Physics of Surfing
Energetics of a Surfer

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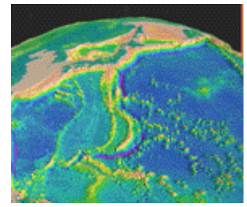
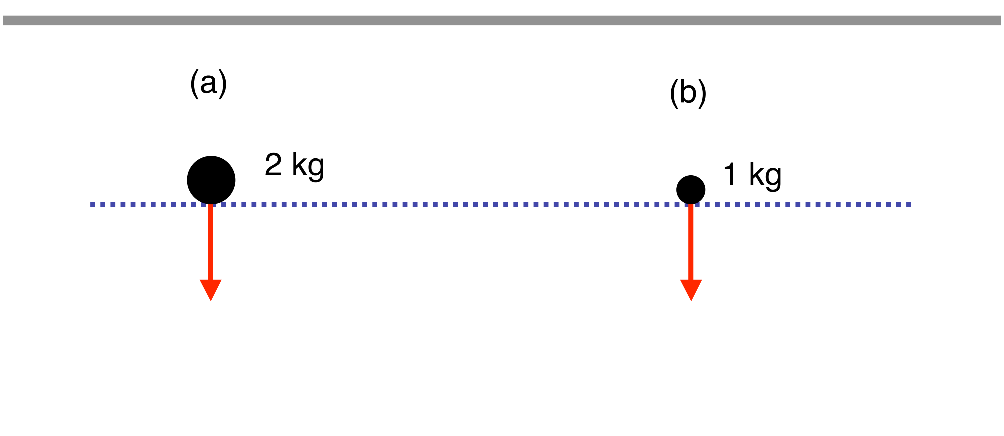
(http://topex.ucsd.edu)



- Four styles of surfing
- Waves
  - Big swell coming? (storms)
  - What makes "sets"? (dispersion)
  - Why is Blacks Beach good for surfing? (refraction)
- Riding waves
  - "catching" the wave (speed)
  - "dropping-in" (energy conservation)
  - "tube riding" (tapping wave energy)
  - "need more speed" (surfboard drag)

Which ball is going faster when it reaches the bottom?



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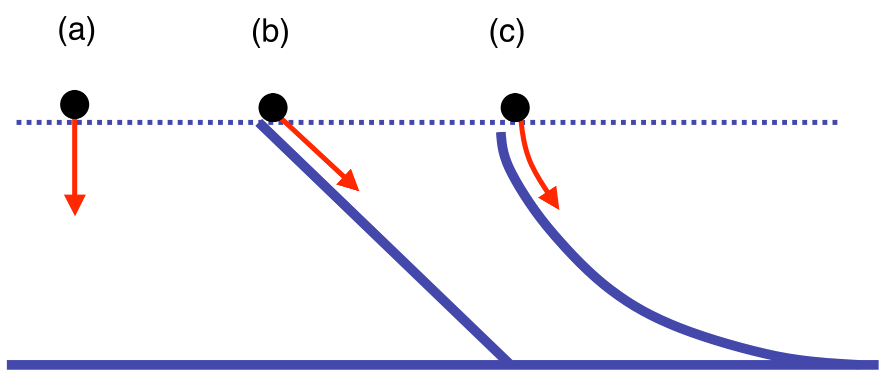
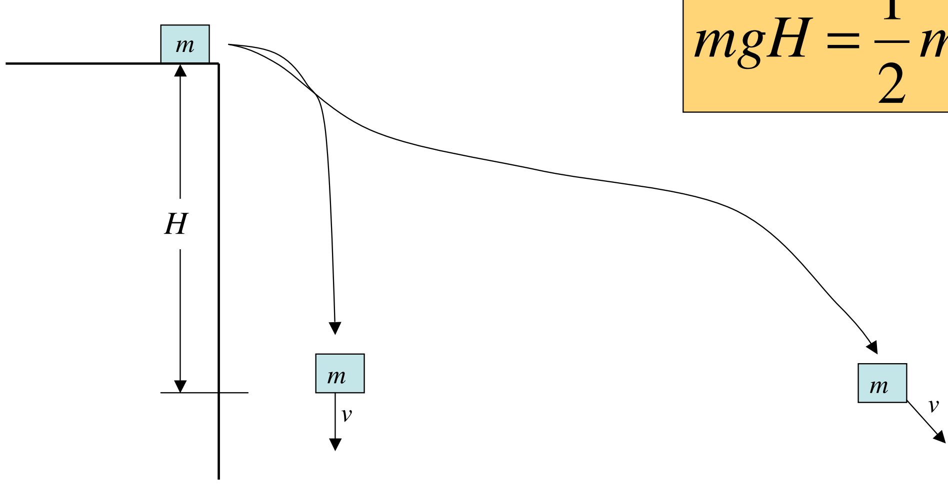


conservation of energy

(assume no friction)

kinetic energy + potential energy = constant

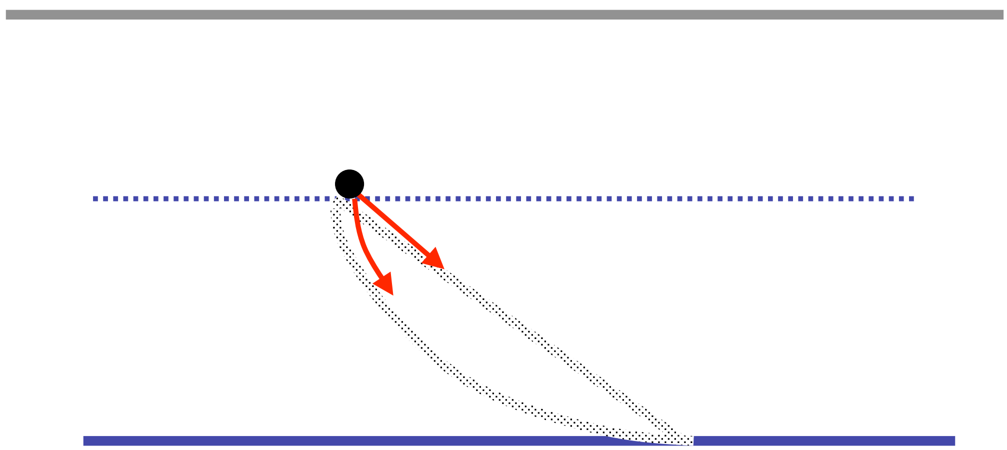


$$mgH = \frac{1}{2}mv^2$$

optimal skateboard ramp

(The brachistochrone problem)

What is the best ramp shape for the minimum time down?



longboard wave

SIO Pier, La Jolla,
height = 1.5 m

fun wave

Blacks, La Jolla,
height = 5 m

tube wave

Pipeline, Hawaii
height = 8 m

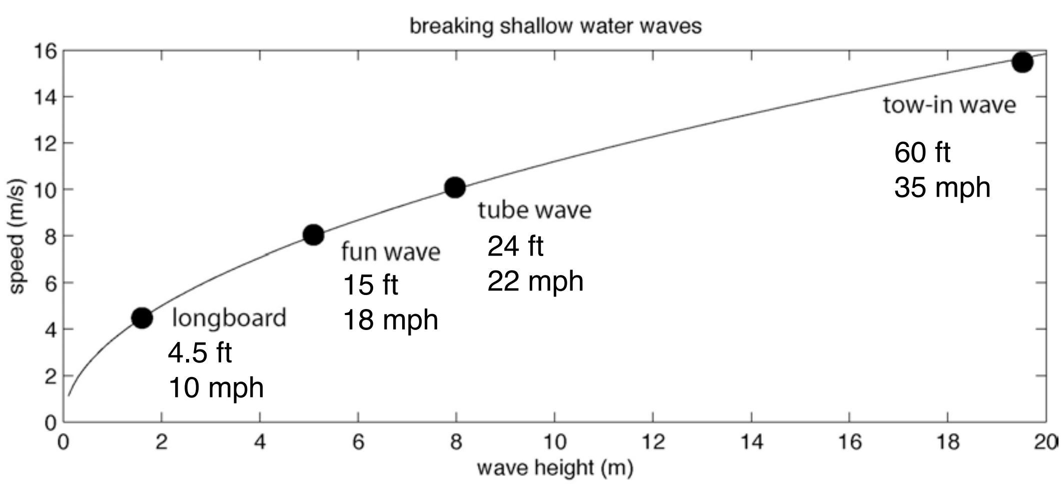
tow-in wave

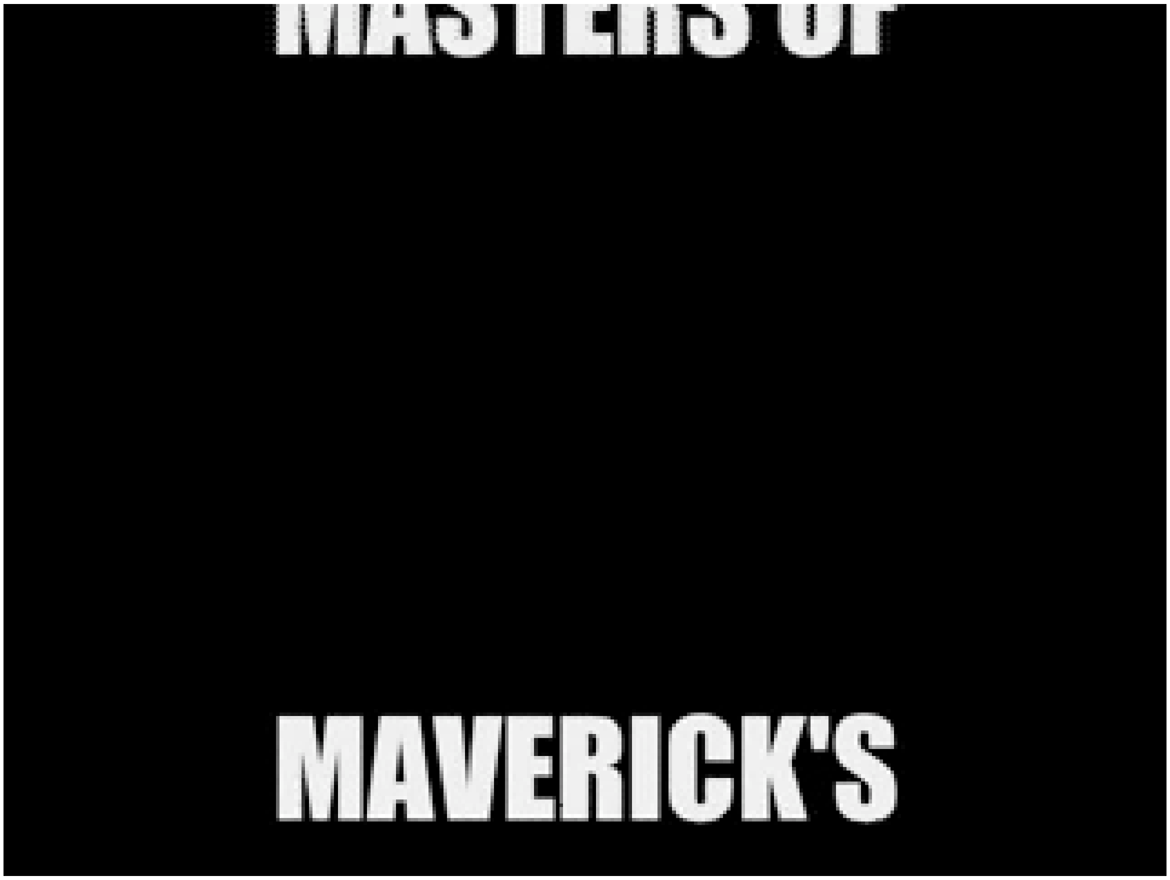
Mavericks, California
height = 23 m

ocean depth and breaker height - **empirical**

$$d_b = 1.28 H_b$$

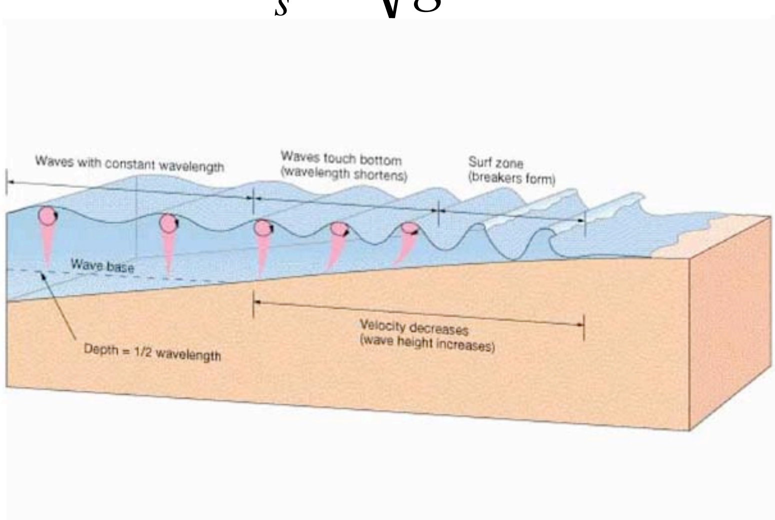
H_b - height of breaker
d_b - depth where wave breaks



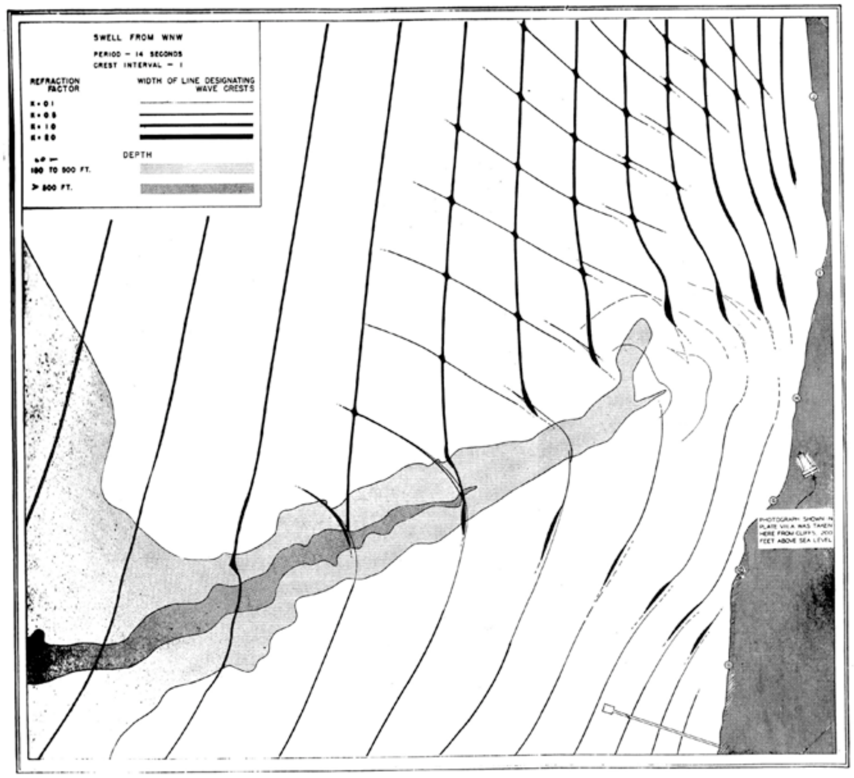


shallow water waves

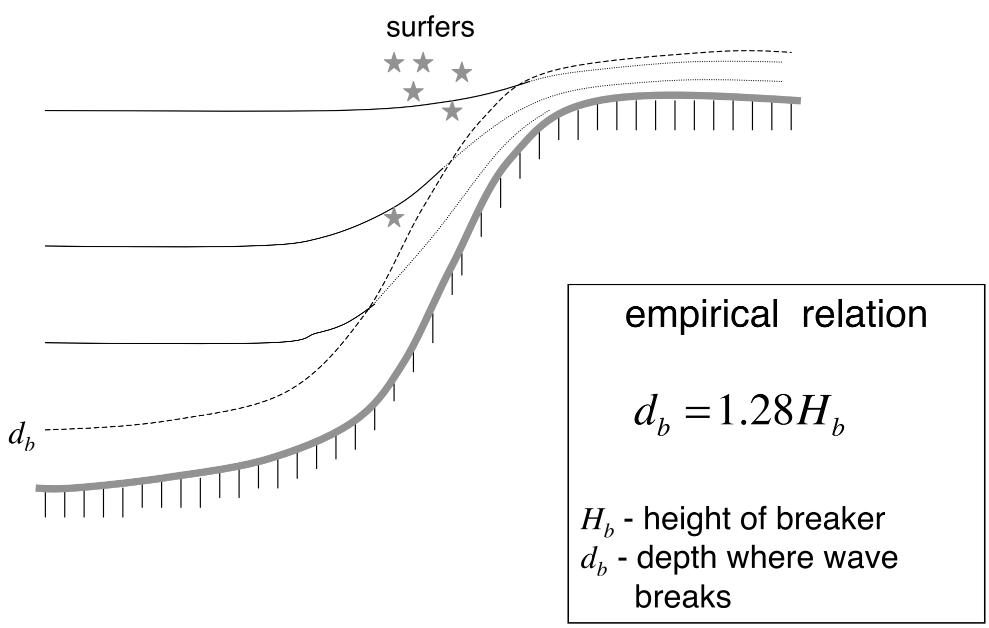
$$c_s = \sqrt{gd}$$



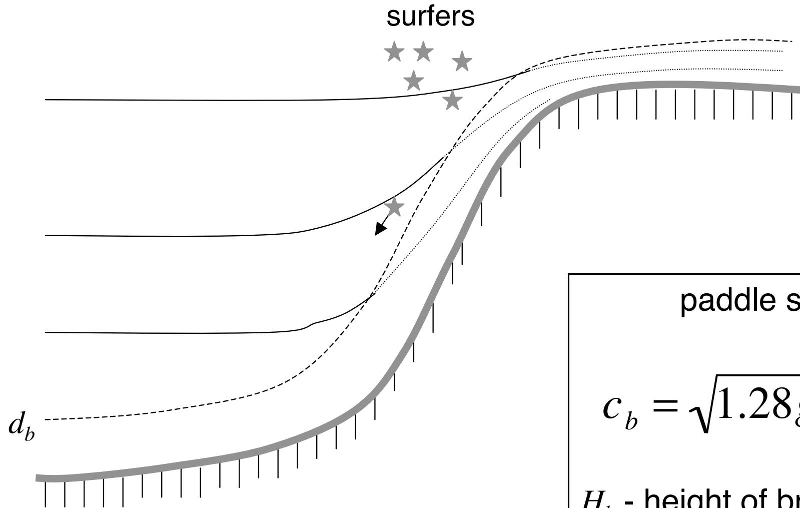
Munk, W. H. and M. A. Traylor, Refraction of Ocean Waves, J. Geology, v. LV, No. 1, 1947



breaking waves



“catching the wave”

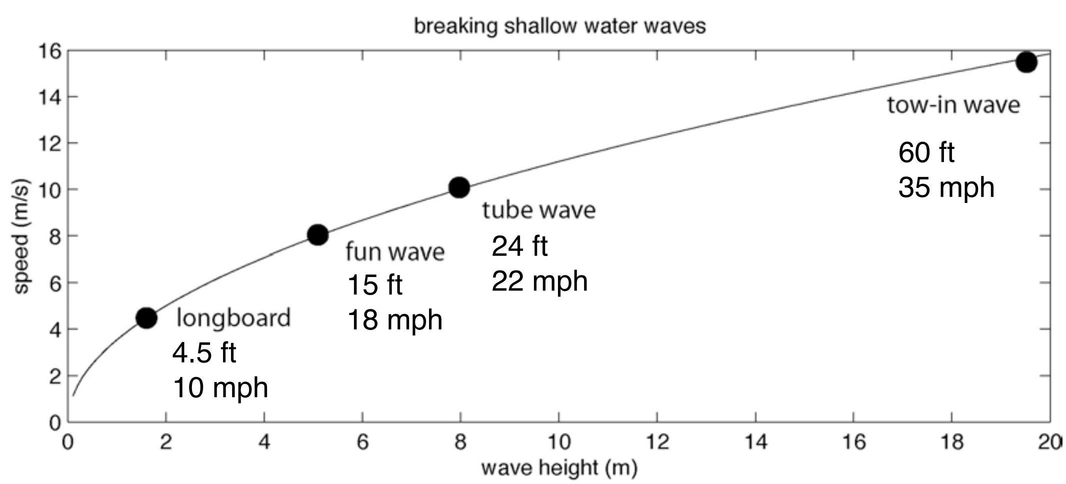


paddle speed

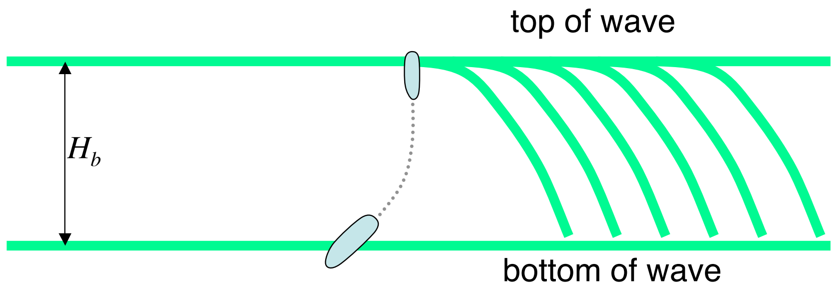
$$c_b = \sqrt{1.28 g H_b}$$

H_b - height of breaker
d_b - depth where wave breaks

paddle speed <= wave speed



"dropping in"



$KE_{bottom} = KE_{top} + PE$

$$\frac{1}{2}mv_d^2 = \frac{1}{2}mc_b^2 + mgH_b$$

$$v_d^2 = c_b^2 + 2gH_b = 3.28gH_b$$

g - acc. Gravity

c_b - wave speed

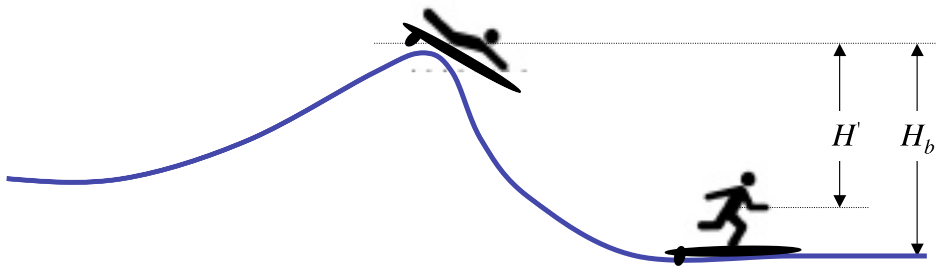
v_d - surfer speed after drop

"dropping in"

style	H_b (m)	c_b (m/s)	v_d (m/s)	v_d (mph)
longboard	1.5	4.3	6.9	15.2
fun	5	7.9	12.7	27.9
tube	8	10.0	16.0	35.2
tow-in	23	17.0	27.2	59.8

correction for surfer height

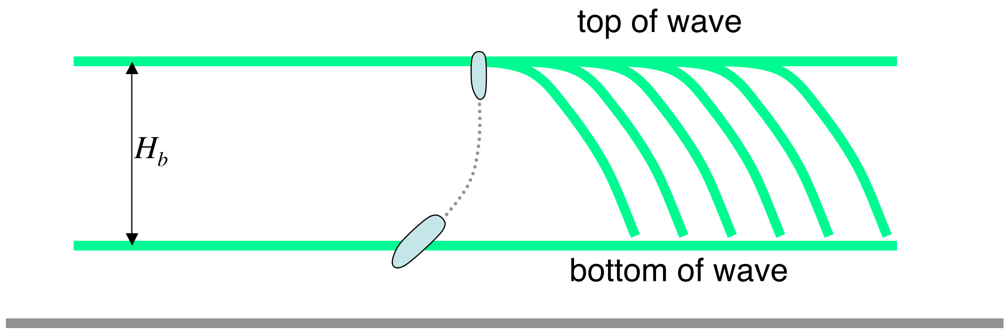
- overhead waves are good
- waist high waves are bad
- short surfers and heavy boards have an advantage in small waves



$$H' = H_b - 1/2\ H_s$$

effective height = breaker height - 1/2 surfer height

“dropping in”



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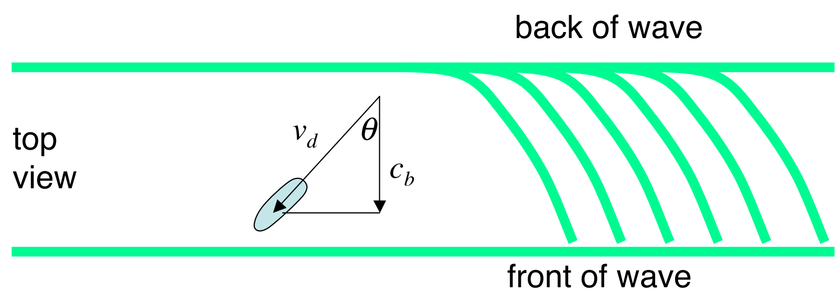
“cutting across”



$$\frac{c_b^2}{v_d^2} = \frac{1.28}{3.28} = \cos^2\theta$$

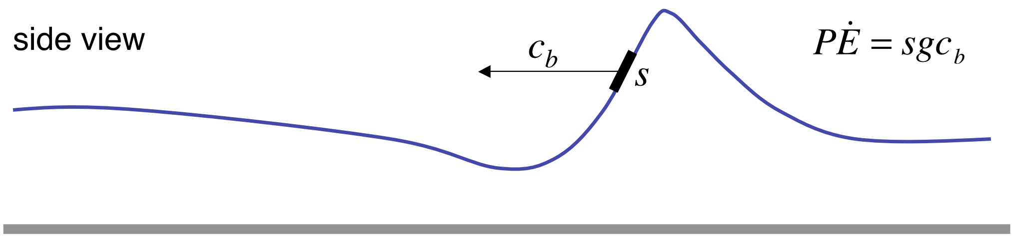
This angle is independent of wave height or wave speed!

$$\theta = \sim 50^\circ$$

“riding the wave”

Suppose the surfer remains on the steepest part of the wave having a slope s. What is the rate of potential energy increase supplied to the surfer?

side view



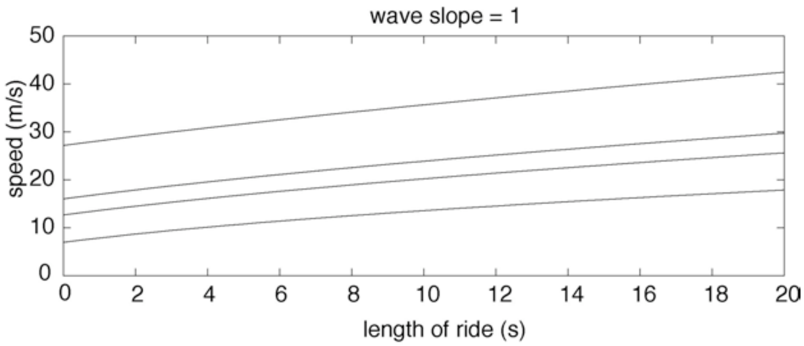
$$\dot{PE} = sgc_b$$

How does speed increase with time?

$$v(t)^2 = v_d^2 + \int_o^t sgc_b dt$$

$$v(t)^2 = 3.28gH_b + tsg\sqrt{1.28gH_b}$$

“the drag”



$$v(t)^2 = 3.28 g H_b + 1.13 g^{3/2} \, s \, H_b^{1/2} \, t - drag$$

total velocity = paddle drop in + slope of “the curl” · breaker height · duration of ride - energy dissipation

Future Research

– Are the best surf spots in areas of narrow continental margin?

– Are “sets” real? What are the statistical properties of sets? Do “sets” become amplified when they reach shallow water?

– How does the shape of the bottom translate into the “perfect wave”?

– What is the terminal velocity for a given breaker height? (Can we establish the magnitude of the drag term?)

– Need to instrument surfers with intertial sensors.