Physics 113 – September 27, 2012

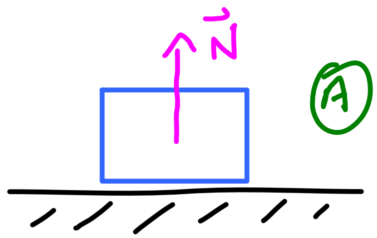
- Exam I in 1 week – material coverage thru middle of Sept 25 lecture

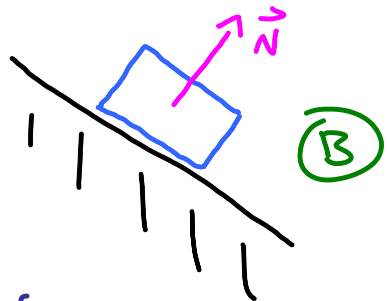
Word of Warning: I cut off material (for Exam) so you have time to do wkshop + PS on material

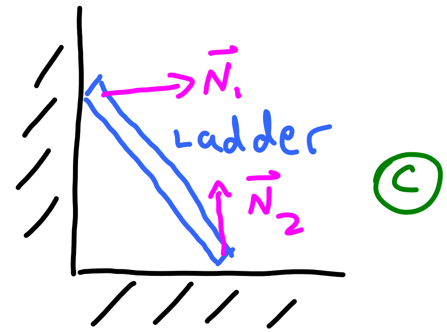
→ Fight your temptation to disconnect from class totally while prepping for exam ... will bite you later

Force between two surfaces in contact → Normal force

"Normal" → $\perp$ to plane of contact



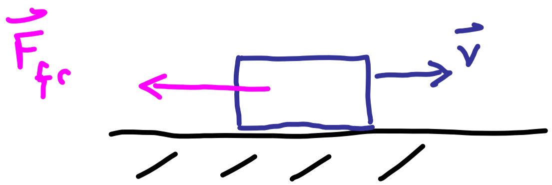




Examples of Normal Forces

Generally you'll have to infer existence of Normal forces ... i.e., will not be called out explicitly in text of problem.

Contact between 2 surfaces
↳ Normal force
↳ Friction force (unless told otherwise)



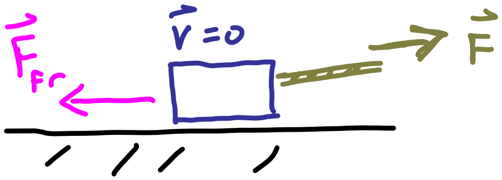
(A)

Kinetic friction (sliding surfaces) opposes motion

$$F_{Fr} = \mu_k N$$ (B)

↑ coefficient of kinetic friction

(A)



Static Friction (No Motion)

$\vec{F}_{Fr}$ opposes other forces

sufficient to cancel (No Motion)

can only be so big ... anybigger → Motion

(4)

If friction present - Must include it in Newton's Law probs

(B) $F_{Fr} \leq \mu_s N$

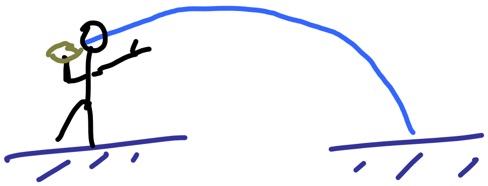
↑ Coefficient of Static Friction

limiting condition $F_{Fr} = \mu_s N$

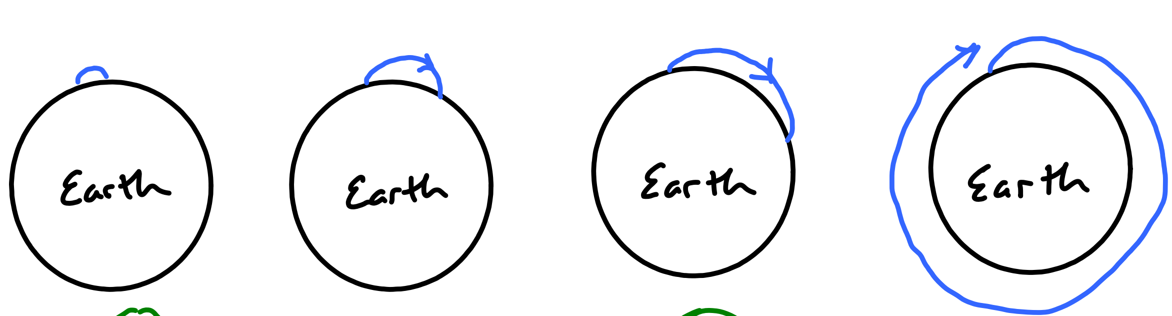
→ Flagged with wording in the problem

"What is the smallest μ_s that does so + so"

"At what inclined plane angle will box begin to slip ..."



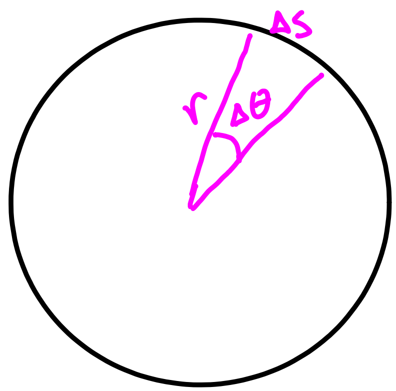
(A)



(B) (C) (D) (E) Orbit

Circular motion

Recall

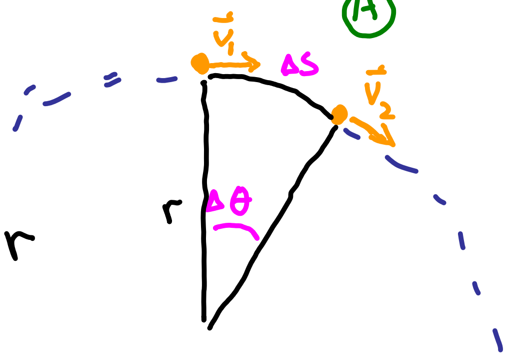


(F)

radians

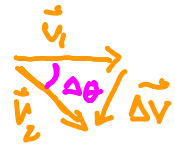
$\Delta s = r\,\Delta\theta$

Object moving on Circle of radius r

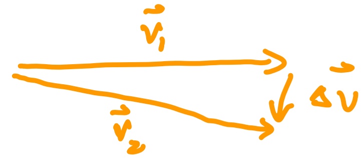


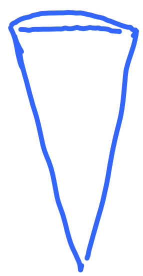
A

$|\vec{v}_1| = |\vec{v}_2| = v$

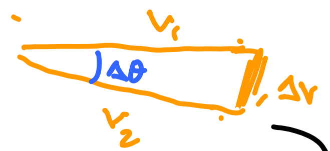


B





C



$S = r\theta$

$\Delta S = r\Delta\theta$

D

$\Delta v = v\,\Delta\theta$

E

$$\frac{\Delta v}{\Delta t} = v\,\frac{\Delta\theta}{\Delta t}$$

$\Delta S = r\Delta\theta \rightsquigarrow \Delta\theta = \frac{\Delta S}{r}$

$$\frac{\Delta v}{\Delta t} = \frac{v\,\frac{\Delta S}{r}}{\Delta t} = \frac{v}{r}\,\frac{\Delta S}{\Delta t}$$

F

in limit of small Δt

(A)

$$\frac{\Delta v}{\Delta t} = \frac{v}{r}\frac{\Delta s}{\Delta t} \longrightarrow \frac{dv}{dt} = \frac{v}{r}\frac{ds}{dt}$$

$\frac{dv}{dt}$: Acceleration ... on circle → centripetal Acceleration $\equiv \vec{a}_c$

$\frac{ds}{dt}$: linear velocity along circle → Tangential Velocity

speed going around outside of circle

(D)

$$\vec{F}_c = \frac{mv^2}{r}$$

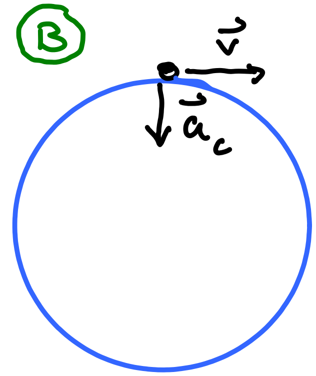
(C)

$$|\vec{a}_c| = \frac{\cancel{m}|\vec{v}|^2}{r}$$

True if on circle

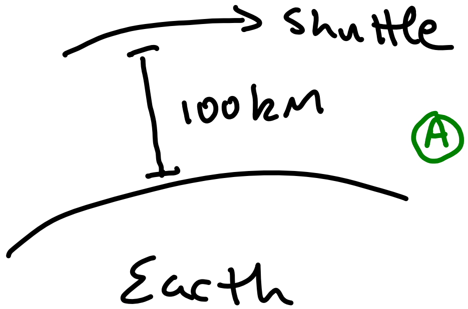
If on circle than this is True

(B)



Example Z

What is speed of space shuttle when in orbit at ht of 100 km



(A)

assume $g = 9.8\ m/s^2$ at shuttle ht.

Assume Circular orbit

$a = \frac{v^2}{r}$ (B)

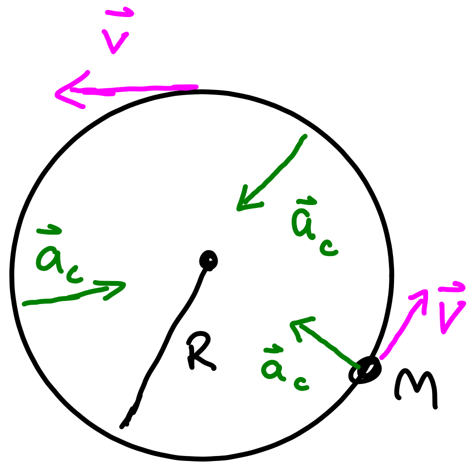
(C) $9.8\ m/s^2 = \frac{v^2}{R_e + 100{,}000m}$

$R_e = 6.37 \times 10^6\ m$

$v = 7962\ m/s$

$= 17{,}812\ mi/hr$

Summary of circular motion



Circular Motion

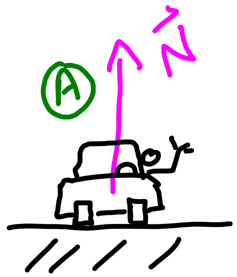
$$\Leftrightarrow \quad |\vec{a}_c| = \frac{|\vec{V}|^2}{R}$$

$F = Ma$

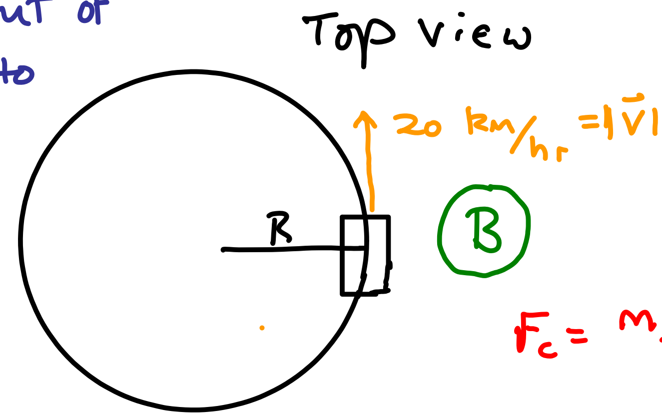
centripetal force

$$F_c = m a_c = m\frac{v^2}{r}$$

Example

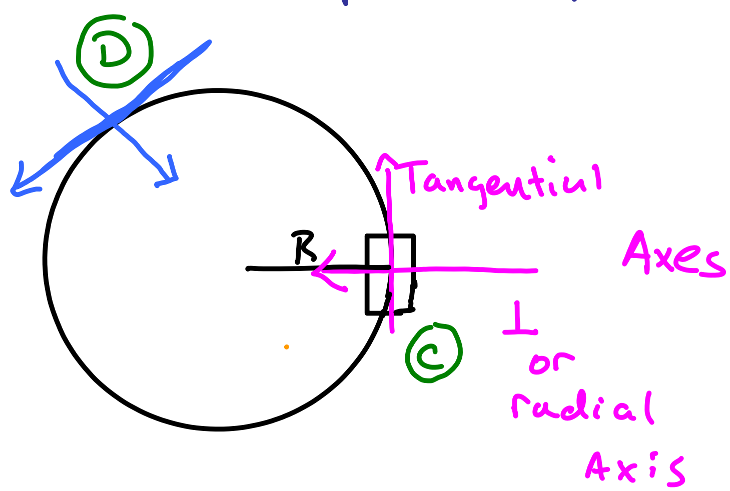


Car driven at 20 km/hour in a circle of radius R = 50 m.
What is minimum coefficient of static friction required to keep car on road (keep on circle).



$$F_c = \frac{mv^2}{R}$$

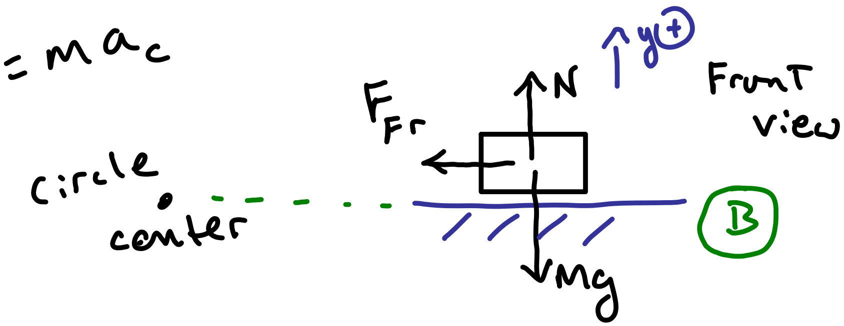
Axes Rotate with car



If road is "banked" problem is different. Not banked unless stated otherwise.

(A) $20\ \frac{km}{hr} \times \frac{1000\ m}{1\ km} \times \frac{1\ hour}{60\ min} \times \frac{1\ min}{60\ seconds} = 5.5\ m/s$ (11)

$F_c = m a_c$



up-down direction

(C) $\Sigma F_y = 0 = m a_y = N - mg$

$N = mg$

$F_{Fr} = \mu_s N$

Force of Friction

along ⊥ direction (radial direction)

(D) $\Sigma F_{\perp} = m\frac{v^2}{R} = \mu_s N = \mu_s m g$

(E) $$\mu_s = \frac{v^2}{Rg}$$

units ok!

large v → larger μ_s needed

large R → smaller μ_s needed

Work + Energy

What is work?

Make Money?

Biological work versus work in physics

Work ≡ ~ (Force)(Distance)

What is Energy?

Energy ≡ Ability to do work

Can take different forms:

Kinetic (energy of Motion)

heat

light

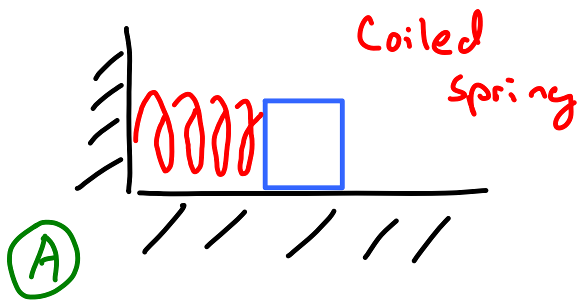
Sound

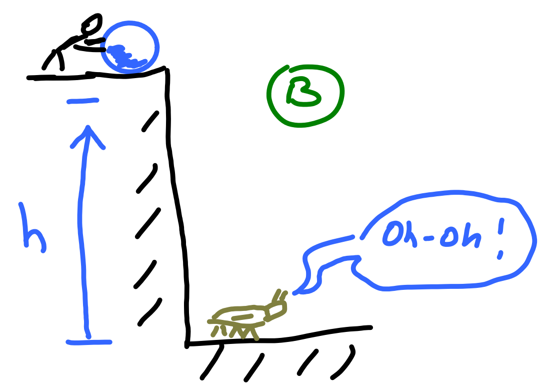
Mechanical

Mass ($E=mc^2$)

Potential Energy - Stored

Potential to do work





Energy = Work

Units → Joules
(MKS)

1 Joule = 1 Newton · meter

$1\ Nm = 1\ kg\ m/s^2\ m = 1\ kg\ \frac{m^2}{s^2}$

recall $F = ma$

In physics

Work = (Force) (Distance moved along direction of that Force)
(A)

- or -

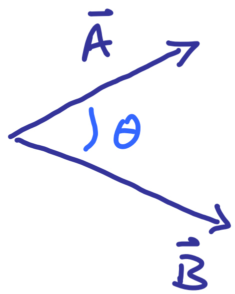
Work = (Magnitude of force component along Direction of Movement) (Distance Moved)
(B)

Work = (Force) (Displacement)
Scalar Vector Vector

Need to use a form of Vector Multiplication that projects out Component of one vector along the other

"Dot product" -or- "Scalar product"

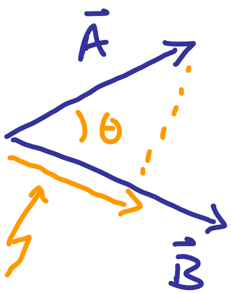
(A)



(D) $\vec{A}\cdot\vec{B} \equiv$ "A dot B" $= |\vec{A}||\vec{B}|\cos\theta$

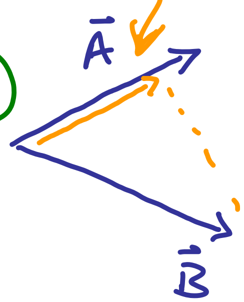
Scalar = Not a vector, just a #

(B)



component of $\vec{A}$ along $\vec{B} = |\vec{A}|\cos\theta$

(C)



component of $\vec{B}$ along $\vec{A} = |\vec{B}|\cos\theta$

$$\vec{A}\cdot\vec{B} = \vec{B}\cdot\vec{A}$$ (E)

(A) Prove $\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$

(B) $\vec{A}\cdot\vec{B} = (A_x\hat{i} + A_y\hat{j} + A_z\hat{k})\cdot(B_x\hat{i} + B_y\hat{j} + B_z\hat{k})$

(C)
$$= A_xB_x\,\hat{i}\cdot\hat{i} + A_xB_y\,\hat{i}\cdot\hat{j} + A_xB_z\,\hat{i}\cdot\hat{k}$$
$$+ A_yB_x\,\hat{j}\cdot\hat{i} + A_yB_y\,\hat{j}\cdot\hat{j} + A_yB_z\,\hat{j}\cdot\hat{k}$$
$$+ A_zB_x\,\hat{k}\cdot\hat{i} + A_zB_y\,\hat{k}\cdot\hat{j} + A_zB_z\,\hat{k}\cdot\hat{k}$$

(D) Terms → 0 because unit vectors ⊥ to each other → dot product = 0

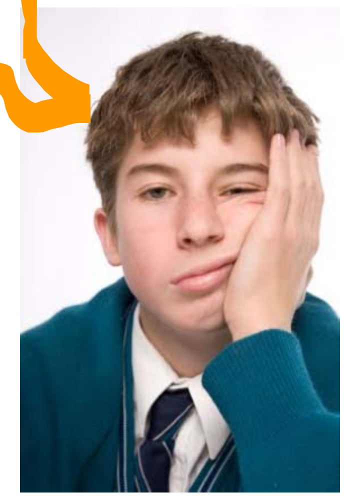
(E) = 1 $\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = 1$

(F) ∴ $\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$ useful formula

(G) True in addition to $\vec{A}\cdot\vec{B} = |\vec{A}||\vec{B}|\cos\theta$

No ... I will not ask you to do vector proofs like this on an exam

You know – That's fine and nice but why do I care about all this dot crap??

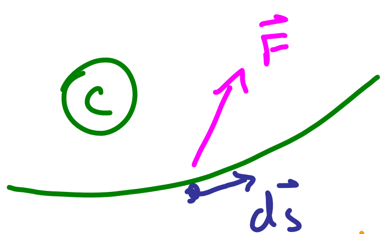


Because

Work is (Force)×(Displacement)
where we multiply the projection of one vector along the other with the magnitude of the other.

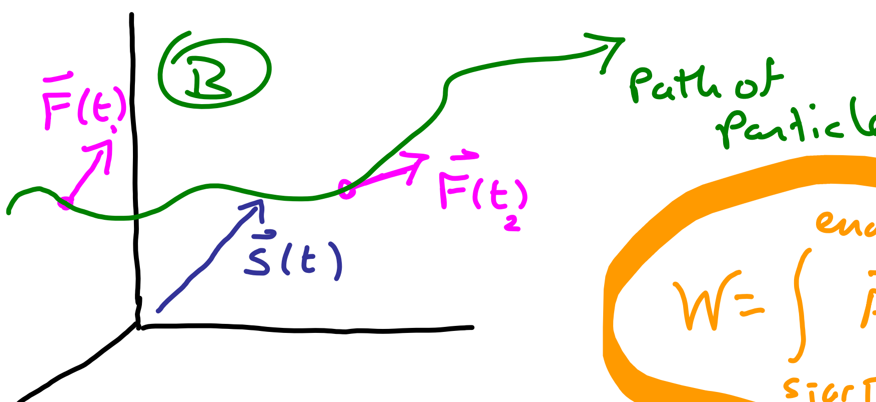
(A) $\text{Work} = \vec{F} \cdot \vec{D}$

(C)



$dw = \vec{F} \cdot d\vec{s}$

(B)



(D)

$$W = \int_{\text{start}}^{\text{end}} \vec{F} \cdot d\vec{s}$$