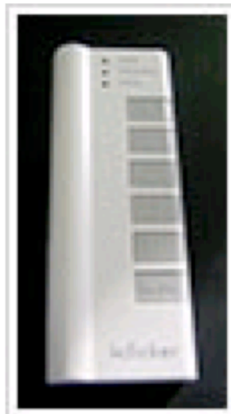
Welcome! to Phys 2210

1) Press & HOLD power ➔ blue *flash.*
2) Key in DA ➔ green *flash*

Do you have a clicker with you today?

A) Yes, I have a clicker with me.
B) No, I don't have a clicker so I can't vote.



Phys 2210 Sp 12 SJP

80% A, 17% B (!!?) (2% E), 40/75 students have clickers on day 1.

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HW due Thursday
Online hw/participation due Tues
(go to learn.colorado.edu)

Exams Feb 16, Mar 22 (7 PM) + final

2

Phys 2210 Sp 12 SJP

Midterms are scheduled for Feb 16 and Mar 22
We could do them in-class, or evening (7-9 PM)

Advantage of evening: More time, less stress!

Are you available those two evenings?

A) Yes
B) No

3

Phys 2210 Sp 12 SJP
(Discussed, didn't vote)

Font Check !

This is 32 point font.

This is 28 point font.

This is 24 point font.

This is 20 point font.

This is 16 point font.

This is 14 point font.

What's your math background
(not counting this term) ?

A) (mostly) APPM, *through* calc III
B) (mostly) MATH, *through* calc III
C) (mostly) APPM, *beyond* calc III
D) (mostly) MATH, *beyond* calc III
E) other!

(APPM 2360 or Math 4430 is co-req)

5

Phys 2210 Sp 12 SJP

70% were C and D.

What's your physics background?

A) CU Phys 1110&20, and 2170
B) Honors Phys 1&2, + 2170
C) Phys 1 and/or 2 elsewhere, +2170
D) I took 2130, not 2170
E) Other!

6

Phys 2210 Sp 12 SJP

50% AB& C evenly spread.

Summarize: what is classical mechanics?

7

Phys 2210 Sp 12 SJP

Class activity, first alone, then in groups.

In Classical Mechanics,
can this equation be derived?

$$\vec{F}_{net} = \frac{\mathrm{d}\vec{p}}{\mathrm{d}t}$$

A) Yes

B) No

C) I want to waffle on this

8

Phys 2210 Sp 12 SJP

Outcomes Sp11: 59 [41] - - -

SP 12: 55, [38]], 8

Good for discussion!. I claim "no", this is empirical/experimental fact. (But, there are subtle issues to discuss and debate.) Few students at this level will argue that it can be "derived" from Hamilton's principle, or the Lagrangian/principle of least action, they haven't learned that yet. Fewer still can argue that it comes from a classical limit of QM (Ehrenfest's theorem). Some students will argue that you can "derive" equations from experiment – this may be semantics, but I might want to argue that that's not really how science works. Experiments don't "derive" equations, Newton's law is in essence a well-tested hypothesis, consistent with many experiments in the classical regime.

In Sp 12, some students wondered if we could "derive" this from conservation of momentum/energy (somehow), and one vocally argued that it is true by *definition* (not from experiment), which led to a nice discussion about definition vs empirical observation, and operational definition of force…

Original author: M. Dubson

In Classical Mechanics,
can this equation be derived?

$$\vec{\tau}_{net} = \frac{\mathrm{d}\vec{L}}{\mathrm{d}t}$$

A) Yes

B) No

C) I want to waffle on this

9

Phys 2210 Sp 12 SJP

Outcomes Sp11: [74] 24 - -

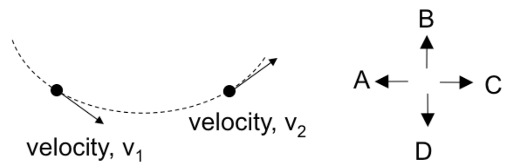
Sp12: [50], 33, 17

Here I claim yes, it's derivable from Newton's law and the *definitions* of torque (rXF) and L = rXp,

We again had some discussion about whether this was a definition of torque (it is not).

Original author: M. Dubson

An object has velocity $\mathbf{v_1}$ at an earlier time, and $\mathbf{v_2}$ later, as shown. What is the direction of $\Delta\mathbf{v} = \mathbf{v_2} - \mathbf{v_1}$?

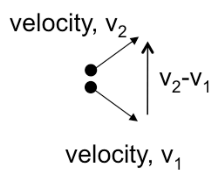


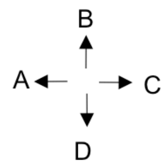
E) Other/???

10

Skipped for time. (Draw it! Up. See next slide)

An object has velocity $\mathbf{v_1}$ at an earlier time, and $\mathbf{v_2}$ later, as shown. What is the direction of $\Delta\mathbf{v} = \mathbf{v_2} - \mathbf{v_1}$?



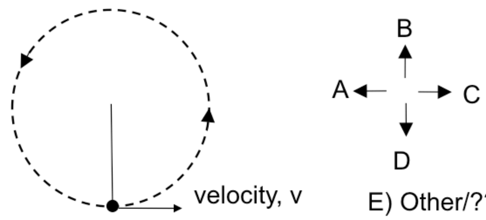


E) Other/???

11

Solution is B

A rock is twirled in a circle with constant speed by an astronaut in intergalactic space. At the moment shown, what is the direction of the acceleration of the rock?

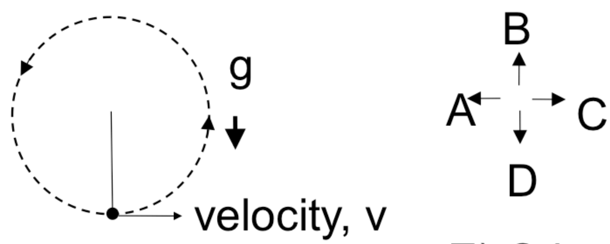


E) Other/???

12

Skipped, no time. (Centrpetal, up.)

A rock is twirled in a vertical circle near the surface of earth with constant speed.
At the moment shown, what is the direction of the acceleration of the rock?



E) Other/0/ ???

13

Phys 2210 Sp 12 SJP

Outcomes Sp11: 0 [94] 0 0 6

Sp12: 0 [89], 0 0 11

Comments:Easy for them, but it was good to discuss the difference between kinematics and dynamics. One student (Sp12) brought up that you might think it was zero if you imagined v^2/R “cancelled” with g. This led to a nice discussion that acceleration is kinematics, it’s got to be v^2/R up (period!)

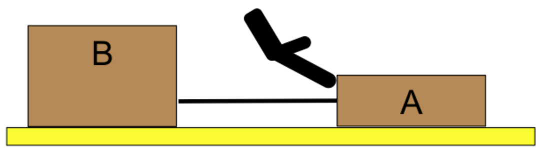
I also prefaced the question with the comment that it is not trivial to MAKE a rock twirl with “constant speed” (you need a rigid rod, I guess, not a string!)

Answer: Must be upwards if you are going in a circle with constant speed! (g is down, T is up, T is stronger, by the centripetal piece v^2/R)

They weren’t “tricked”, even though we didn’t do the previous one. I discussed the fact that acceleration is *kinematics*, (dynamics doesn’t have to be considered). Also pointed out that it’s not easy to DO this, by the way, moving in a vertical circle with constant speed...

Blocks A and B are on a frictionless table, connected by a massless string.
Your hand pushes on the back of block A.
Compare the force of your *hand* on A to the force of the *string* on B :

$|F|_{\text{hand on A}}$ is A)> B)< C) = $|F|_{\text{string on B}}$
D) Not enough info



14

Phys 2210 Sp 12 SJP

Outcomes Sp11: [62] 15 24 0 0
Sp12: [43] 11 23 23

Comments: Discussion centered first on “choice of system”, and drawing FBD. There was also some question about whether we are “given” that A will accelerate (so we talked that through – for the system as a whole, with no friction, the answer follows from N-2) When I asked how you know “force of string on A = force of string on B”, we had a good discussion too. One student said “that’s the definition of an ideal spring”, so we discussed what “definitions” tell us. Students tried to invoke N-III for this one, which is ok if you think of the string as “mediator”, but I brought up the idea that F(net) =ma for the string, which has m=0, and thus must have Fnet=0.

Answer is A, greater than. System accelerates, so F(hand on A) > F(tension). But, F(tension) = F(string on B) (The latter can be thought of as N-III, or more accurately, as N-II on the string. It’s the fact that tension is the same at both ends of string)

Based on a UW Tutorial question, modified by SJP

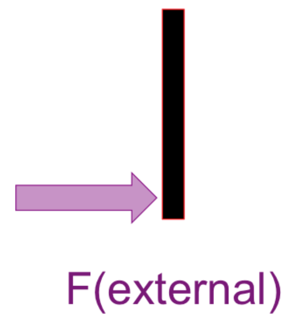
If you push horizontally on the *bottom* end of a long, rigid rod of mass m (floating in space), what does the rod do?

A) Rotates in place, but the CM doesn't move

B) Accelerates to the right, with $a_{CM}<F/m$

C) Accelerates to the right, with $a_{CM}=F/m$

D) Other/not sure/depends...



15

I didn't have time – I think this would be a very good question, and would help with the next one. A student spontenously "invented" this case when talking about the next (bike wheel) problem, and he argued effectively he thought it would be B (or even A?)

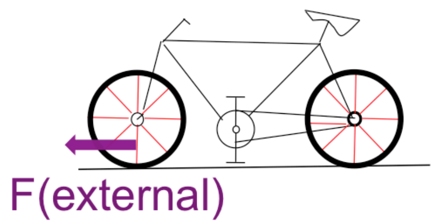
C. (Which part of Newton's law do the students not understand? This is glib – this problem generates lots of argument in Phys 1110 –some

students seem to think this force is "partly used up" to create rotation, or something... Some even think it will ALL go into rotation, and nothing into CM acceleration! This latter belief is easy to counter-demonstrate by flicking a pen sitting on the desk, by they way. It will spin, but also very clearly flies away from you)

Question inspired by Tutorial questions from UW group.

If you push forwards on a lower spoke as shown, the bike moves

A) Left B) right C) no motion D) ??



16

Phys 2210 Sp 12 SJP

Outcomes Sp11: [24] 62 15

Sp12: 20, 55 22 4

Nice! Physics is not a democracy. This one could have had a much longer followup discussion, but we ran out of time. (No time at all in Sp12!~)

Too bad. I brought in a bike (!) and did the demo, I think that's a great touch.

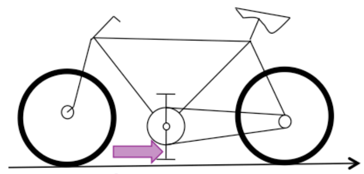
Some questions about "how hard are you pushing", "is friction negligible", etc. I had half a dozen students come up after class to discuss this further, and try it out themsleves.

I think one needs to be careful with this question, especially when used in lecture #1. It looks simple, but turns out to be quite difficult. Students will argue, and many will be convinced that your force "turns the wheel CW" (and thus, moves the bike backwards). This is wrong, see below.

I have seen students feeling uncomfortable about looking stupid or not being able to do freshman physics, and getting worred about their ability in this course right off the bat. So, it should be framed properly as a puzzler –(perhaps an argument for why clicker questions ARE useful even in advanced mechanics!) I have seen

If you push backwards on the *bottom* pedal of a fixed-gear bike as shown,
the bike moves

A) Left B) right C) no motion D) ??



17

Phys 2210 Sp 12 SJP Didn't get time to do this.

Answer is *very* surprising for many students (the bike goes backwards) Try it!

I put this question up for them to think about, but didn't vote, and most left without engaging with it. A couple students came up after class and debated it for a long time.

Last year, A couple students came up after class and debated it for a long time.

(After some reflection, the answer might be different if the gearing ratio was *extremely* low (so low that, as you pedal your bike, the bottom of the pedal is actually moving backwards with respect to the ground). In that case, I think the answer would be C, no motion. But, for any realistic bike, certainly a "fixed-gear" as stated, I stick with the answer – it moves backwards.)

S. Pollock

Which of these integrals can be solved using "integration by parts"?

i) $\int dx \frac{\ln x}{x^2}$ ii) $\int dx\ e^{x^2}$

iii) $\int dx\ x^2 e^{2x}$

A) none B) i & ii C) ii & iii
D) i & iii E) all of them

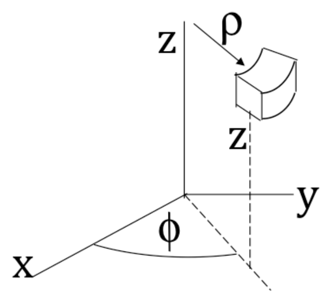
18

Looks to me like i works (u dv, with u = lnx) and iii does to (u dv, with u = x^2). The second one doesn't work.

I didn't use this in class.

In cylindrical coordinates, what is the correct volume element, dV = ?

A) $d\rho\, d\Phi\, dz$
B) $\rho\ d\rho\, d\Phi\, dz$
C) $\rho^2\ d\rho\, d\Phi\, dz$
D) $\sin\Phi\ d\rho\, d\Phi\, dz$
E) $\rho \sin\Phi\ d\rho\, d\Phi\, dz$



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Phys 2210 SP12 SJP
3, [[80]], 4, 3, 10 (preclass question)
Sp 11: 6, [[66]], 2, 2, 23

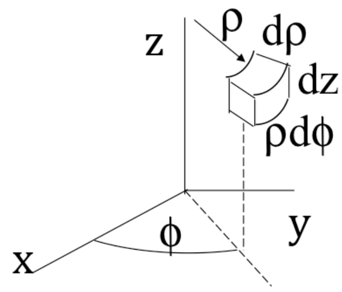
Ask it preclass, but then show next slide (which contains a hint) and ask again.

It’s B, because (see next slide) the inside/outside edge is r dphi.

S. Pollock

In cylindrical coordinates, what is the correct volume element, dV = ?

A) dρ dΦ dz
B) ρ dρ dΦ dz
C) ρ^2 dρ dΦ dz
D) sinΦ dρ dΦ dz
E) ρ sinΦ dρ dΦ dz



20

Phys 2210 SP12 SJP

Asked it again after drawing picture:

0, [[91]], 3, 0, 6

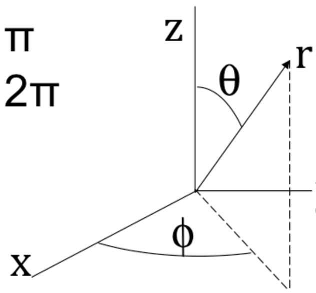
Sp ‘11: 0, [[96]], 2, 0, 2

The picture of course gives it away. Talked about UNITS, and also tried to motivate the one interesting side in this figure, rho dphi. The point is that one need not memorize such formulas, but “think them through” when you need them.

S. Pollock

In spherical coordinates, to integrate over a sphere (radius R, centered at origin) what are the correct limits of integration?
(note the physics convention for θ and ϕ)

A) r: 0 to R, θ: 0 to π, φ: 0 to 2π
B) r: 0 to R, θ: 0 to 2π, φ: 0 to 2π
C) r:-R to R, θ: 0 to 2π, φ: 0 to π
D) r: -R to R, θ: 0 to 2π, φ: 0 to 2π
E) None of these!



21

Phys 2210 SP12 SJP. Lecture #2.
[[97]], 3, 0,0,0
Sp ‘11: [[82]], 9, 4, 2, 2

Helpful to discuss fact that math classes reverse theta and phi! Doesn’t require too much time, just ask the class to explain why theta only needs to go 0 to pi, not 2pi.

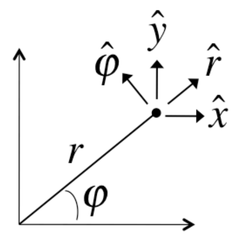
Original authors: M. Dubson and M. Betterton

A ball is moving around in a plane.

Which of the following unit vectors might vary with time?

I: $\hat{x}$ II: $\hat{\varphi}$ III: $\hat{r}$

A) All
B) none
C) II only
D) III only
E) II and III



22

Phys 2210 SP12 SJP Lecture #2

animated this slide so you can introduce rhat and phi-hat “rhetorically”. (Answer is E)

7,4,0,3,[[86]]

Sp ‘11: 5, 2, 0, 5, [[89]]

I had explained this pretty well before the clicker question (with a little “prop” of a coordinate axis system), so they were well primed. Rhat and phihat are NEW ideas for students, math doesn’t typically use them, and the idea that the unit vector depends implicitly on what point in space your considering is very confusing and challenging for students. (It IS strange, “rhat” is really meaningless by itself, until you know where the point is that you’re dealing with)

Comments from last year: No problems, but it took them a little longer than I expected to get to it, so I do think it was worthwhile. They are still trying to figure out just what “rhat” and “phihat” mean....

(Answer is E)

Original idea: from M. Dubson and M. Betterton

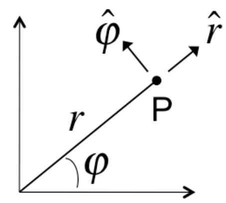
Which gives the position vector "**r**" of the point P at (x,y)=(1,1)?

A) $\vec{\mathbf{r}} = \sqrt{2}\,\hat{r}$

B) $\vec{\mathbf{r}} = \sqrt{2}\,\hat{r} + \frac{\pi}{4}\hat{\phi}$

C) $\vec{\mathbf{r}} = \sqrt{2}\,\hat{r} - \frac{\pi}{4}\hat{\phi}$

D) $\vec{\mathbf{r}} = \frac{\pi}{4}\hat{\phi}$ E) Other



23

Phys 2210 SP12 SJP, Lecture #2.

BEFORE this question, I had written rhat = **r** / |r| to define rhat. And I had talked about "position vector" in cartesian.

First vote, silent: [[16]], 77, 3,3,1 So it's 84% wrong.

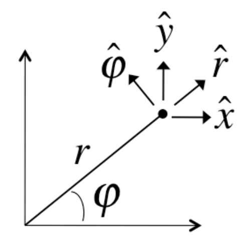
Do it again, letting them talk, pointing out only that most of them are wrong, and suggesting they think about looking at the PICTURE, thinking of the real r vector (which way does it point?) and the two unit vectors (which way do THEY point).

Second vote: [[59]], 32, 0, 1, 7

In Sp 11: [[20]], 73, 0, 2, 5 in silent vote, then [[65]], 25, 0, 2, 8 afterwards

A, it's just an instance of vector r = r rhat. (Units of B don't make sense, but it's very popular. Students seem to think that it's analogous to (1,1) = 1xhat + 1 yhat.) This is quite puzzling to students. Note that if we had picked any other point on that same circle, the answer would be the same. Isn't that odd? The formula in polar coordinates for DIFFERENT points looks the same. I think this is a good discussion to get out in the air, especially if one is just about to start taking derivatives of **r** = r rhat in order to get velocity, and then acceleration, in polar coordinates.

$$\hat{\mathbf{r}} = ??\,\hat{\mathbf{x}} + ??\,\hat{\mathbf{y}}$$



24

Phys 2210 SP12 SJP, Lecture #2

Let them wrestle with this, call it out. We had “r”’s in there (point out it’s rhat, not r), and then sin/cos mixup. Good for them to puzzle it out first. See next slide.

$$\hat{\mathbf{r}} = \cos\phi\,\hat{\mathbf{x}} + \sin\phi\,\hat{\mathbf{y}}$$

What is $\hat{\phi}$?

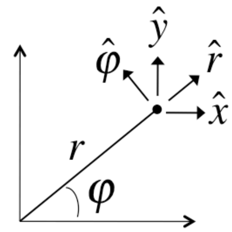
A) $\hat{\phi} = -\cos\phi\,\hat{\mathbf{x}} + \sin\phi\,\hat{\mathbf{y}}$

B) $\hat{\phi} = \sin\phi\,\hat{\mathbf{x}} + \cos\phi\,\hat{\mathbf{y}}$

C) $\hat{\phi} = -\sin\phi\,\hat{\mathbf{x}} + \cos\phi\,\hat{\mathbf{y}}$

D) $\hat{\phi} = -\sin\phi\,\hat{\mathbf{x}} - \cos\phi\,\hat{\mathbf{y}}$

E) Other!



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Phys 2210 SP12 SJP Lecture #2

Before giving this, (the slide is animated), I worked out the rhat formula on the board. (Rhetorical question, I drew the angle between rhat and xhat and had them tell me it was also phi)

Results: 28, 7, [[63]], 1, 0

From Sp ‘11: 27, 5, [[68]], 0, 0

Pretty much just the cos/sin issue to wrestle with. I drew the angle phi between phihat and yhat to help them (let them call out if that was phi, or 90-phi. It’s phi) Then, also worthwhile talking through the “check by limiting case” story.

Comments from Sp 11:

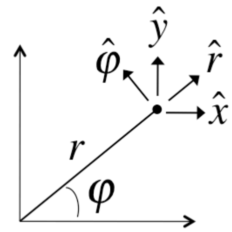
Signs seemed to be guiding them.

We did talk about “orthogonality” as check

S. Pollock

$$\hat{\mathbf{r}} = \cos\phi\,\hat{\mathbf{x}} + \sin\phi\,\hat{\mathbf{y}}$$

What is $\hat{\phi}$?



C) $\hat{\phi} = -\sin\phi\,\hat{\mathbf{x}} + \cos\phi\,\hat{\mathbf{y}}$

26

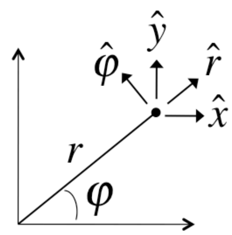
Just to emphasize

Suppose our point is moving around, so Φ depends on time!

Then:

$$\hat{\mathbf{r}}(t) = \cos[\phi(t)]\,\hat{\mathbf{x}} + \sin[\phi(t)]\;\hat{\mathbf{y}}$$

$$\hat{\phi}(t) = -\sin[\phi(t)]\hat{\mathbf{x}} + \cos[\phi(t)]\hat{\mathbf{y}}$$



27

Here I introduce a new notation.

I left this up during the activity from OSU (see 1Velocity_accel_polar)OSU_handout), having THEM construct drhat/dt, and dphihat/dt, and thus constructing v, and then a, on a worksheet together.

The idea that taking derivatives of rhat involves (chain rule!) derivatives of phi(t) was slipping by a lot of students.

How was the tempo of our last class?

A) Way too fast, I got lost (repeatedly)!
B) Bit fast, but I (mostly) hung in
C) Just about right for me
D) A little slow, I think I could handle a bit more
E) Way too slow, pick it up!

28

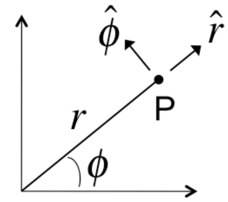
Phys 2210 Sp'12 SJP Lecture #3

7, 35, 45, 13, 0

Sp '11 the distribution was 4, 41, 50, 2, 2. I also covered two more concept tests in Sp '11 compared to Sp 12'.

It's a little on the "slow" side, but just barely (13%). I think this is about what I'd like.

Summary of last class: Kinematics
Plane polar coordinates



$$\hat{r} = \cos\phi\ \hat{x} + \sin\phi\ \hat{y}$$

$$\hat{\phi} = -\sin\phi\ \hat{x} + \cos\phi\ \hat{y}$$

$$\vec{r} = r\ \hat{r}$$

$$\vec{v} = d\vec{r}/dt$$

$$\vec{v} = (\dot{r})\hat{r} \quad + \quad (r\ \dot{\phi})\hat{\phi}$$

Then, take one more derivative.
We didn't do this in class – do it for yourself!

$$\vec{a} = (\ddot{r} - r\dot{\phi}^2)\hat{r} \quad + \quad (r\ddot{\phi} + 2\dot{r}\dot{\phi})\hat{\phi}$$

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Phys 2210 Sp'12 SJP Lecture #3
(Animated ppt, part of lecture, not a clicker question)

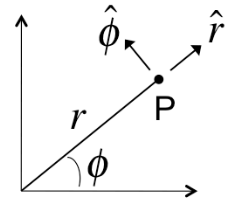
Did this in parallel with a development on the board, where I was doing this in Cartesian and polar "side by side".

This is mostly review, I let them call things out as I wrote them up (or animated the line)

I did in fact do the full algebra (fast!) to get acceleration on the board.

Comments from Sp 11: I told them the story of my waking up at 6 AM because I had gotten the sign wrong on the last term in an earlier version of this slide: talked them through my physical explanation of why it must be plus (walk outward on a merry go-round that is roating in +phi direction. You are speeding up sideways as you move out, so some force must be applying a force on you in that direction to speed you up!)

Summary of last class: Kinematics
Plane polar coordinates



$$\vec{a} = (\ddot{r} - r\dot{\phi}^2)\hat{r} \quad + \quad (r\ddot{\phi} + 2\dot{r}\dot{\phi})\hat{\phi}$$

30

Phys 2210 Sp'12 SJP Lecture #3

Just to summarize last slide.

Newton's law, in polar coordinates!

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

$$= F_r\hat{r} \; + \; F_\varphi\hat{\varphi}$$

$$F_r = m\ddot{r} - mr\dot{\varphi}^2$$

$$F_\varphi = mr\ddot{\varphi} + 2m\dot{r}\dot{\varphi}$$

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Phys 2210 Sp'12 SJP Lecture #3

This is just to emphasize that any vector must have a well-defined r and phi component, just tilt your head)

I'm recapitulating the last slide – and also discuss that this is our equation of motion. It's not "definition" of force, force is physical, these equations then show how r and phi respond/depend on time.

Also point out that each term here can be interpreted (we'll cycle back to this for next few slides)

In Phys 1110, centripetal acceleration was usually written $a = v^2/R$, or else (in terms of angular speed $\omega=v/R$), $a=\omega^2R$.

Which term is the "centripetal force"?

$$F_r = \overset{A}{m\ddot{r}} - \overset{B}{mr\dot{\varphi}^2}$$

$$F_\varphi = \overset{C}{mr\ddot{\varphi}} + \overset{D}{2m\dot{r}\dot{\varphi}}$$

E) None, or *more* than 1 of these!

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3, [[85]], 4, 3, 4

Sp 12: 0, [[95]], 2, 0, 2 (this was at the end of lecture #2)

Answer is B. Review of Phys 1?

Think about signs, some students wanted to discuss what "A" means (several during the discussion were trying to argue that both A and B point in the r direction, and thus are centripetal! So, they voted E)

Comments from Sp '11: They mostly all got it, but it took minutes, and the discussion was good. They were remembering/reminding each other of v^2/R, and what omega was, etc.

S. Pollock

In Phys 1110, angular acceleration was $\alpha = a_{tangent}/R$. Which term involves "α"?

$$F_r = \overset{A}{m\ddot{r}} - \overset{B}{mr\dot{\varphi}^2}$$

$$F_\varphi = \overset{C}{mr\ddot{\varphi}} + \overset{D}{2m\dot{r}\dot{\varphi}}$$

E) None, or *more* than 1 of these!

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1,1,[[90]], 1, 6

C. Is correct. Some students liked both C and D (or just D), like the previous one, they thought that any "phi" component must refer to alpha. I wanted students to generate the idea that alpha = phi(double dot) on their own, but that was hard. We did it at the board.

At the end of this, one student wanted me to go back and discuss the physical intrrerpretation of all 4 terms. That was a good thing to do! Got lots of good voices from the class about what each term "means', and I made the point that although we're seeing Physics 1 material showing up again, this new formalism is better. For instance, term D has shown up, it's new, we never saw it in Physics 1! I asked them to "name" it (someone said Coriolis – I think that's ok in this 2-D polar world) (I pointed out that if you are walking outwards on a merry go round, there must be some SIDEWAYS force to allow that - that's basically term D….)

The position of a moving particle is given by

$$\mathbf{r}(t) = b\cos\omega t\ \hat{\mathbf{x}} + b\sin\omega t\ \hat{\mathbf{y}}$$

Describe this orbit:

A) circular, uniform motion
B) circular, non-uniform motion
C) helical
D) elliptical
E) Other!!

Bonus q: Is it moving CW or CCW?

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[[93]], 6, 1, 0,0

Sp 11: [[98]], 2, 0,0,0

Trying to help them visualize orbits, move back and forth from polar to rectangular coords.

Circular, uniform motion. But, when I asked them how they know, they started off by talking about x and y components, "tracing" out a circle. This was not a problem. But then we noted that |r| is a constant (that makes It circular), and we can compute v, find |v|, and find it's constant, omega b. That's kind of nice, a little different than the hand waving arguments they were making that it just "looks smooth".

Bonus – it's counterclockwise.

Comments from '11:

No problem for them. Didn't take long. However, they were not thinking of it entirely like I was, I took |r| and found b,

and calculated dr/dt to get v, then |v| = b omega. That seemed nice, and helpful for

The position of a moving particle is given by

$$\mathbf{r}(t) = b\cos\omega t\hat{\mathbf{x}} + c\sin\omega t\hat{\mathbf{y}}$$

Describe this orbit:

A) circular, uniform motion
B) circular, non-uniform motion
C) helical
D) elliptical
E) Other!!

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0, 3, 0, [[97]], 0

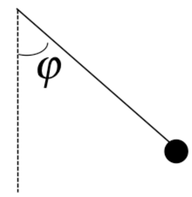
Sp '11: 2,0,2,[[96]], 0

Elliptical. Bonus – it's counterclockwise. (And, |v| is not independent of time, so I it's not uniform either! Even though there's still that same simple constant omega in the formula, that doesn't mean the SPEED is uniform) This was quick, they did fine, but the conversation was loud, it seemed worth while.

Last year the "uniform" question generated some debate.

S. Pollock

Pendulum: What are the physical forces



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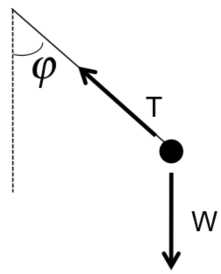
Let them realize that the "F" side of F=ma is not kinematics, or formulas, or "centripetal"… it's real physical identifiable pushes and pulls.

$$F_r = m\ddot{r} - mr\dot{\varphi}^2$$

$$F_\varphi = mr\ddot{\varphi} + 2m\dot{r}\dot{\varphi}$$

What is T_φ?



A) T
B) Tcosφ
C) Tsinφ
D) 0
E) Something else (signs!)

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Before showing next slide: it was about 65% correct

After showing next slide:0, 7, 12,[[75]], 6

Sp ‘11: 2, 14, 8, [[69]], 6 (after showing the next slide)

D. If they don’t mostly get this, you can then show the next slide. This is apparently subtle for them. One student had shouted out the answer before I showed the options, but it didn’t matter, there was still a healthy discussion. Some students didn’t really understand my notation, the subscript indicating the component (despite having had it on several previous slides)

There was some debate about whether the string was rigid or not, whether it matters if it goes to large angles, etc.

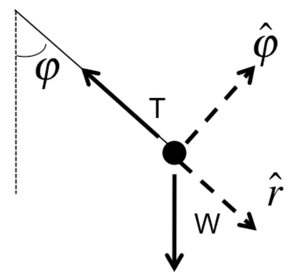
Comments from Sp’11: Good discussion, they are still confused about what is the difference between phi and phihat, and what “T_phi” means (is it a vector? A number? Is it signed?) It was definitely a helpful concept test.

Note that the context here is solving the “pendulum” problem, or Taylor Ex 1.2

$$F_r = m\ddot{r} - mr\dot{\varphi}^2$$

What is T_φ?

$$F_\varphi = mr\ddot{\varphi} + 2m\dot{r}\dot{\varphi}$$



A) T
B) Tcosφ
C) Tsinφ
D) 0
E) Something else (signs!)

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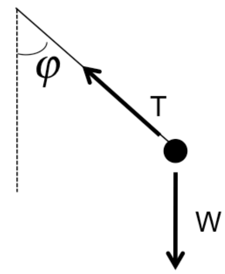
(Animated the coordinate system for them, might make it easier) Still, it wasn’t 100%. There was some discussion about whether phi-hat flips sign on the other side of the axis (it does not). There was some discussion of whether this is a “snapshot” in time. There was some issue at first with the notation (e.g, does T_phi mean a partial derivative with respect to phi)

$$F_r = m\ddot{r} - mr\dot{\varphi}^2$$

$$F_\varphi = mr\ddot{\varphi} + 2m\dot{r}\dot{\varphi}$$

What is W_φ?



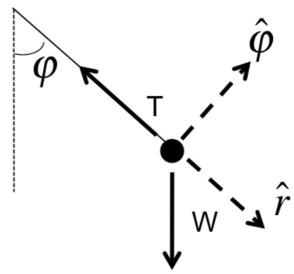
A) mg
B) mg cosφ
C) mg sinφ
D) 0
E) Something else (signs!)

(I decide to just keep the coordinates – see next slide)

$$F_r = m\ddot{r} - mr\dot{\varphi}^2$$

$$F_\varphi = mr\ddot{\varphi} + 2m\dot{r}\dot{\varphi}$$

What is W_φ?



A) mg
B) mg cosφ
C) mg sinφ
D) 0
E) Something else (signs!)

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3, 19, 42, 0, [[36]]

Sp '11: 0, 12, 44, 2, [[42]]

Good straightforward followup to last one. The problems are no longer "conceptual", it seems, but more practical (mixing up sin/cos, getting signs). I'm not sure why 2 people voted A, but at least nobody wanted D!

Answer is E. Many like C, but there's a minus sign. (Some groans about this, but it matters!)

I drew the picture, had them convince me that the angle between W and rhat was also phi (to keep cos and sin straight). Think about limit of phi=0 if you're not sure!

One student was confused about what "W" meant (weight, it's the force of gravity on the mass)

Comments from Sp'11:

They are still struggling with the various ideas from the previous CT, so it was good that we did this one. Took the opportunity to discuss fact that you can "check" that the angle between W and rhat is phi (not 90-phi) by considering the limit phi=0.

For a pendulum, we found

$$mR\ddot{\varphi} = -(mg)\sin\varphi$$

For small angle oscillations, which is the best statement about the period, T?

A) Larger mass means smaller T
B) Longer pendulum means longer T
C) Smaller starting angle means smaller T
D) On Jupiter, the period would be larger
E) None of these, or *more than one*, is correct

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Didn't discuss this. (Though, I did talk through the small angle ODE here, and its solution)

B: A is false, B is correct, C is false (in limit of small angles/SHM, at least), D is opposite,

Original idea: from M. Dubson and M. Betterton