High Speed Movies for Introductory Physics Lab

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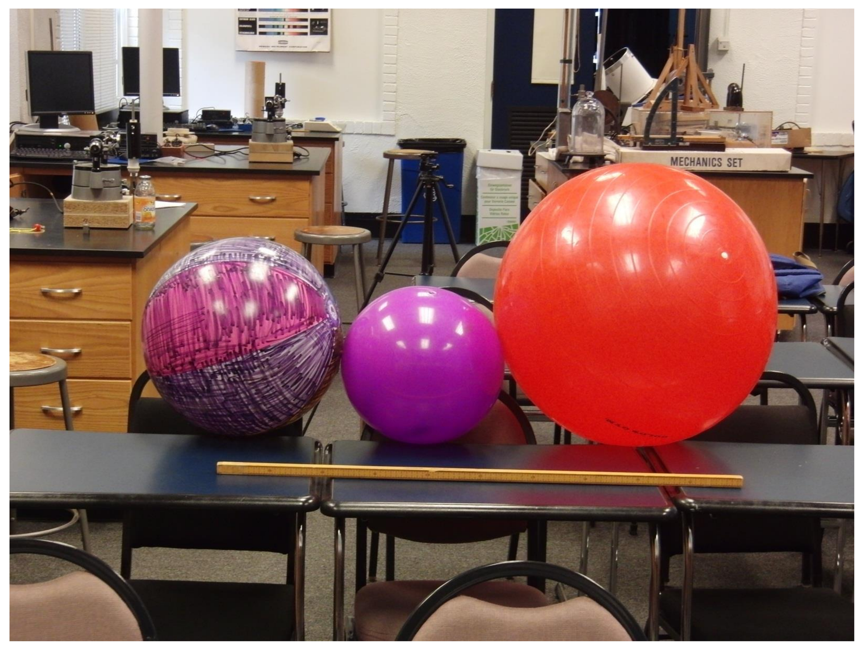
Some modern digital cameras have the ability to take digital video at up to 1000 frames per second (FPS). While not true "high speed video", using higher than the default 20 FPS video provides higher temporal resolution and reduced motion blur. We present an exercise where students study vertical motion with air resistance of several objects including a basketball and a beach ball. Students determine the drag coefficients by measuring the terminal velocity of the objects' vertical motions. Some additional applications are also presented.

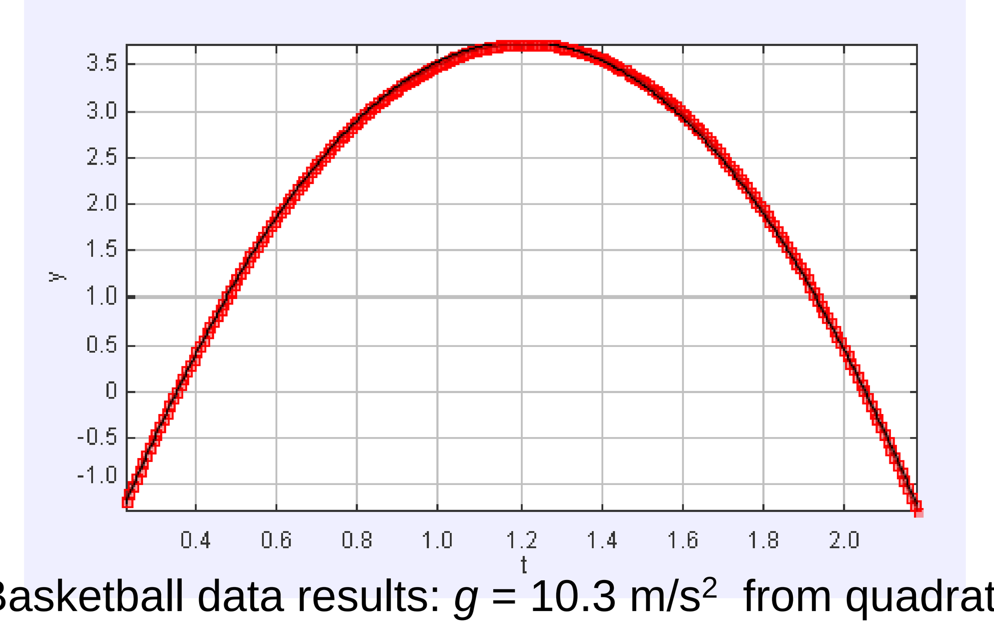
Gravity and beyond

High Speed Video Advantage :

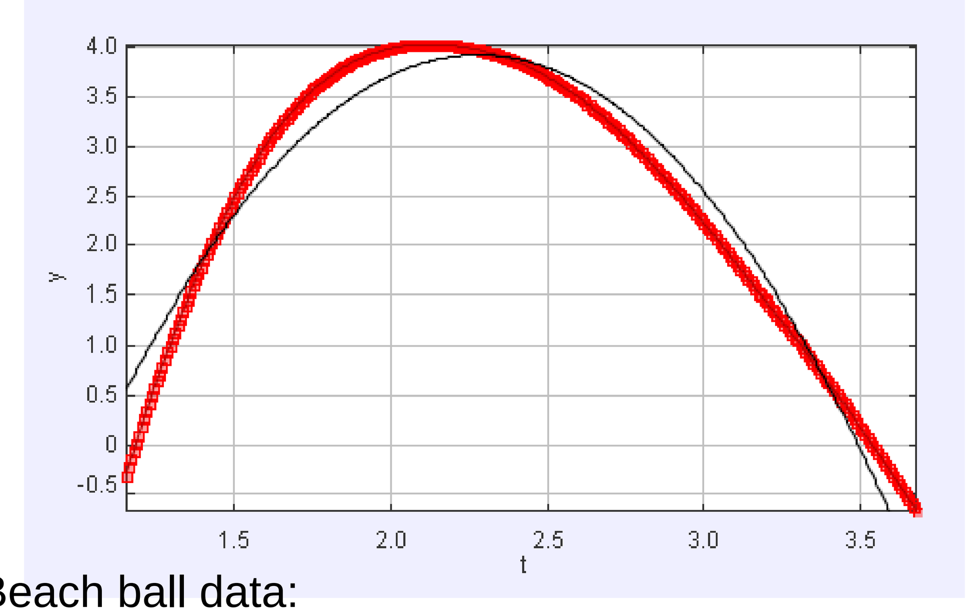
- Reduced Motion Blur
- Auto tracking requires more "hand holding" for 30 fps.



A partial Cast of Characters
For Vertical Motion at 120 fps



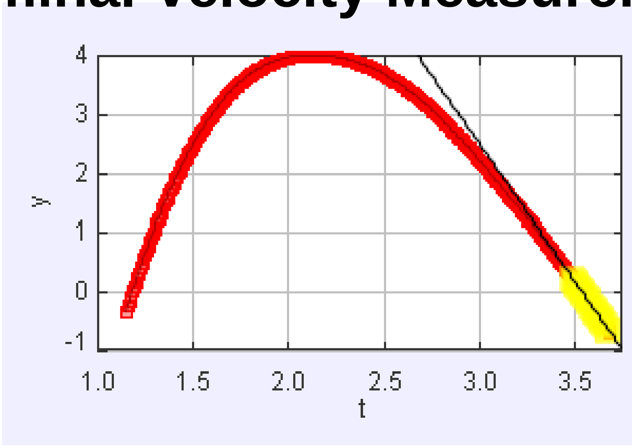
Basketball data results: g = 10.3 m/s² from quadratic coefficient of parabolic fit.



Beach ball data:

- Quadratic is not a close fit.
- Signs of terminal velocity.

Terminal Velocity Measurements



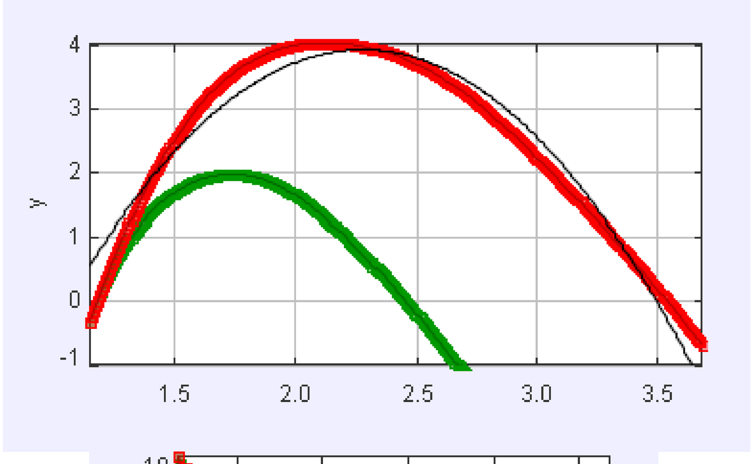
v_T determined from slope of last segment of y position data.

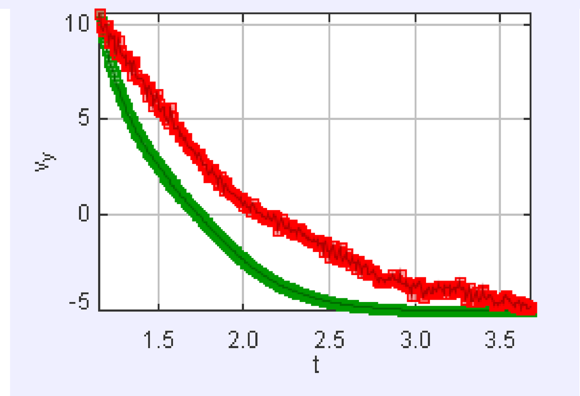
$$\sum F_y = -mg - \frac{1}{2}\rho v_y |v_y| C_d A = ma$$

$$v_T = \sqrt{\frac{2mg}{\rho C_d A}}$$

	BasketBall	middle Ball	Large Ball	Beach Ball
m (kg)	0.624	0.166	0.830	0.103
Weight (N)	6.12	1.63	8.14	1.01
Radius (m)	0.119	0.170	0.298	0.210
v_{max} (m/s)	11.0	11.0	11.0	10.0
F_D, max	1.52	3.11	9.50	3.91
v_T (theory)	22.1	8.0	10.2	5.1
v_T (exp)		6.4, 6.9	10	4.7
h for v_T	24.8	3.2	5.3	1.3

Modeling Problems

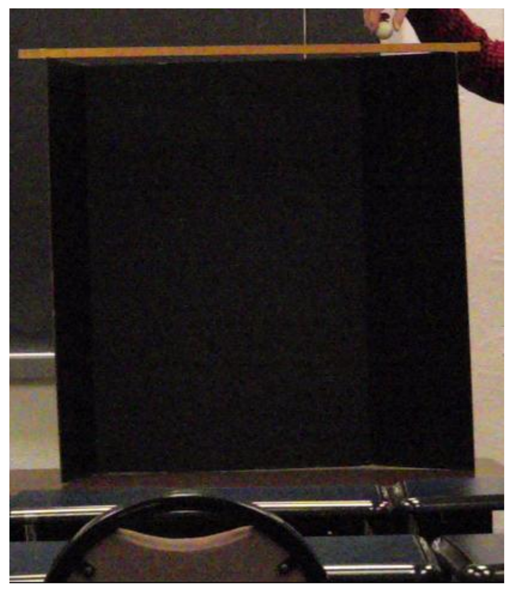


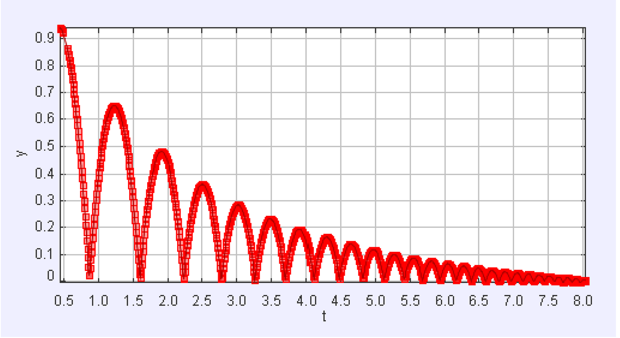


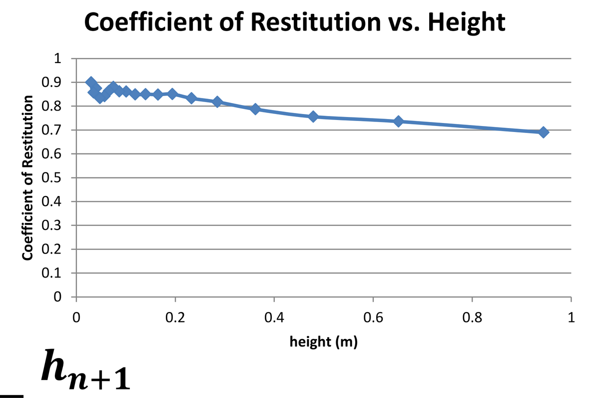
Modeling with Tracker Video Analysis Tool using $a = -g - g v_y |v_y| / v_T^2$

Coefficient of Restitution

Ping Pong Ball

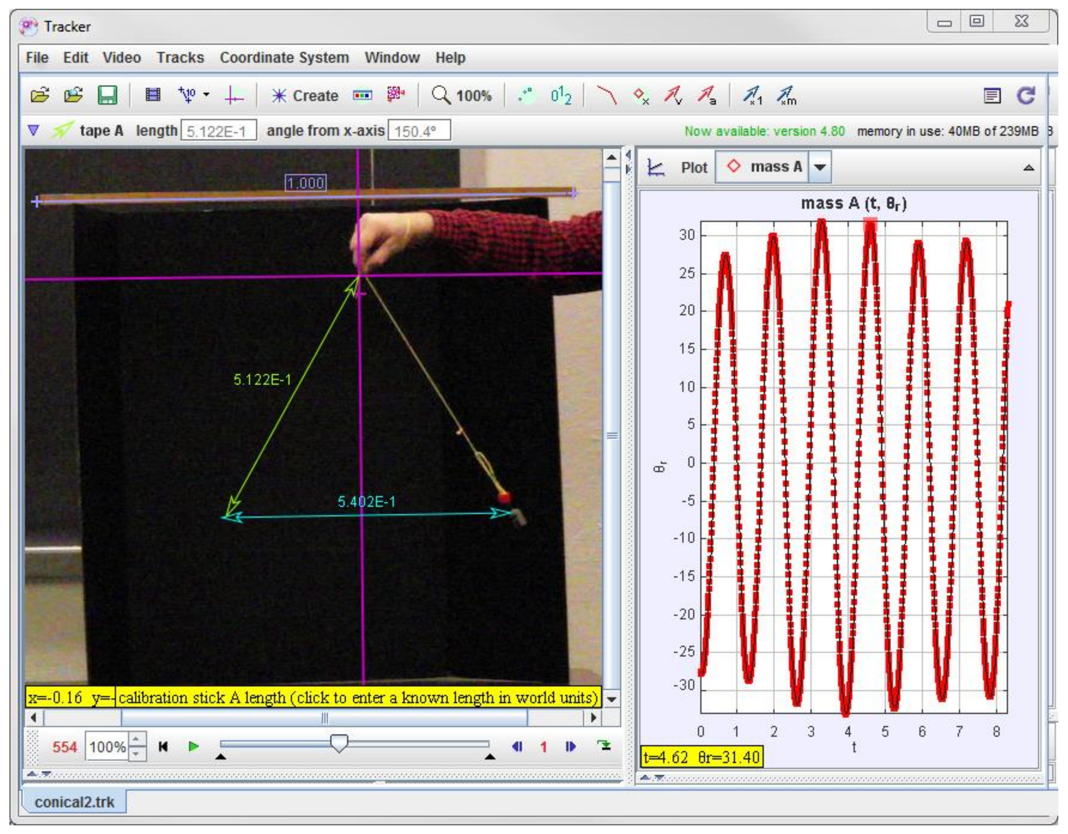






$$CoR = \frac{h_{n+1}}{h_n}$$

Conical Pendulum



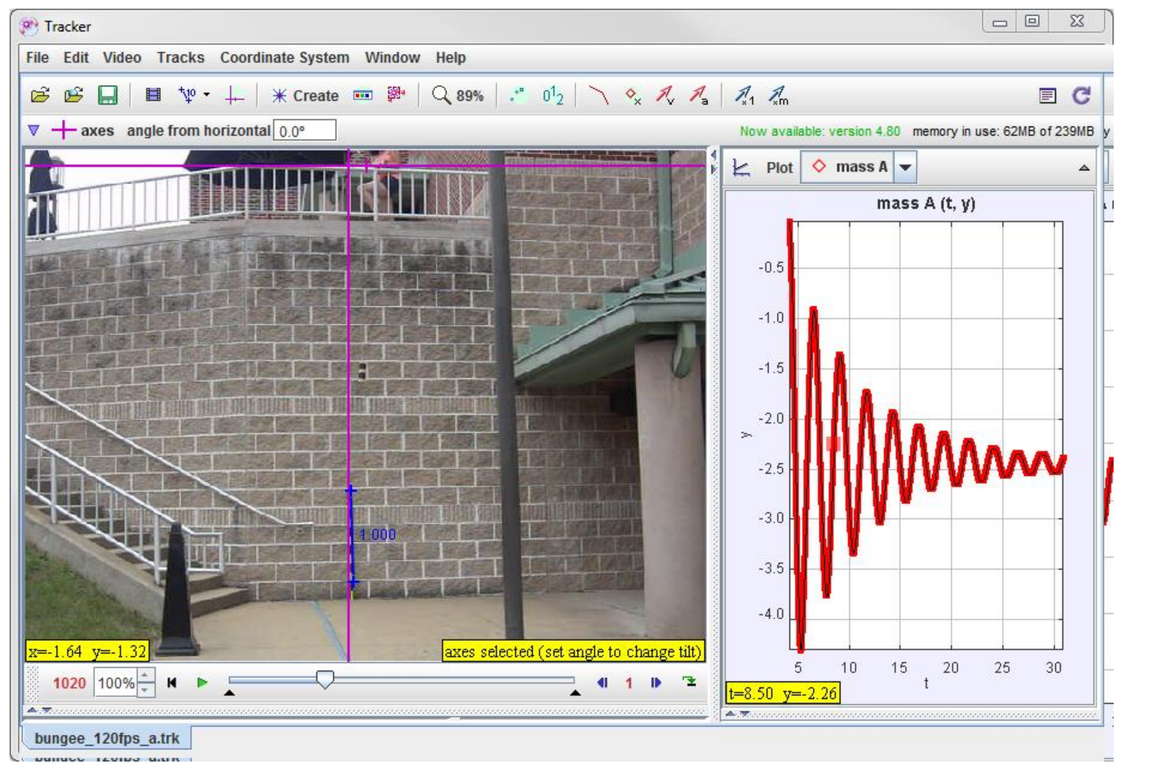
Analyze one full orbit:

$$\theta_{theory} = \tan^{-1}\left(\frac{v^2}{Rg}\right)$$

Period, orbit radius and angle(s) measured in video

dt	1.32
R	0.27
v	1.29
θ_{th}	32.10
θ_{exp}	32.18

"Bungee Jumping"



Work in progress

- Trackable weight
- Student constructed/designed "bungee cord"
- Simple Model

Other Opportunities

- Amusement Park Physics
  Swing rides, fast motion, etc
- Collisions
- Projectile Motion
  with drag & better modeling

Conclusions

High Speed Movies advantages

- Less motion blur (better tracking)
- Higher time resolution
- More data

High Speed Movies disadvantages

- More money ($250-ish)
- More data (clicking not practical)
- It's not *really* high speed video

Camera Specs

Casio Exilim EXS-FH100

Hi-speed Movies (HS) :

224 x 64 (1000 fps), 224 x 168 (420 fps), 448 x 336 (240 fps), **640 x 480 (120 fps)**,448 x 336 (30-240 fps), 640 x 480 (30-120 fps)

HD Movies : 1280 x 720 (30 fps)

STD Movies : 640 x 480 (30 fps)

Other Options?

A Feb, 2011 PC World review Includes reviews of Casio, Samsung and Canon Cameras.

http://www.pcworld.idg.com.au/roundup/376706/cameras_high-speed_video_recording/