.

$$F_{fr} \leq \mu_s F_N$$

Once ~~an~~ applied force exceeds static friction, object will begin to move, and friction becomes kinetic.

Ex: 4-20

13.



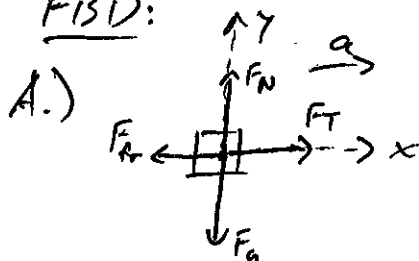
$$m_A = 5.0 \text{ kg} \quad \mu_k = .20$$
$$m_B = 2.0 \text{ kg}$$

* Force Applied to one end of cord has same magnitude at other end.

"Tension force"

~~Find a.~~ Find a.

FBD:



$$\sum F_y = m_A a_y = F_N - F_g = 0$$

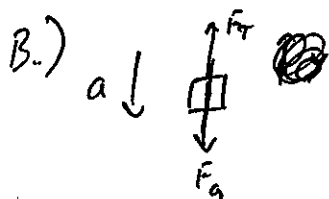
$$F_N = F_g = m_A g$$

$$\sum F_x = m_A a_x = F_T - F_f$$

Note: $F_f = \mu_k F_N = \mu_k m_A g$

$$\boxed{F_T = m_A a_x + \mu_k m_A g}$$

Note: $a_x = a$



$$\sum F_y = m_B a_y = -F_T + m_B g$$

Note: $a_y = a$

$$\boxed{F_T = m_B a + m_B g}$$

Combine:

$$-m_B a + m_B g = m_A a + \mu_k m_A g$$

$$-m_B a - m_A a = \mu_k m_A g - m_B g$$

$$-a(m_B + m_A) = \mu_k m_A g - m_B g$$

$$\boxed{a = \frac{m_B g - \mu_k m_A g}{m_B + m_A} = 1.4 \text{ m/s}^2}$$

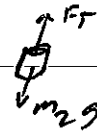
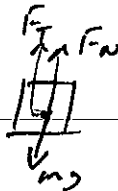
QUESTIONS

14.

Problems: (in class) 19, 21, 39

19.) $m_1 = 72.0 \text{ N}$

a.) $m_2 g = 30.0 \text{ N}$



$$\sum F_y: m_1 a_y = 0$$
$$= F_T + F_N - m_1 g$$

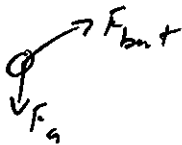
$$|F_N = m_1 g - m_2 g|$$

$$\sum F_y: m_2 a_y = 0$$
$$= m_2 g - F_T = 0$$

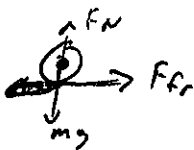
$$F_T = m_2 g$$

NOTE: F_N can't be negative. ϵ is zero.

21.)



39.)



$$\sum F_y: F_N - m_3 g = 0 \quad F_N = m_3 g$$

$$\sum F_x: m a_x = F_{fr} = \mu_s F_N$$

$$\mu a_x = \mu_s m_3 g$$

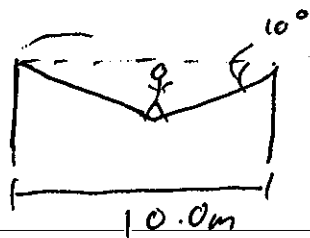
$$|a \approx 8 \text{ m/s}^2|$$

Problems at home: 23, 25, 27

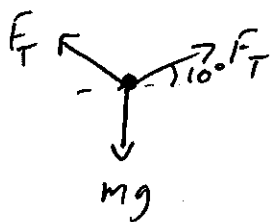
Problems at home: 23, 25, 27

Q: 15, 16, 12.

23.) $m = 50.0 \text{ kg}$



forces acting on one point in rope:



$$\Sigma F_x = m a_x = 0$$

$$\Sigma F_y = F_T \sin \theta + F_T \sin \theta - mg = m a_y = 0$$

$$2 F_T \sin \theta = mg$$

$$F_T = \frac{mg}{2 \sin \theta} = 1410 \text{ N}$$

25.) $m = 3.2 \text{ kg}$

a.)



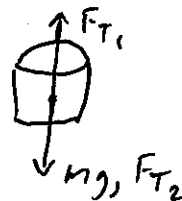
FBD: 2.)



$$\Sigma F_y = m_2 a_y = F_{T2} - m_2 g$$

$$F_{T2} = m_2 g \approx 32 \text{ N}$$

1.)



$$\Sigma F_y = m_1 a_y = 0$$

$$= F_{T1} - m_1 g - F_{T2} \Rightarrow F_{T1} = m_1 g + m_2 g \approx 64 \text{ N}$$

25.) b) $a_y = 1.60 \text{ m/s}^2$

$$\Sigma F_i = ma_y = F_{T1} - mg - F_{T2}$$

$$F_{T1} = ma_y + mg + F_{T2} = \cancel{25 + 1.6} = \cancel{26.6 \text{ N}}$$

$$\Sigma F_2 = ma_y = -mg + F_{T2}$$

$$F_{T2} = ma_y + mg = 36.5 \text{ N}$$

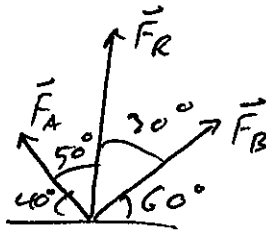
$$F_{T1} = 73 \text{ N}$$

27.)

$$F_A = 4500 \text{ N}$$

$$\theta_A = 90 - 50 = 40$$

$$\theta_B = 90 - 30 = 60$$



Note: $\Sigma F_x = 0$; only vertical movement

$$F_{Ax} = F_A \cos \theta_A$$

$$F_{Bx} = F_B \cos \theta_B = F_{Ax}$$

$$F_B = \frac{F_A \cos \theta_A}{\cos \theta_B} = \cancel{5900 \text{ N}} \quad \boxed{6900 \text{ N}}$$

$$\cancel{F_R = F_A + F_B = 4500 + 6900 = 11400 \text{ N}}$$

$$F_x = F_{Ax} + F_{Bx} = F_A \cos \theta_A + F_B \cos \theta_B = 0$$

$$F_y = F_{Ay} + F_{By} = F_A \sin \theta_A + F_B \sin \theta_B = \boxed{8900 \text{ N}}$$

PROBLEMS

9. $m = 0.140 \text{ kg}$

$V_0 = 35.0 \text{ m/s}$

$X_0 = .11 \text{ m}$

$X = 0 \text{ m}$

$V = 0 \text{ m/s}$

$$V^2 = V_0^2 + 2a(X - X_0)$$

$$V_0^2 = 2ax_0$$

$$a = \frac{V_0^2}{2x_0}$$

$$\Sigma F = ma = \frac{mV_0^2}{2x_0} = 780 \text{ N}$$

13. $m = 4850 \text{ kg}$

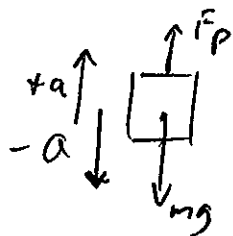
$a = \pm 0.0680g$

$$\Sigma F = ma = F_T - F_g$$

$$F_T = ma + F_g = ma + mg$$

$$F_T = m(a + g) = mg(1.0680) = 50762 \text{ N}$$

$$= m(-a + g) = mg(1 - .0680) = 44298 \text{ N}$$



17. $F_p = .25 F_g$

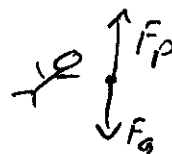
$F_g = mg$

$m = 132 \text{ kg}$

a.) $\Sigma F = ma = F_p - F_g$

$$ma = .25mg - mg$$

$$a = -.75g = -7.35 \text{ m/s}^2$$

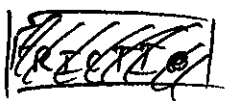


b.) $a = 0$

$$\Sigma F = ma = 0$$

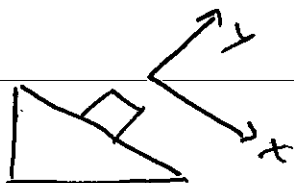
$$\Sigma F = F_p - F_g$$

$$F_p = F_g \approx 1320 \text{ N}$$



Quick Note on Inclines.

Recall step 1: Align axis in direction of acceleration:



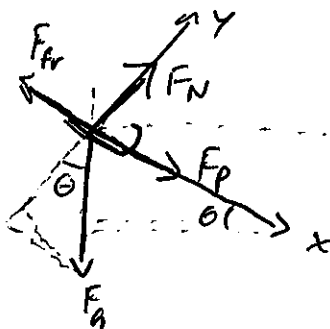
45.) $\mu_k = .10$

$$m = 22 \text{ kg}$$

$$\theta = 6.0^\circ$$

$$V = 60 \times 10^3 \text{ m/h} = 16.667 \text{ m/s}$$

$$x = 75 \text{ m}$$



$$\sum F_y = ma_y = 0$$

$$\sum F_y = F_g \cos \theta + F_N = 0$$

$$F_N = F_g \cos \theta$$

$$\sum F_x = ma_x = F_p - F_f + F_g \sin \theta$$

$$\Rightarrow F_f = \mu_k F_N = \mu_k F_g \cos \theta \Rightarrow a$$

Note: $V^2 = V_0^2 + 2a(x - x_0) \Rightarrow V^2 = 2ax \Rightarrow a = \frac{V^2}{2x}$

$$F_p = ma + \mu_k mg \cos \theta = mg \sin \theta = \boxed{40 \text{ N}}$$

$$55.) m = 18 \text{ kg}$$

$$\theta = 37^\circ$$

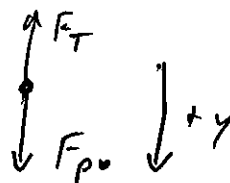
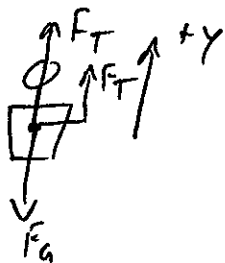
$$a = .270 \text{ m/s}^2$$

$$F_R = mg \sin \theta - ma = \boxed{101 \text{ N}}$$

$$\mu_k = \frac{F_R}{mg \cos \theta} = .719$$

29.) FBD: Washer:

Rope:



$$m = 65 \text{ kg}$$

$$a = 0$$

a.)

Washer:

$$\sum F_y = ma_y = 0$$

$$\sum F_y = 2F_T - mg$$

$$2F_T = mg$$

Rope:

$$\sum F_y = ma_y = 0$$

$$\sum F_y = F_p - F_T$$

$$F_p = F_T$$

b.)

$$F_p = 1.15 \left(\frac{1}{2} mg \right)$$

Rope:

$$\sum F_y = ma = F_p - F_T = 0 \quad F_T = F_p$$

Washer:

$$\sum F_y = ma = 2F_T - mg \Rightarrow \frac{1}{2} a = 2F_p - mg = (1.15 - 1) \frac{1}{2} g$$

$$a = .15g \approx \boxed{1.5 \text{ m/s}^2}$$

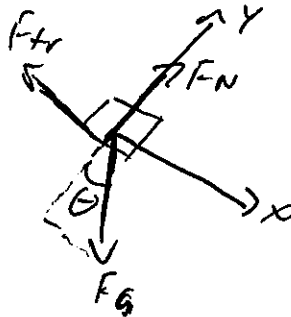
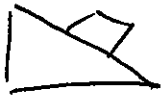
29, 41, 55, ~~62~~

41. $m = 15 \text{ kg}$

Find F_{fr} ; μ_k .

$\theta = 32^\circ$

$a = 0.30 \text{ m/s}^2$



$$\sum F_y = ma_y = 0$$

$$\sum F_y = F_N - F_g \cos \theta = 0$$

$$F_N = mg \cos \theta$$

$$\sum F_x = ma = F_g \sin \theta - F_{fr}$$

$$F_{fr} = F_g \sin \theta - ma = \boxed{73 \text{ N}}$$

$$F_{fr} = \mu_k F_N = \mu_k mg \cos \theta$$

$$\boxed{\mu_k = \frac{F_{fr}}{mg \cos \theta} = .59}$$

UNIFORM CIRCULAR MOTION

~~Uniform~~ magnitude of velocity stays the same.

Acceleration is what?

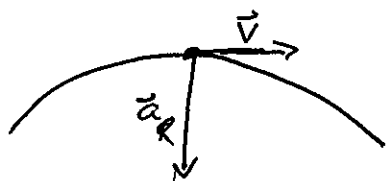
change in velocity: magnitude + direction!

If an object moves in a circle, it is changing direction!

Thus, it is accelerating!

Uniform - magnitude of velocity is constant!

acceleration is not zero!



radial acceleration
or
centripetal acceleration.

$$\boxed{\vec{a}_R = \frac{v^2}{r} \text{ inward.}}$$

Period + Frequency

frequency: revolutions per second. (f)

period: time required for one revolution (T)

$$T = \frac{1}{f}$$

Since T is the time required for an object to travel one full circle (circumference), we can say that

$$\boxed{v = \frac{2\pi r}{T}}$$

Chapter 5

2

Example: 5-2: Moon

$$r = 384,000 \text{ km} = 3.84 \times 10^8 \text{ m}$$

$$T = 27.3 \text{ days} = 2.36 \times 10^6 \text{ s}$$

$$a = ?$$

$$a_R = \frac{v^2}{r} ; \quad v = \frac{2\pi r}{T}$$

$$\boxed{a_R = \frac{(2\pi r)^2}{T^2 r} = 2.72 \times 10^{-3} \text{ m/s}^2}$$

Note: No value for mass in this equation. This is ~~known~~ ~~exactly~~ the acceleration of ANY object towards earth at this altitude.

Questions: 2, 17, 20

~~Problems~~

Centripetal Force

Newton's 2nd Law: An accelerating object must have a net force acting on it, so any object in uniform circular motion experiences a net centripetal force.

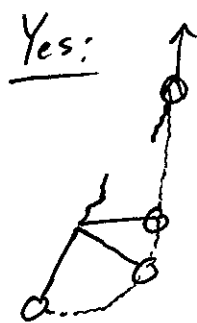
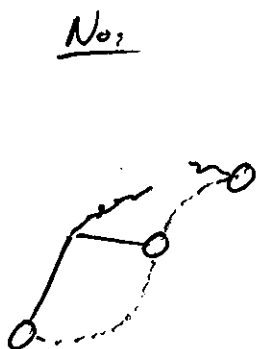
$$\boxed{\sum \vec{F}_R = m a_R = m \frac{v^2}{r}} \quad \text{inward!}$$

This is ~~a~~ a force causing circular motion, NOT circular motion causing a force!

Example: spinning ball on string requires force.

Note: No centripetal ^{fugal} ~~force~~ force!

Examples Ball flying off string:



Ex: 5-4: Swing vertically

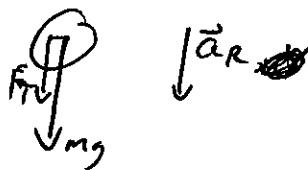
$$r = 1.10 \text{ m}$$

$$m = \text{~~1.50~~ } 1.50 \text{ kg}$$

a.) What is v at top of circle?

Draw FBD:

$$\begin{aligned} \sum F_R &= ma_R = m \frac{v^2}{r} \\ &= F_T + mg = m \frac{v^2}{r} \end{aligned}$$

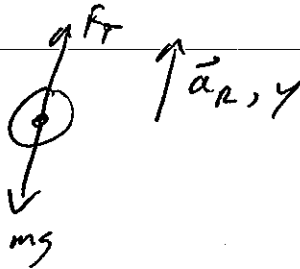


Note: Minimum speed $\rightarrow F_T = 0$.

$$\text{So: } mg = m \frac{v^2}{r} \Rightarrow \underline{\underline{v = \sqrt{gr} = 3.28 \text{ m/s}}}$$

Ex. 5-4 cont...

Calculate F_T at bottom if $v = 2 \text{ m/s}$



$$\Sigma F_R = m \frac{v^2}{r} = F_T - mg$$

$$F_T = m \frac{v^2}{r} + mg = 7.34 \text{ N}$$

~~Problems~~

Questions: Exercise B, Exercise C, Question 10.

c.) Top: $\Sigma F_R = m \frac{v^2}{r} = mg - F_N$

$$F_N = mg - m \frac{v^2}{r}$$

Bottom: $\Sigma F_R = m \frac{v^2}{r} = F_N - mg$

$$F_N = m \frac{v^2}{r} + mg$$

Problems: 1, 2, 3

1.) $r = 1.10 \text{ m}$ $m = 25.0 \text{ kg}$
 $v = 1.25 \text{ m/s}$

a.) $a = \frac{v^2}{r} = \boxed{1.42 \text{ m/s}^2}$

b.) $F_R = m \frac{v^2}{r} = \boxed{35.5 \text{ N}}$

2.) $v = 525 \text{ m/s}$
 $r = 6.00 \times 10^3 \text{ m}$

$a = \frac{v^2}{r} = 46 \text{ m/s}^2 = \boxed{4.7 \text{ g's}}$

3.) $r = 1.5 \times 10^{11} \text{ m}$ $m = 6 \times 10^{24} \text{ kg}$
 $T = 365 \text{ days}$

$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2} = \boxed{5.95 \times 10^{-3} \text{ m/s}^2}$

$\Sigma F_R = m a_r = 3.57 \times 10^{22} \text{ N}$

Ch. 5

Example 5-6: Skidding on a curve

$$m = 1000 \text{ kg}$$

Will it slide?

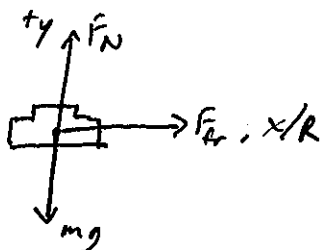
$$r = 50 \text{ m}$$

$$a.) \mu_s = 0.60$$

$$v = 14 \text{ m/s}$$

Note: it will slide when $F_{fr} > \mu_s F_N$

FBD:



$$\Sigma F_y = ma_y = 0$$

$$\Sigma F_y = F_N - mg$$

$$\Rightarrow F_N - mg = 0$$

$$\boxed{F_N = mg}$$

$$\boxed{\Sigma F_R = ma_R = m \frac{v^2}{r} = 3900 \text{ N}}$$

(compare with F_{fr})

~~$$\Sigma F_R = F_{fr} = \mu_s F_N = \mu_s mg = 5900 \text{ N}$$~~

~~$$\Sigma F_R = F_{fr} = \mu_s F_N = \mu_s mg = 5900 \text{ N}$$~~

$$\Sigma F_R = F_{fr}$$

$$\Rightarrow \boxed{F_{fr} = 3900 \text{ N}}$$

~~$$F_{fr} = \mu_s F_N = \mu_s mg = 5900 \text{ N}$$~~

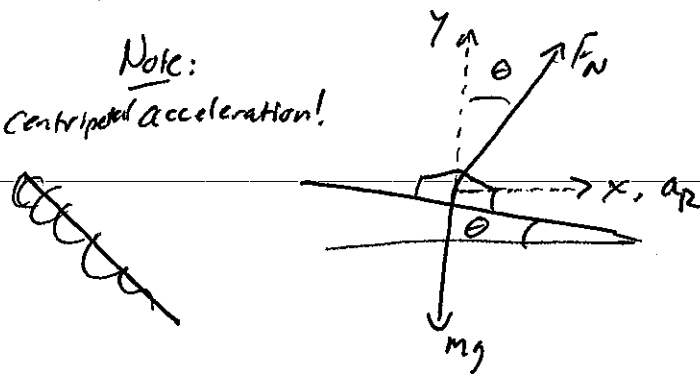
$$F_{fr \max} = \mu_s F_N = \mu_s mg = 5900 \text{ N}$$

So: $F_{fr} < F_{fr \max}$. No skid!

$$b.) \mu_s = 0.25$$

$$F_{fr \max} = \mu_s mg = 2500 \text{ N}$$

$F_{fr} > F_{fr \max}$. Skid like crazy!

Banked CurveFBDNote:
centripetal acceleration!

$$\Sigma F_y = m a_y = 0$$

$$\Sigma F_y = F_N \cos \theta - mg \Rightarrow F_N \cos \theta = mg$$

$$\Sigma F_R = m a_R = m \frac{v^2}{r}$$

$$\Sigma F_R = F_N \sin \theta \Rightarrow \boxed{F_N \sin \theta = m \frac{v^2}{r}}$$

Note: For a banked turn at angle θ ,
there is no need for friction to keep
the car on the road!

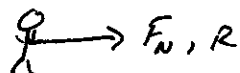
~~Problems~~: Problems: 11: Hint: Normal force of wall is what she feels on her back.

13:15:

11. $r = 12.0 \text{ m}$

$F_N = 7.85 \text{ mg}$

FBD:



$$\Sigma F_R = ma_R = m \frac{v^2}{R}$$

$$\Sigma F_R = F_N = 7.85 \text{ mg}$$

$$7.85 \text{ mg} = m \frac{v^2}{r}$$

$$7.85 \text{ g} = \frac{v^2}{r}$$

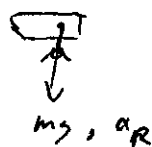
$$v = \sqrt{7.85 \text{ g} r} = \boxed{30.4 \text{ m/s}}$$

$$1 \text{ rev} = 2\pi r = 75.3982$$

$$\frac{\text{rev}}{\text{s}} = \frac{30.4 \text{ m}}{\text{s}} \cdot \frac{1 \text{ rev}}{75.3982 \text{ m}} = \boxed{.403 \frac{\text{rev}}{\text{s}}}$$

13. Minimum speed $\rightarrow F_N = 0!$

$r = 7.4 \text{ m}$



$$\Sigma F_R = ma_R = m \frac{v^2}{r}$$

$$\Sigma F_R = mg$$

$$mg = m \frac{v^2}{r} \Rightarrow \boxed{v = \sqrt{gr} = 8.5 \text{ m/s}}$$

15. $r = 7.5 \text{ m}$

$F_N = 0$



$$\Sigma F_R = ma_R = m \frac{v^2}{r}$$

$$\Sigma F_R = mg$$

$$\Rightarrow \frac{v^2}{r} = g \Rightarrow v = \sqrt{gr} = 8.57 \text{ m/s}$$

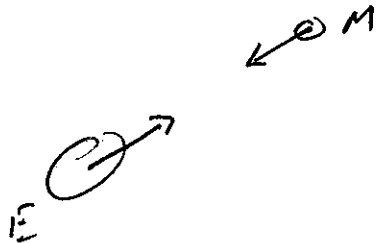
$$\frac{8.57 \text{ m/s}}{2\pi r} = \frac{8.57 \text{ m/s}}{47.12 \text{ m}} = \boxed{.182 \frac{\text{rev}}{\text{s}}} \cdot \frac{60 \text{ s}}{1 \text{ min}} = \boxed{11 \frac{\text{rev}}{\text{min}}}$$

Chapt. 5

Universal Gravitation

Newton's 3rd law states that every action has an equal/opposite reaction.

So, if Earth pulls on Moon, Moon pulls on Earth equally!



Law of Universal Gravitation

Every particle in the universe attracts every other particle!

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

$$G: 6.67 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2} \quad (\text{constant})$$

m_1 : mass of first object

m_2 : mass of second object

r : distance between objects.

Ch. 5

Recall: $F_g = \frac{G m_1 m_2}{r^2}$; To find

Problems: 31, ~~40~~⁴¹, 37

31. $m_1 = m_{moon}$
 $r = 1.5 r_E$

$$\Sigma F = m_2 a = \frac{G m_1 m_2}{r^2}$$

$$a = \frac{G m_1}{r^2}$$

41

~~40.~~ $a = 0.38 g$

$r = 3400 \times 10^3 m$

$$m_2 a = \frac{G m_{mars} m_2}{r^2} \Rightarrow a = \frac{G m_{mars}}{r^2}$$

$$m_{mars} = \frac{a r^2}{G}$$

37. $r = r_{moon}$
 $m = m_{sun}$

$$a = \frac{G m_{sun}}{r_{moon}^2}$$

Note: Density: 1 teaspoon = $5 \text{ cm}^3 \cdot \left(\frac{1 \text{ m}}{100 \text{ cm}}\right)^3$

$$\rho = \frac{m}{\frac{4}{3} \pi r^3}$$

$\Rightarrow 5 \cdot \left(\frac{1}{100}\right)^3 \cdot \rho \equiv m_{\text{teaspoonful}}$