The Northern California GRE Bootcamp for underrepresented minorities

Held at UC Davis, Sept 10-11, 2011

Homepage:
http://www.physics.ucdavis.edu/~dwittman/bootcamp.html

Big tips and tricks

* Dimensional analysis (which answers make sense?)

* Expansions, in particular $(1+x)^n = 1 + n x + \ldots\ldots$

* Limiting cases (e.g. make parameters go to 0 or infinity)

* Special cases (e.g. looking at circles)

* Powers of ten estimation

A distant galaxy is observed to have its H-beta line shifted to a wavelength of 480nm from its laboratory value of 434nm. Which is the best approximation to the velocity of the galaxy? (Note: 480/434 ~ 1.1)

a) 0.01c
b) 0.05c
c) 0.1c
d) 0.32c
e) 0.5c

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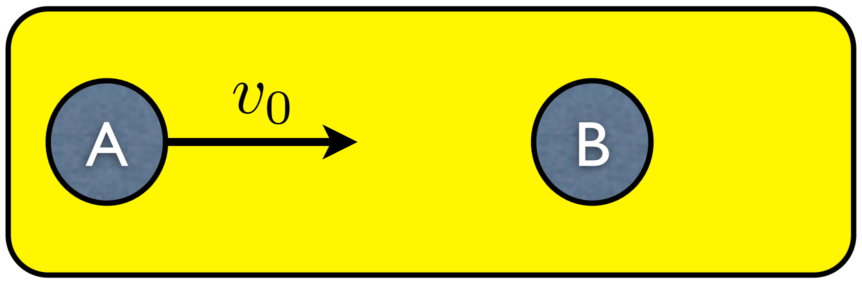
$$\lambda_{\rm obs} = \lambda_{\rm emit}\sqrt{\frac{c+v}{c-v}}$$

$$\frac{\lambda_{\rm obs}}{\lambda_{\rm emit}} = \sqrt{\frac{1+(v/c)}{1-(v/c)}} \approx \sqrt{(1+(v/c))^2}$$

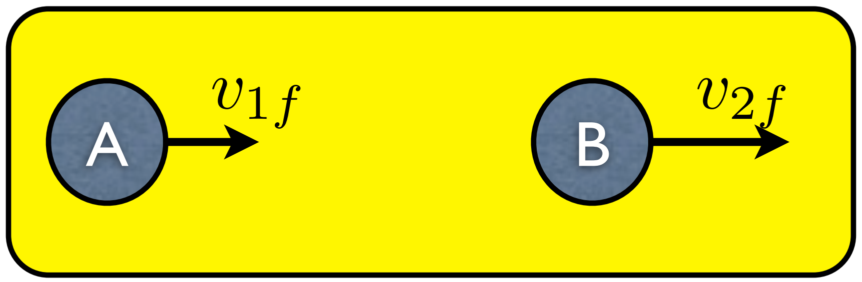
$$v \approx \left(\frac{\lambda_{\rm obs}}{\lambda_{\rm emit}}\right) c$$

Things to know (they always seem to come up)

1) Elastic collision formula



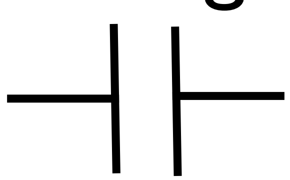
Before collision



After collision

$$
\begin{aligned}
v_{1f} &= \frac{m_1 - m_2}{m_1 + m_2} v_0 \\
v_{2f} &= \frac{2m_1}{m_1 + m_2} v_0
\end{aligned}
$$

2) The limiting behavior of capacitors and inductors in DC

 acts like (while uncharged)

 (while fully charged)

(e.g. high pass filter question)

3) Virial theorem (and the quick way to get it)

$$F(r) = Ar^{+n} \Rightarrow V = \frac{A}{1+n}r^{1+n} = \frac{F(r)}{1+n}r$$

$$\frac{mv^2}{r} = F(r) \Rightarrow \frac{1}{2}mv^2 = \frac{1}{2}F(r)r$$

$$\boxed{\langle KE \rangle = \frac{1+n}{2}\langle V \rangle}$$

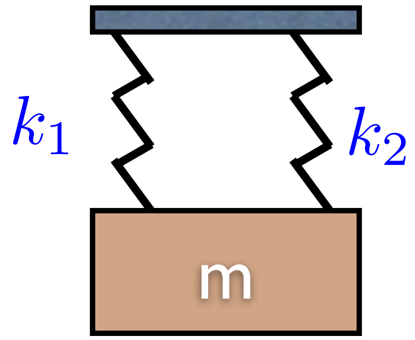
4) The Bohr formula (or know how to get it quickly)

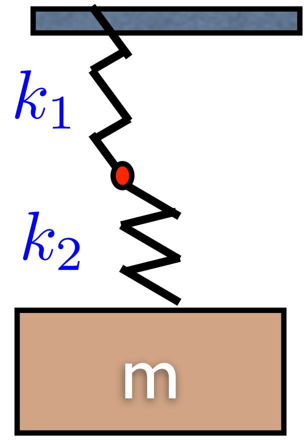
$$\boxed{E = -\frac{Z^2(ke^2)^2 m}{2\hbar^2 n^2}}$$

m is reduced mass!

(To get levels for e.g. positronium, same formula but use reduced mass for that system)

5) Combining masses, springs, capacitors, resistors





Can you find k_{equiv} ?

Frequency of oscillation?

Know reduced mass!

Which of the following is the closest to the **kinetic** energy of an electron in the ground state of Hydrogen using the Bohr model?

a) 6.8 eV
b) 13.6 eV
c) 27.2 eV
d) 0 eV
e) 40.8 eV

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Use the virial thm.

<KE> + <V> = E = -13.6eV

<KE> - 2<KE> = -13.6eV

<KE> = 13.6eV

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d) 0 eV
e) The kinetic energy of the ground state is not defined

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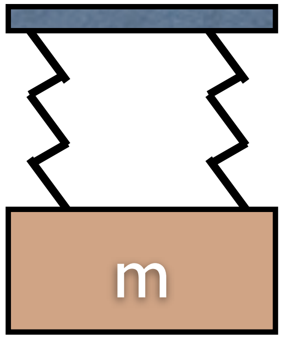
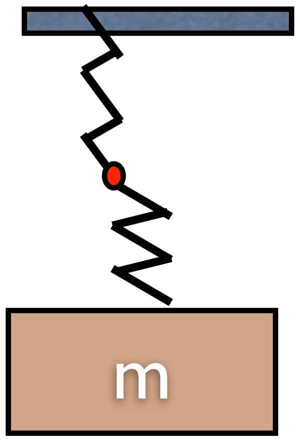
Even though E is well defined, radial position is not (see radial wavefunction). Therefore <V> is not well defined, so <KE> = E - <V> is not well defined either.

What distance from the center of the Earth does a geosynchronous satellite travel at?





Situation 1)

Situation 2)

Two different ways of connecting a mass *m* to two *identical springs* with spring constant k are shown above. If we denote the frequency of oscillation in situation 1 by f_1 and the frequency of oscillation in situation 2 by f_2 then f_1/ f_2 is:

a) 4
b) 2
c) 1/2
d) 1/4
e) depends on m and / or k

Situation 1) Situation 2)

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(Hint: can pretend k_1 and k_2 are not the same to take limits to determine formula for $k_{\rm eff}$)

$$\frac{f_1}{f_2} = \frac{\omega_1}{\omega_2} = \sqrt{\frac{k_{\rm eff,1}/m}{k_{\rm eff,2}/m}} = \sqrt{\frac{k_{\rm eff,1}}{k_{\rm eff,2}}} = \sqrt{\frac{2k}{k/2}} = 2$$

A particle sits in a periodic potential

$$V(x) = d\sin(kx)$$

What is its oscillation frequency about the minimum?

A particle sits in a periodic potential

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What is its oscillation frequency about the minimum?

Let y be the distance from the minimum. Expanding about the minimum we have:

$$V(y) = V_{\text{min}} + \boxed{0y} + \frac{1}{2}\boxed{\frac{d^2V}{dy^2}|_{\text{min}}}\, y^2 + \ldots$$

0 (because min)

Just a number, not a function

Force is

$$F = -\frac{dV}{dy} = -\frac{d^2V}{dy^2}|_{\text{min}} y + \ldots$$

SHM with "spring constant" $k = d^2V/dy^2$ evaluated at min!

spring constant $= -dk^2\sin(kx) = +dk^2$ evaluated at min

$$f = 2\pi\sqrt{\frac{\text{spring const.}}{m}} = 2\pi\sqrt{\frac{dk^2}{m}}$$

6) Making problems look like a harmonic oscillator

$$\omega^2 = \frac{(d^2V/dx^2)|_{\min}}{m}$$

7) Remember spectroscopic notation (ugh)

$$^{2s+1}(\text{orbital angular momentum symbol})_j$$

and the selection rules for an electric dipole

8) Know the *pattern* of spherical harmonics

Y_ℓ^m

$$Y_0^0(\theta,\varphi) = \frac{1}{2}\sqrt{\frac{1}{\pi}}$$

$(\ell = 0)$

$$Y_1^{-1}(\theta,\varphi) = \frac{1}{2}\sqrt{\frac{3}{2\pi}}\,\sin\theta\, e^{-i\varphi}$$

$$Y_1^{0}(\theta,\varphi) = \frac{1}{2}\sqrt{\frac{3}{\pi}}\,\cos\theta$$

$$Y_1^{1}(\theta,\varphi) = \frac{-1}{2}\sqrt{\frac{3}{2\pi}}\,\sin\theta\, e^{i\varphi}$$

$(\ell = 1)$

$$Y_2^{-2}(\theta,\varphi) = \frac{1}{4}\sqrt{\frac{15}{2\pi}}\,\sin^2\theta\, e^{-2i\varphi}$$

$$Y_2^{-1}(\theta,\varphi) = \frac{1}{2}\sqrt{\frac{15}{2\pi}}\,\sin\theta\,\cos\theta\, e^{-i\varphi}$$

$$Y_2^{0}(\theta,\varphi) = \frac{1}{4}\sqrt{\frac{5}{\pi}}\,(3\cos^2\theta - 1)$$

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$$Y_2^{2}(\theta,\varphi) = \frac{1}{4}\sqrt{\frac{15}{2\pi}}\,\sin^2\theta\, e^{2i\varphi}$$

$(\ell = 2)$

Too detailed ...... !

(But if you can remember these, congratulations)

8) Know the *pattern* of spherical harmonics

$$Y_\ell^m$$

m – magnetic quantum number $(-\ell, -\ell+1, \ldots, \ell)$

ℓ – orbital quantum number $(0, 1, 2, \ldots)$

Y_ℓ^m contains φ dependence of the form $e^{im\phi}$

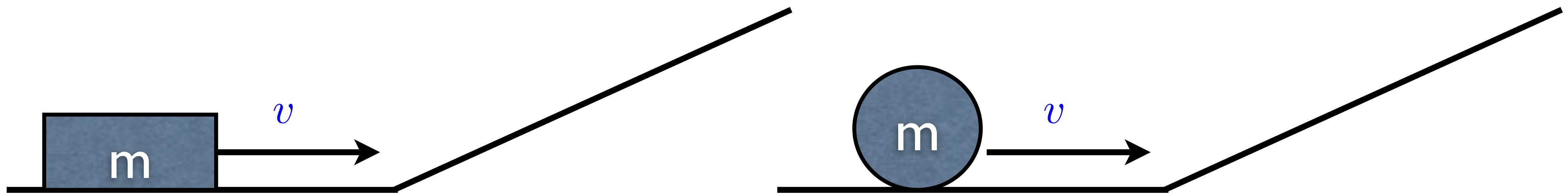
Y_ℓ^m contains ℓ dependence of the form $\sin^\ell\theta, \quad \sin^{\ell-1}\theta\cos\theta, \ldots$

(i.e. can write as ℓ sines or cosines mulitpled, or as $\sin(\ell\theta)$, $\cos(\ell\theta)$.)

Compare these rules to the spherical harmonics listed one slide ago.

Random mechanics problem:

A ball and a block of mass m are moving at the same speed *v*. When they hit the ramp they both travel up it. The block slides up with (approximately) no friction, the ball experiences just enough friction to roll without slipping. Which goes higher?



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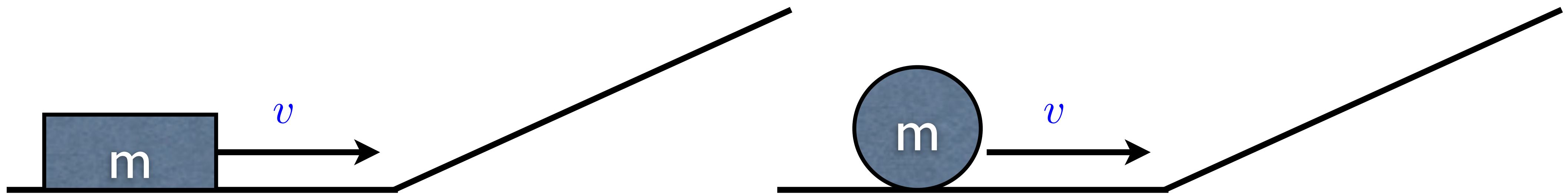

a) the ball goes higher
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The ball has both translational kinetic energy (equal to that of the block) *and* rotational kinetic energy. Therefore

$$KE_{ball,initial} > KE_{block,initial}$$

The ball converts all this energy into potential energy, and therefore goes higher.