Newton's Laws review

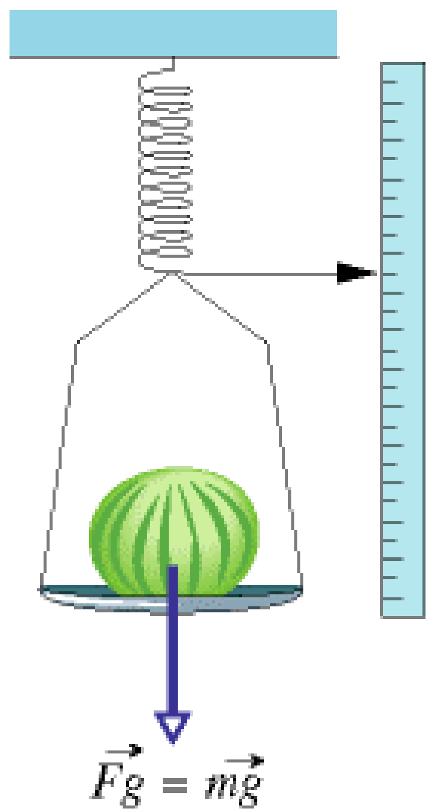
1. Bodies stay at constant velocity unless acted on by outside force!

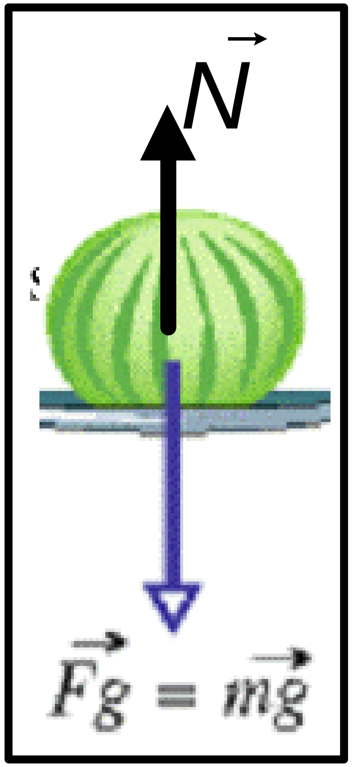
2. $$\sum_{\text{all that act on the body}} \vec{F} = m\vec{a}$$

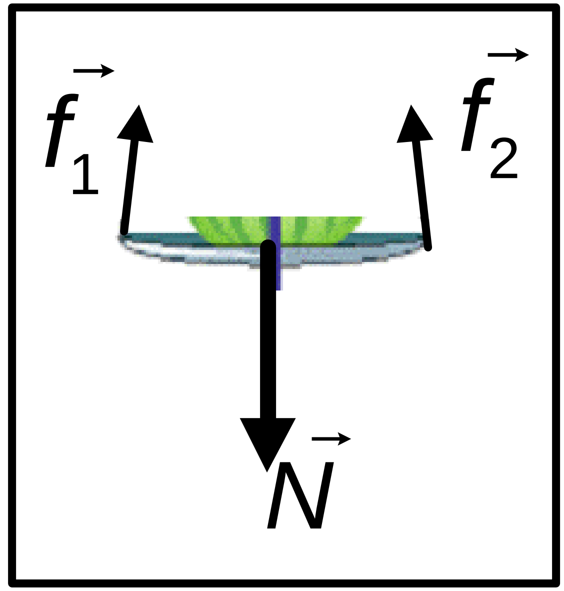
Defines mass, m, as parameter reflecting body's resistance to motion

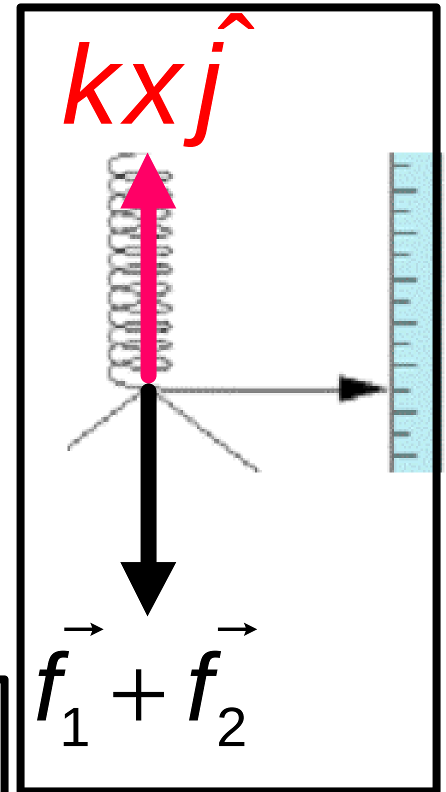
3. Action = Reaction! When force acts on body 2 by body 1, then equal and opposite force acts on body 1 by body 2.

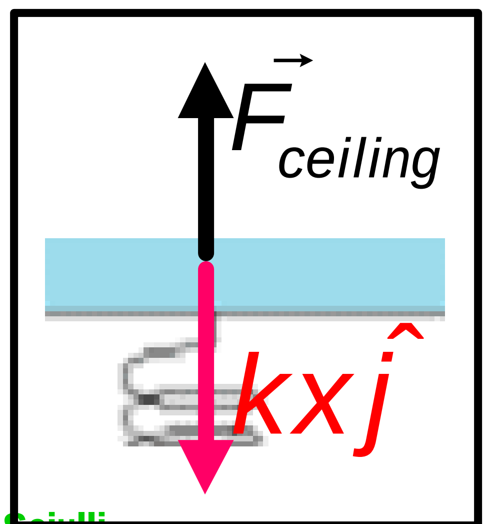
Forces on the isolated pieces (sometimes called “free body diagrams)











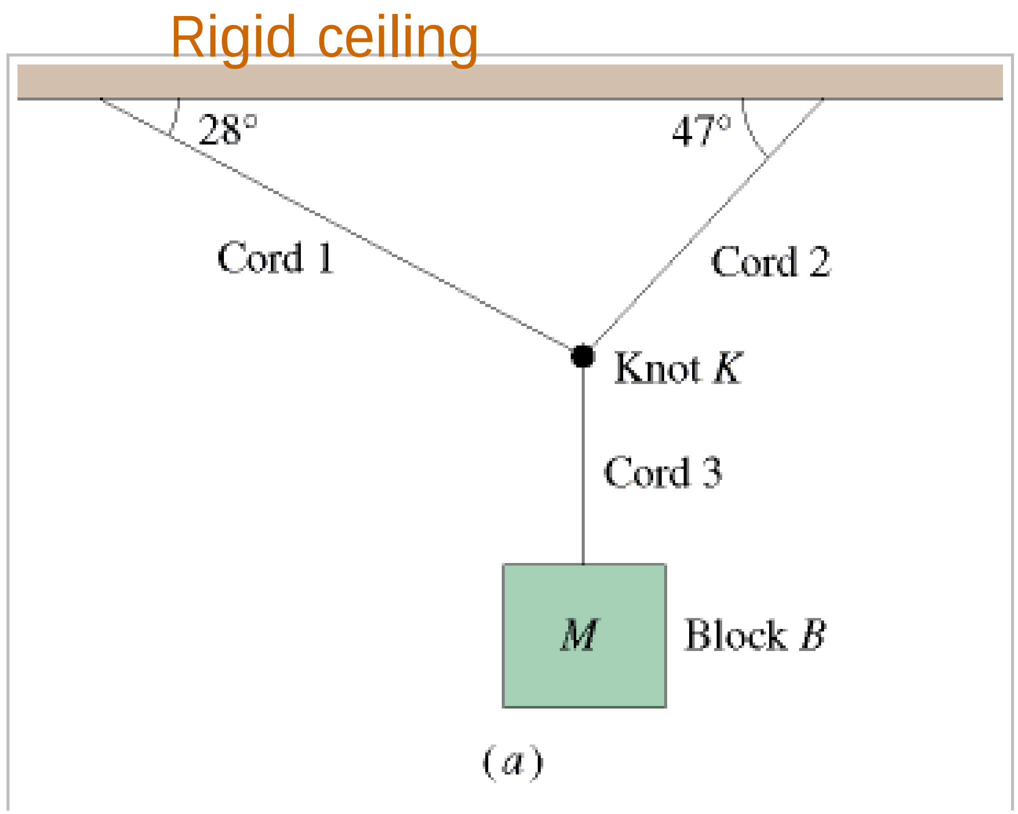
No acceleration

Forces on all bodies balance

Sample Prob 5-6: Rope tensions?

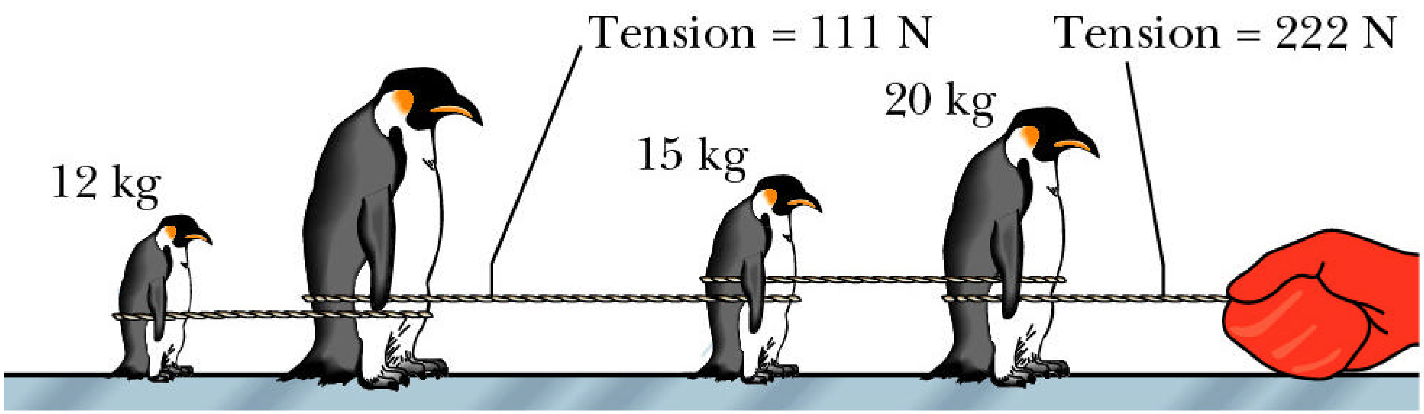
- Illustrates force problem procedures

1. Draw Picture and analyze the problem
2. Isolate specific points or bodies and sketch forces acting on these
3. Use SF=ma at each point
    - If a=0, net force at the point is zero

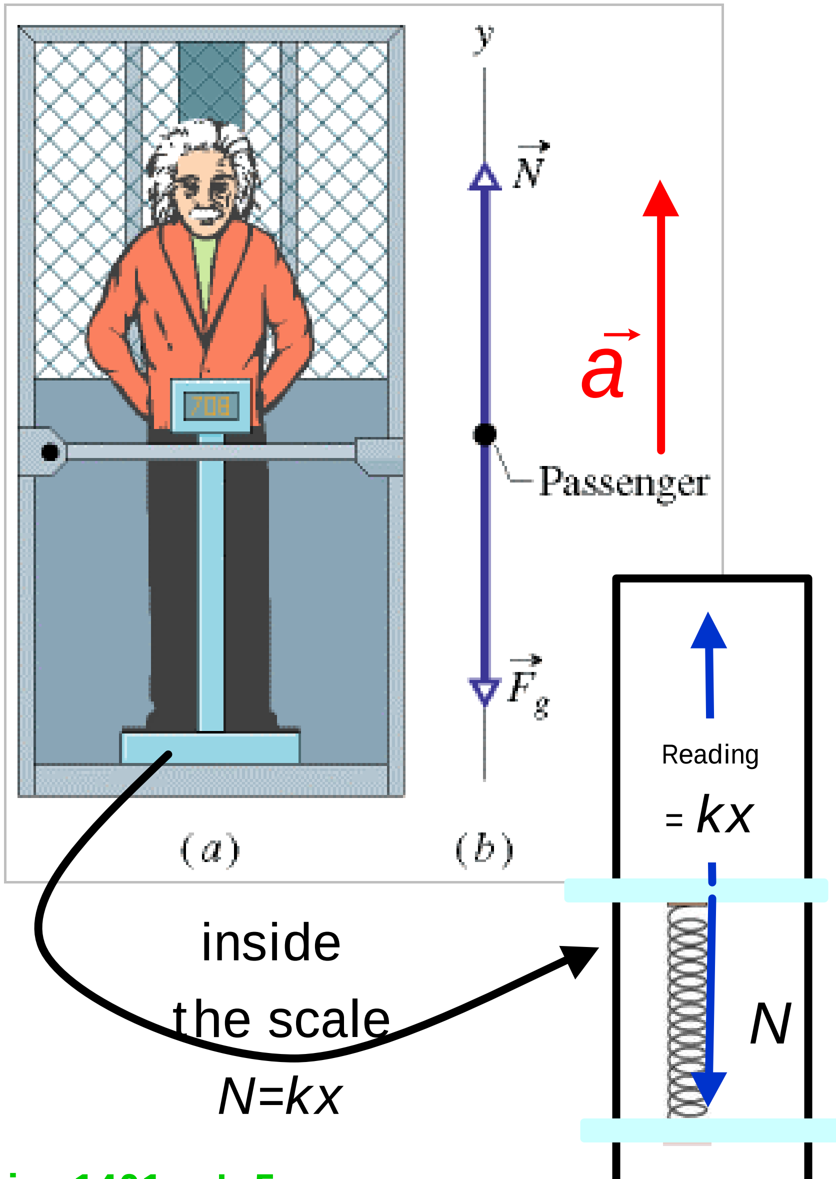


Problem 5-34

The figure shows four penguins that are being playfully pulled along very slippery (frictionless) ice by a curator. The masses of three penguins and the tension in two of the cords are given. Find the penguin mass that is not given.



Sample Prob 5-8



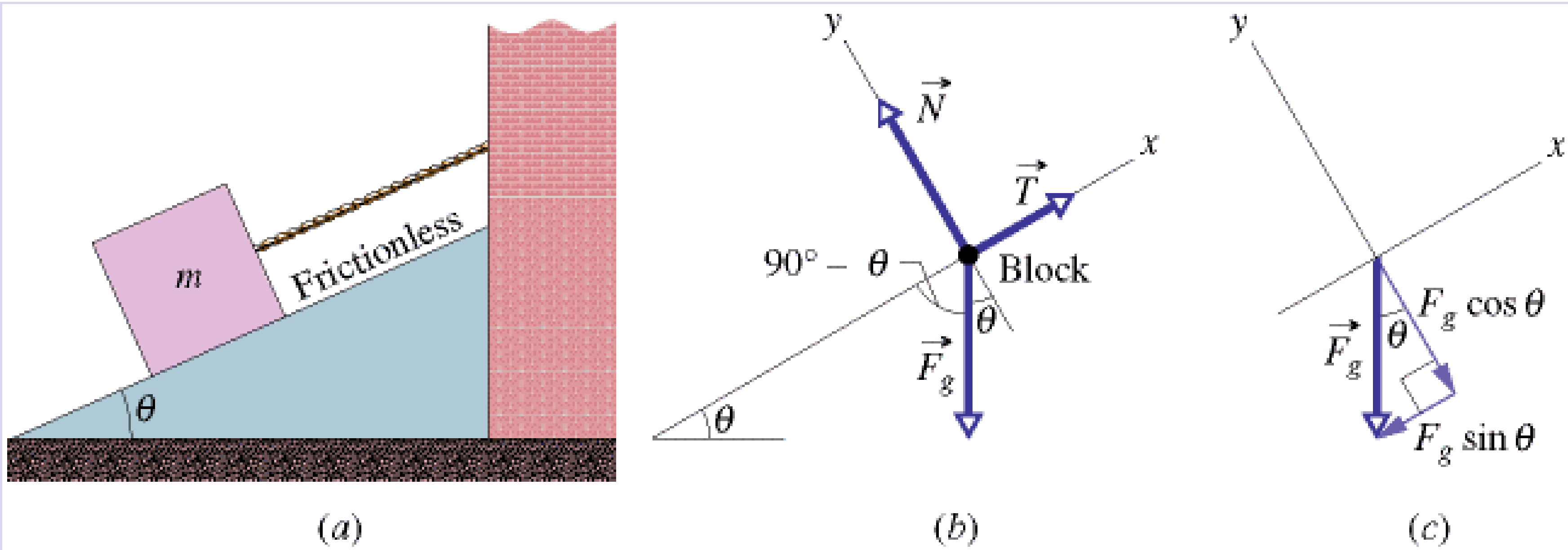
- The "weight" recorded on the scale is N ! <u>Not</u> F_g!
- If $a = 0$, then $N = F_g = mg$.
- But if a is not zero, more complicated … use Newton! (**Note that <u>scale</u> feels a force equal to *N* .)**

$$N - F_g = ma$$

$$N = m(g + a)$$

- Scale can read anything from 0 to ∞
- Note if *a* £ -*g*, must rethink!

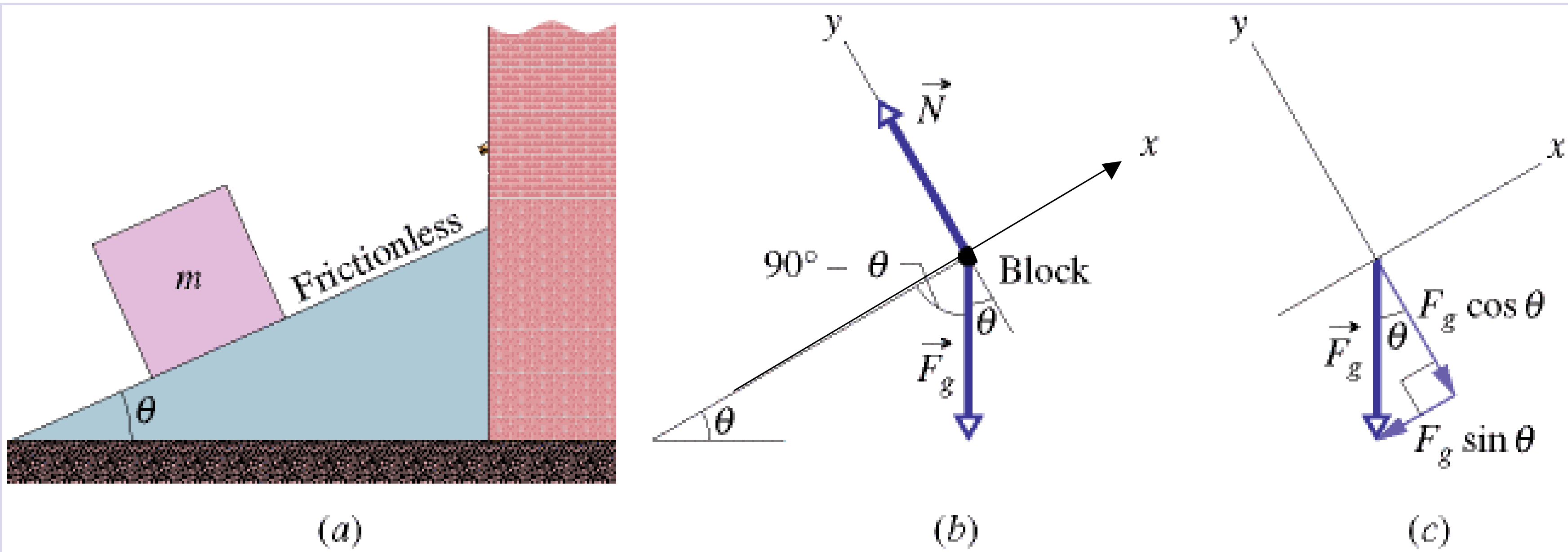
Sample Prob 5-7



$$N = mg\cos q$$

$$T = mg\sin q$$

Sample Prob 5-7 with string cut

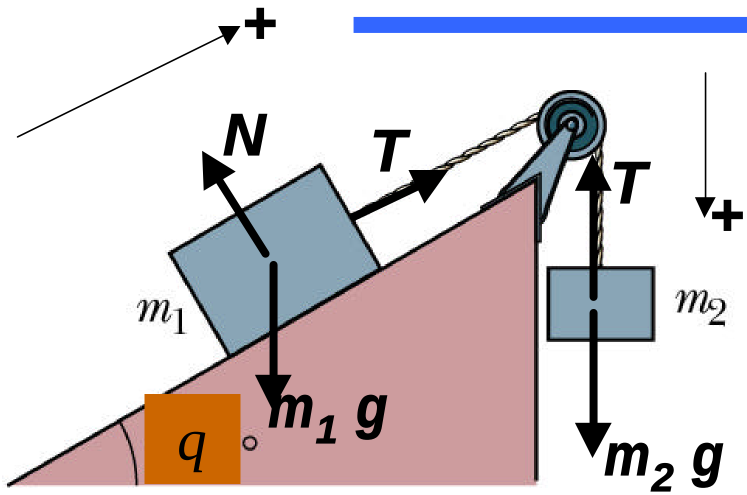


$$N = mg\cos q \quad \text{since} \quad a_y = 0$$

$$-mg\sin q = ma_x \quad \text{so} \quad a_x = -g\sin q$$

intuitive answer?

One Step Harder Problem



no friction

$$T - m_1 g \sin q = m_1 a$$

$$m_2 g - T = m_2 a$$

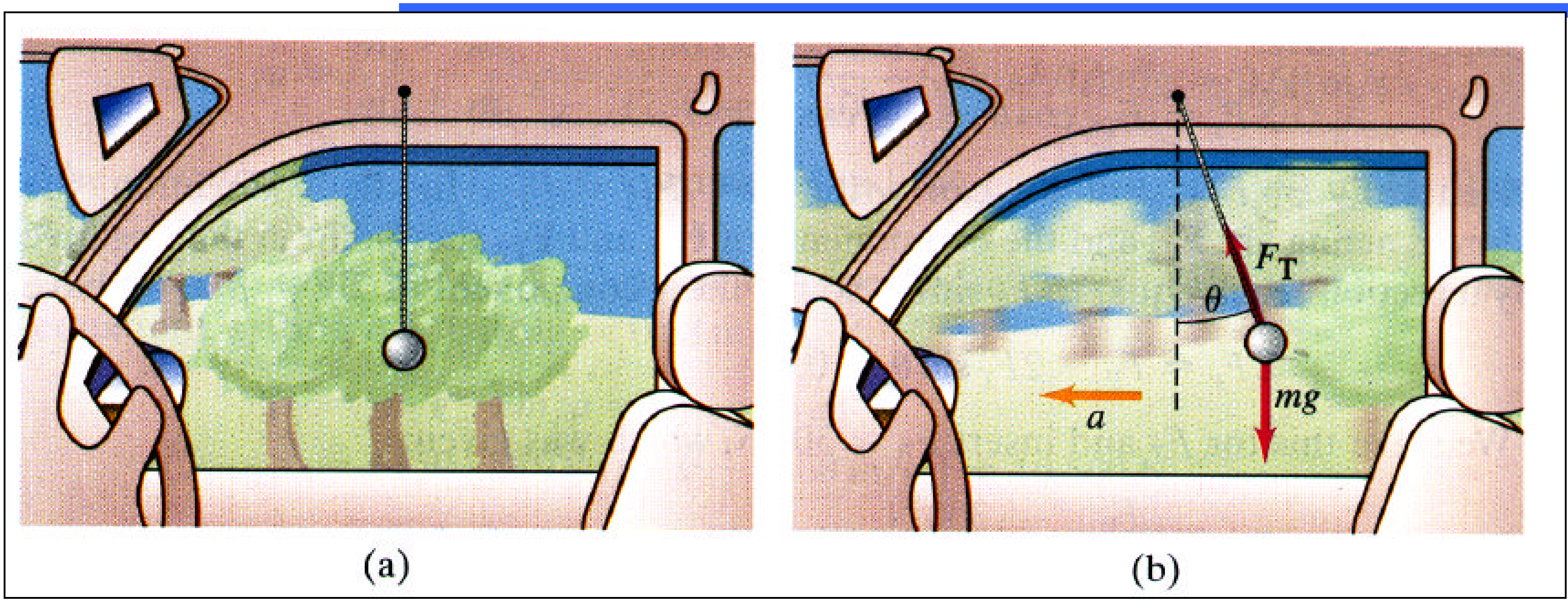
$$m_2 g - (m_1 g \sin q + m_1 a) = m_2 a$$

$$m_2 g - m_1 g \sin q = (m_1 + m_2) a$$

$$a = g\,\frac{m_2 - m_1 \sin q}{m_1 + m_2}$$

Check get intuitive answers in limiting cases

Accelerometer



Measure the acceleration of the car by measuring the angle of the string!

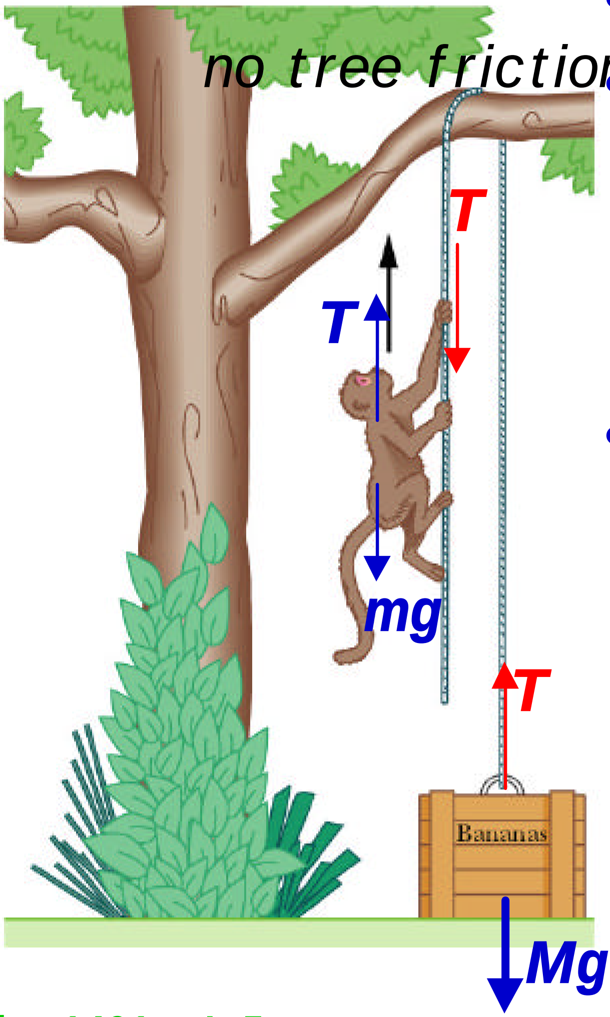
Try it in the subway!

$$F_T \sin q = ma$$

$$F_T \cos q = mg$$

$$a = g \tan q$$

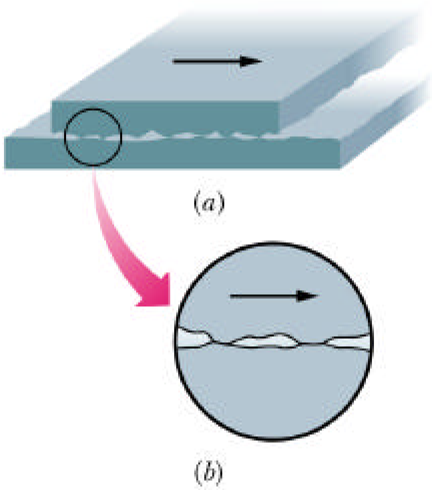
Problem 5 –43 (not assigned)



- **10 kg monkey *(m)***
- **15 kg package *(M)***
- **How can monkey raise the pckage?**
  - Monkey pulls on rope with force *T* (uniform tension throughout rope)
  - Net force on monkey
  - Net force on package
- **Find minimum acceleration of monkey in order to lift package!**

Keep in mind when you do problem 5-50

Friction



$$f_s^{\max} = m_s N$$

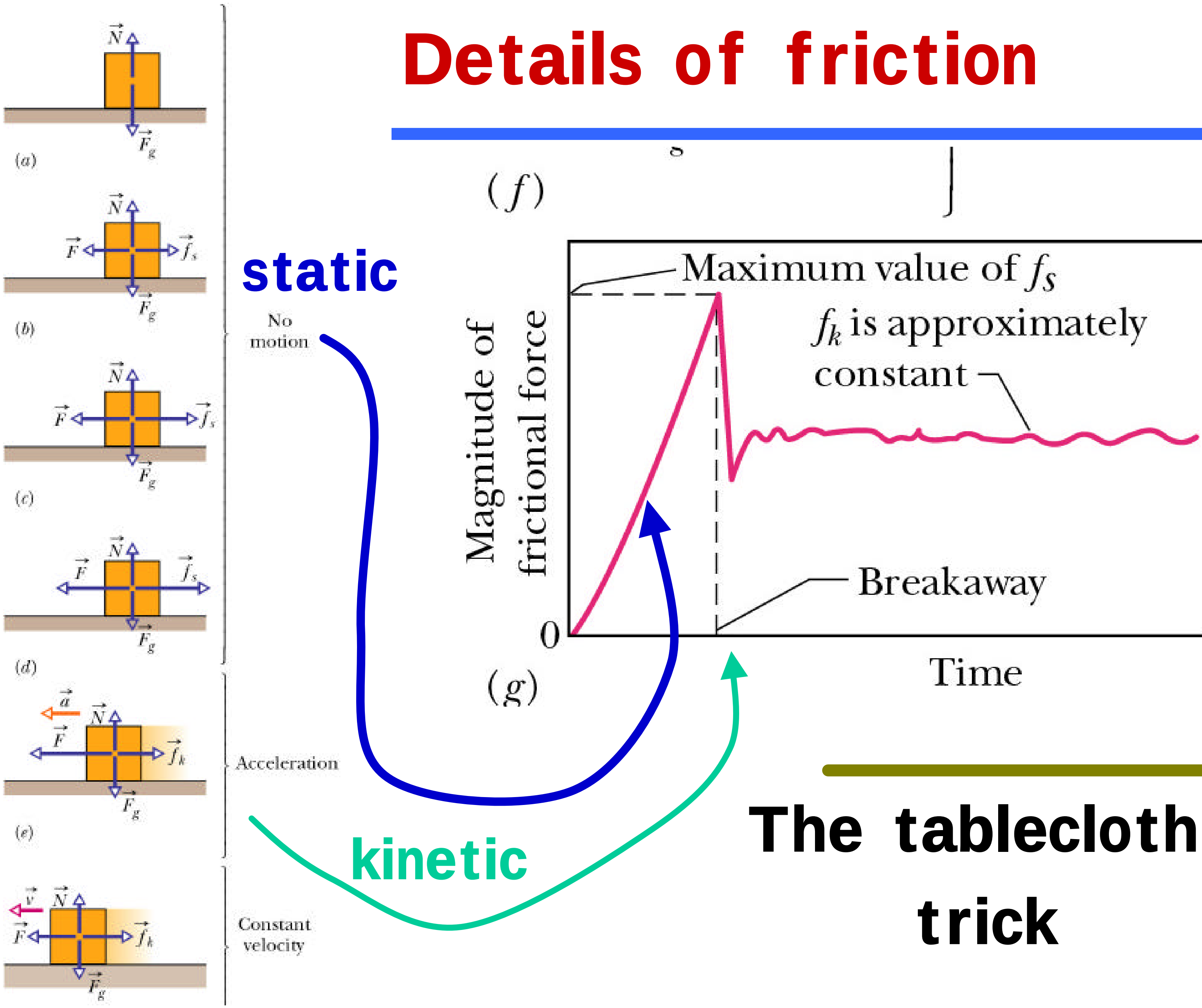
$$f_k = m_k N$$

Approx Coefficients of Friction[†]

Surfaces	Coefficient of Static Friction, μ_s	Coefficient of Kinetic Friction, μ_k
Wood on wood	0.4	0.2
Ice on ice	0.1	0.03
Metal on metal (lubricated)	0.15	0.07
Steel on steel (unlubricated)	0.7	0.6
Rubber on dry concrete	1.0	0.8
Rubber on wet concrete	0.7	0.5
Rubber on other solid surfaces	1–4	1
Teflon® on Teflon in air	0.04	0.04
Teflon on steel in air	0.04	0.04
Lubricated ball bearings	< 0.01	< 0.01
Synovial joints (in human limbs)	0.01	0.01

[†] Values are approximate and are intended only as a guide.

Details of friction



The tablecloth trick

Example of finding coefficient of friction

Problem:

Raise the book until coin starts to fall

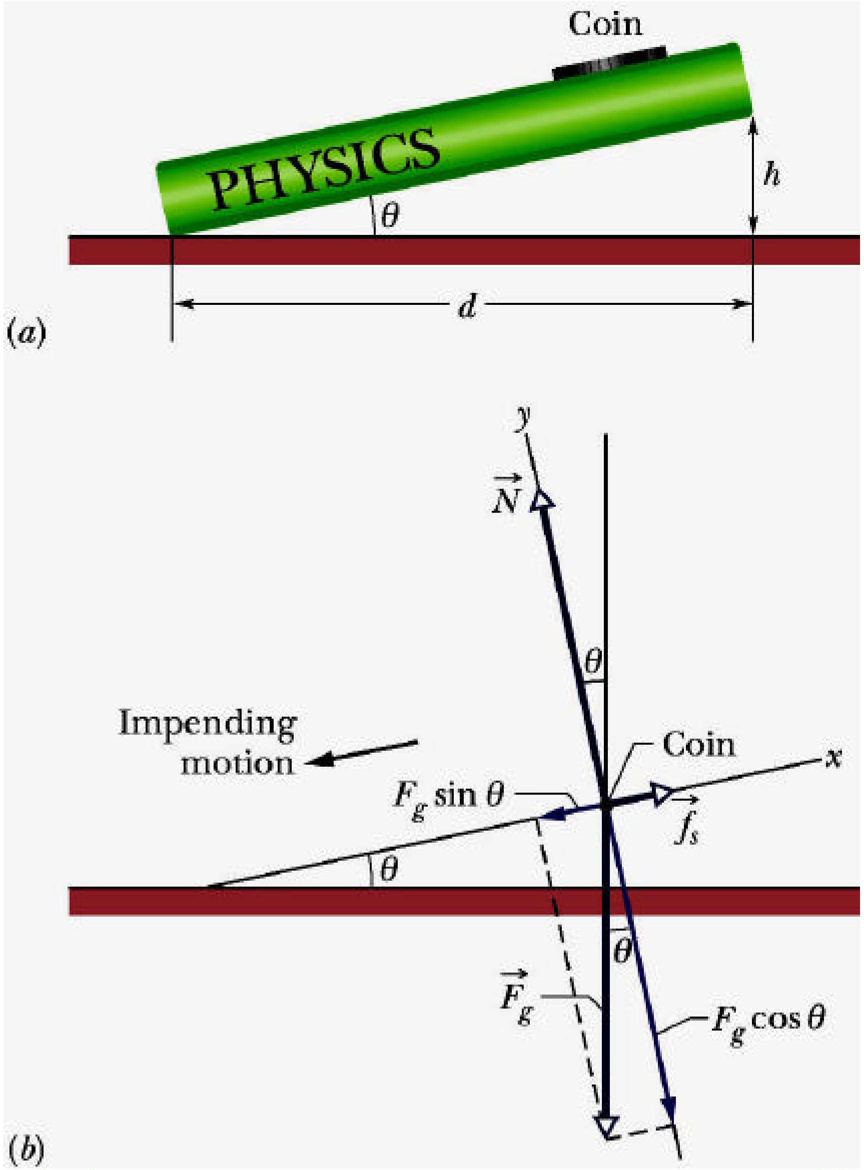
Measure the angle

Calculate the coefficient of static friction

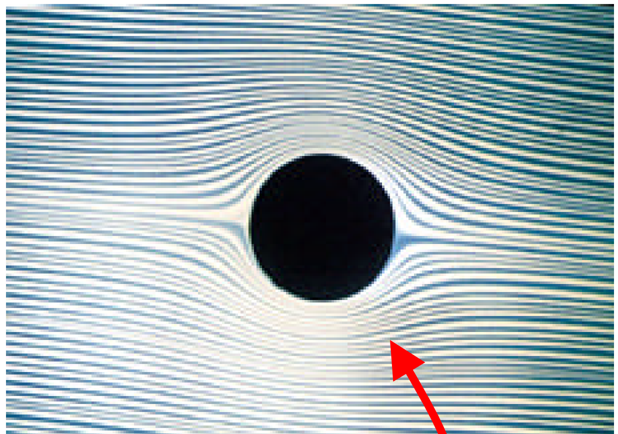
$$f_s = mg\sin\theta$$

$$N = mg\cos\theta$$

$$\mu_s = \frac{f_s}{N} = \tan\theta$$



Fluid Drag Forces



- Nonviscous flow (only thing considered ch 15) = no drag force
- Viscous but laminar
- Viscous and turbulent

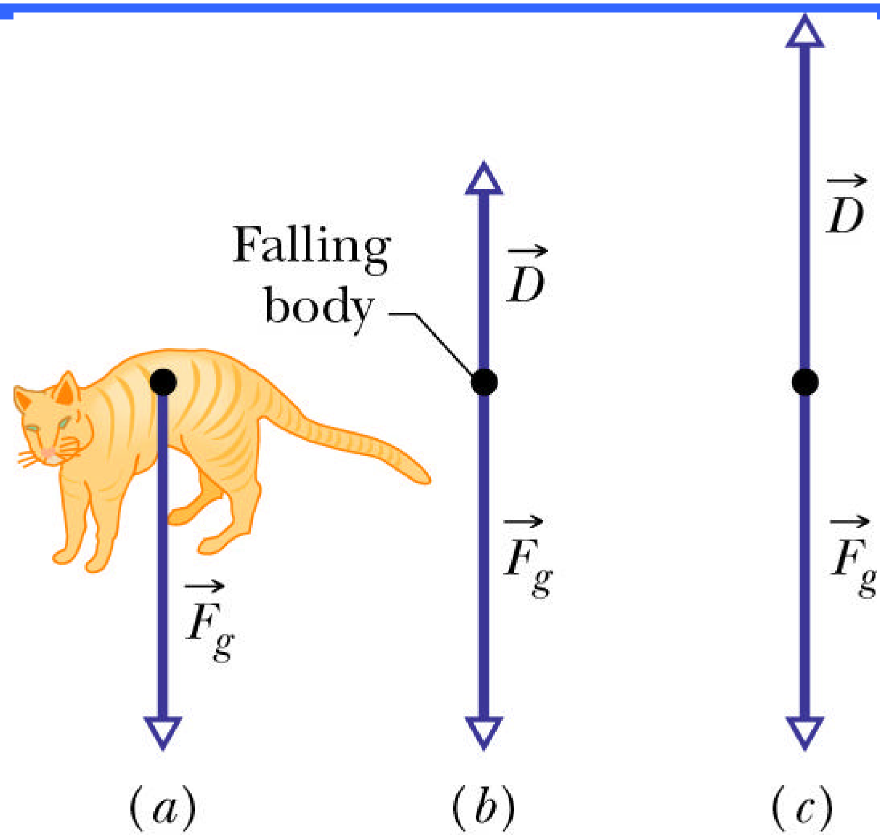
$$F_d = -Kv$$

$$F_d \approx D$$

$$D = \frac{1}{2} C\, r A v^2$$

Drag Considered Ch 6

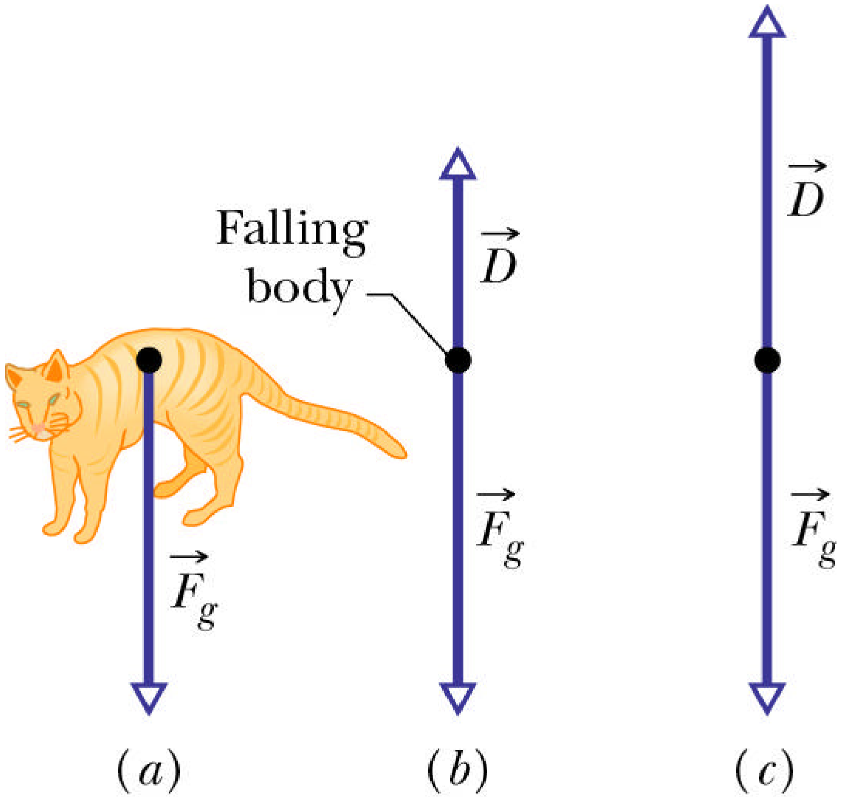
- Turbulent …
- Cat falls and accelerates until $D = F_g$
- At that point, cat has reached <u>terminal velocity</u>
- See specific discussion in section 6-3.



$\vec{D} =$ drag force, oppose motion

$$D = \frac{1}{2} C \rho A v^2$$

Terminal Speed



- In either case,
  D µ - $v^{1 \text{ or } 2}$ …
  - Object will attain a <u>terminal speed</u>
  - Text does the turbulent flow case
  - Laminar flow case:

$$D = -K\eta v$$

$$D = mg \text{ when } v = v_{term} = \frac{mg}{K\eta}$$

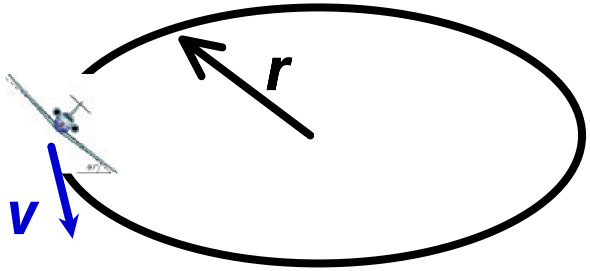
In between:

$$m\frac{dv}{dt} = mg - K\eta v$$

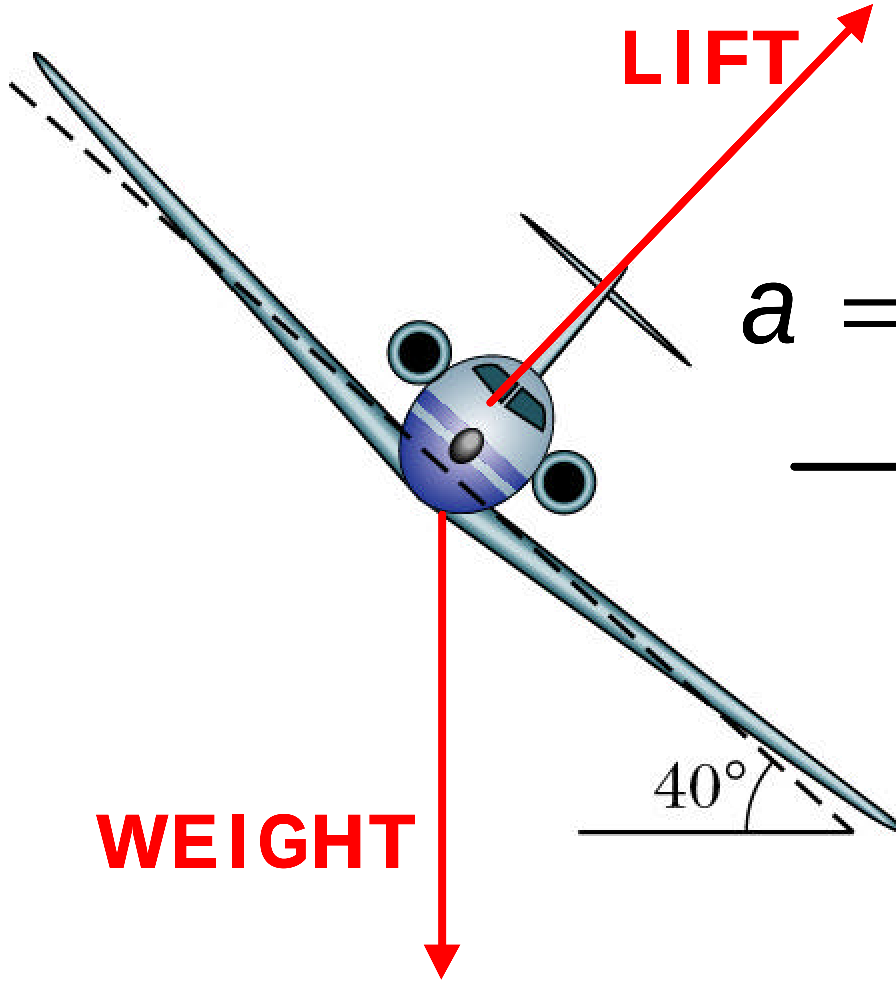
with solution for start at rest

$$v = v_{term}(1 - e^{-\frac{K\eta}{m}t}) \qquad \text{[culture]}$$

HW Problem 6-45 (assigned)



- **Airplane in holding pattern flying in <u>circle</u> of radius, *r*, at constant speed, *v***
- **Given *v* and bank angle, what is *r* ?**

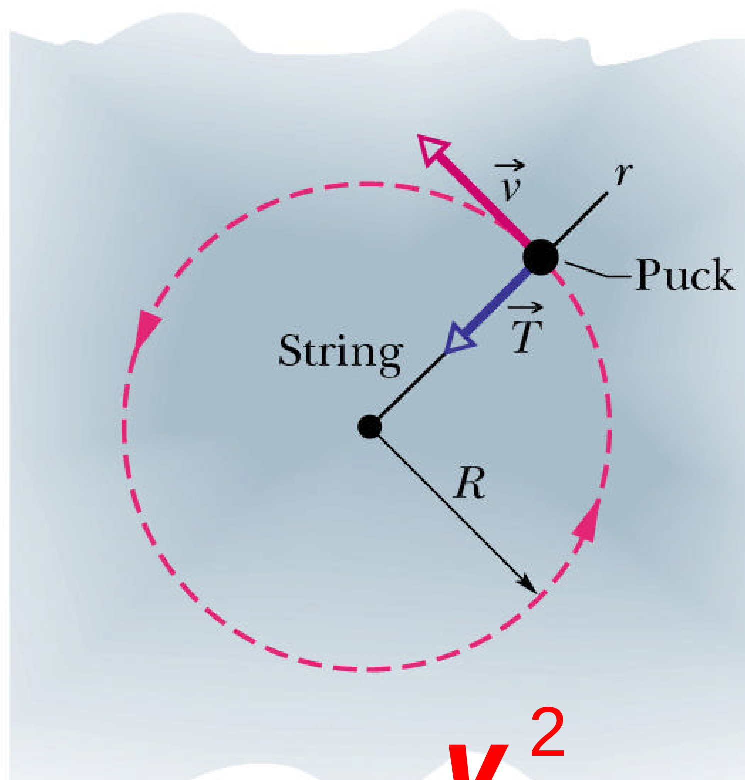


$$\vec{a} = \frac{v^2}{r}$$

Centripetal Force

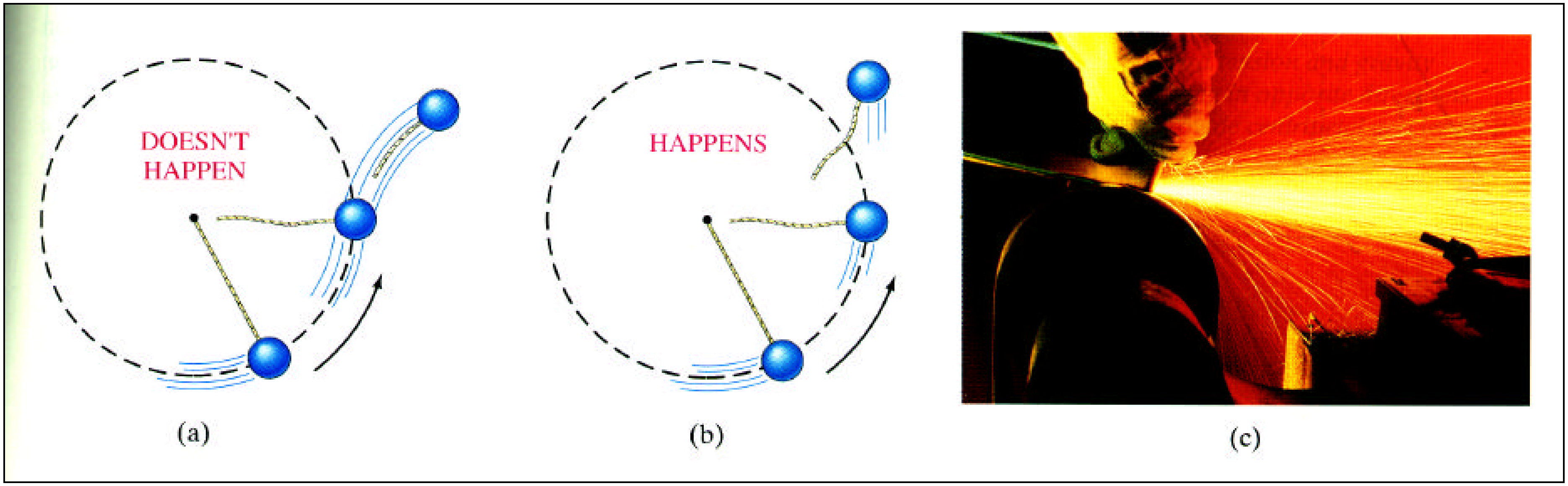
centripetal force.MOV

- Must <u>always</u> be a force to hold an object in circular motion
- This force supplies the centripetal acceleration!
- Hey! What happened to <u>centifugal force</u>?



$$T = m\frac{v^2}{R}$$

Centrifugal Force is a FICTION!



Real life experiences that make clear …
objects without force travel in a straight line at the velocity with which they started!

Conclusion

- **HW 2 due on Monday (problems ch 4,5,6)**
- **Read Chapter 7 before Monday lecture**
- **Sample Midterm 1 at website on Monday**
  - **Will include the solutions**
  - **Recommend strongly you try it <u>before</u> reading solutions**
- **Midterm exam <u>in class</u> following Monday 9/29**
  - **Will cover chapters 1 – 6**