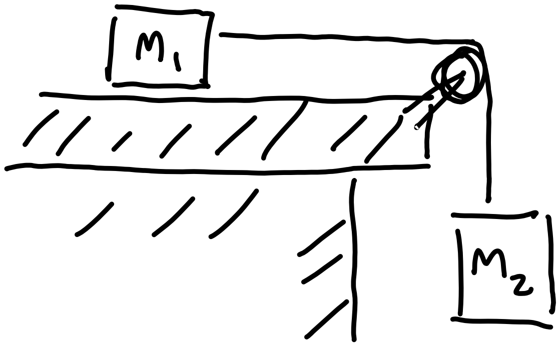
Physics 113 - October 1, 2013

Slides meant to go with accompanying Audio file

Hope the EXAM went well!

See you next week -

Example

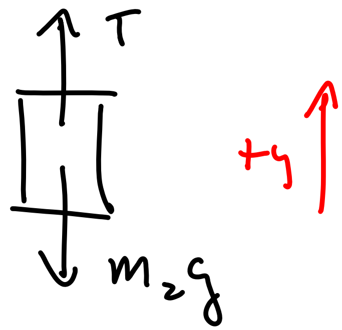


Suppose System is
at rest
in equilibrium
(No Accel, No Motion)

Let $M_2 = 20kg$
$M_1 = 10kg$

Determine the smallest μ_s (between surface of table and M_1) that can lead to this situation

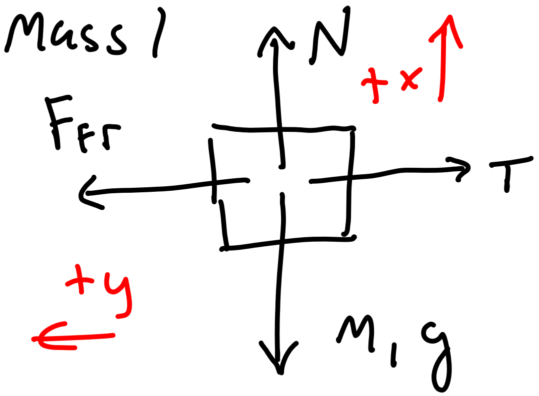
FBD MASS 2



$$\sum F_y = m_2 a_{y_2} = 0 = T - m_2 g$$

$$\boxed{T = m_2 g}$$

FBD Mass 1



(A)

// to Table (B)

$$\Sigma F_y = m_1 a_y = 0 = F_{fr} - T$$

$$F_{fr} = T$$

$$\boxed{\mu_s N = T} \quad (D)$$

⊥ to Table (C)

$$\Sigma F_x = m_1 a_{1\perp} = 0 = N - m_1 g$$

$$\boxed{N = m_1 g}$$

Sub in

$$\mu_s m_1 g = m_2 g \quad (E)$$

or

$$\boxed{\mu_s = \frac{m_2}{m_1}} \quad (F)$$

Ans. to Problem

units? unitless ✓

$$\boxed{T = m_2 g}$$

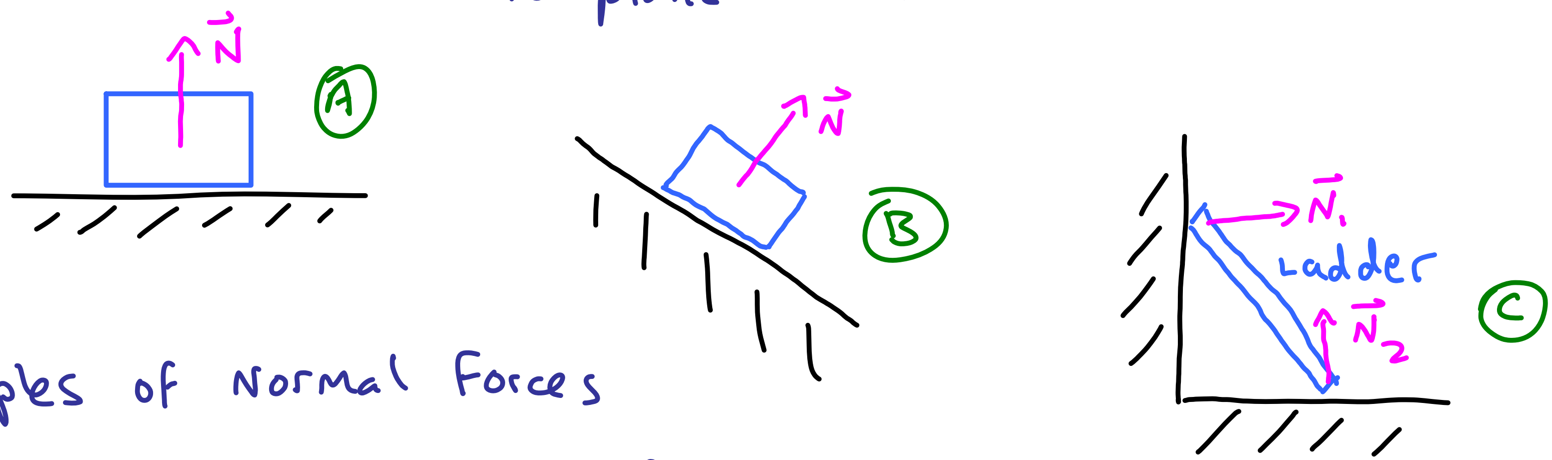
From last page

(16)

2

Force between two surfaces in contact ⟶ Normal force

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



Examples of Normal Forces

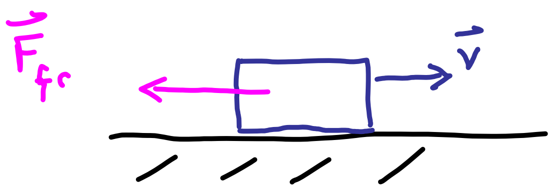
Generally you'll have to infer existence of Normal forces ... i.e., will not be called out explicitly in text of problem.

3

Contact between 2 surfaces

↳ Normal force

↳ Friction force (unless told otherwise)



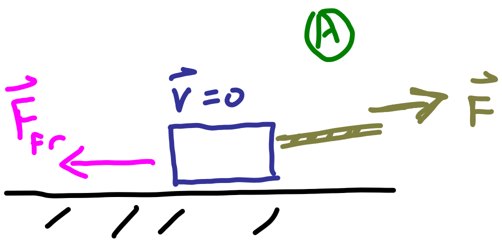
A

Kinetic friction (sliding surfaces) opposes motion

$F_{Fr} = \mu_k N$ B

↑ coefficient of kinetic friction

4



Static Friction (No Motion)

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

sufficient to cancel (No Motion)

can only be so big ... Any bigger → Motion

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

Coefficient of Static Friction

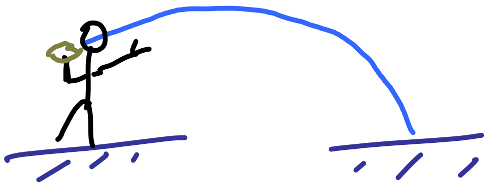
limiting condition $F_{Fr} = \mu_s N$

→ Flagged with wording in the problem

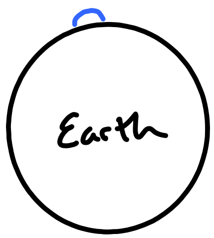
"What is the smallest μ_s that does so + so"

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

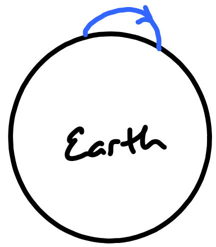
If friction present - Must include it in Newton's Law probs



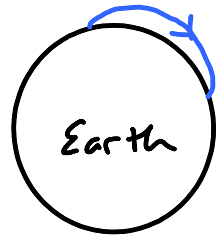
A



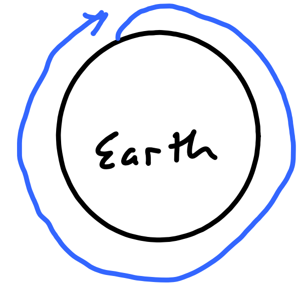
B



C



D

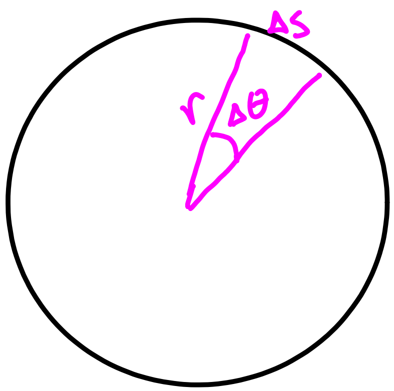


E

Orbit

Circular motion

Recall



F

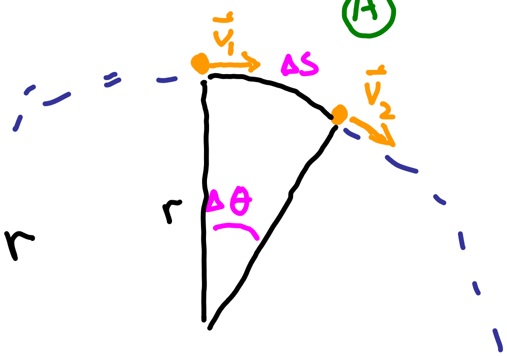
radians

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

6

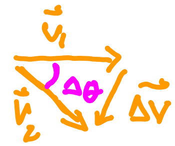
Object moving on Circle of radius r

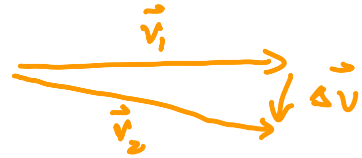
A



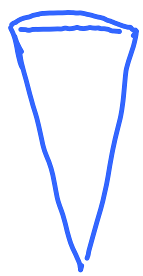
$|\vec{v}_1| = |\vec{v}_2| = v$

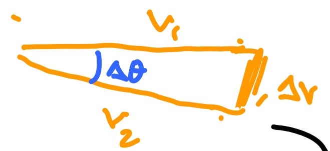
B





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

7

in limit of small Δt

(A)

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

Acceleration

... on circle → centripetal Acceleration

$\equiv \vec{a}_c$

linear velocity along circle → Tangential Velocity

speed going around outside of circle

(D)

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

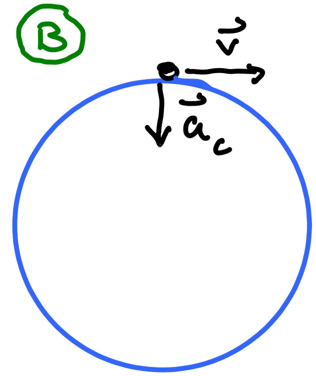
(C)

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

True if on circle

If on circle than this is True

(B)



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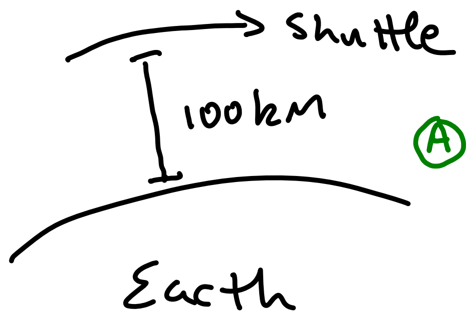
Example

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

$\rightarrow a = \dfrac{v^2}{r}$

B

C

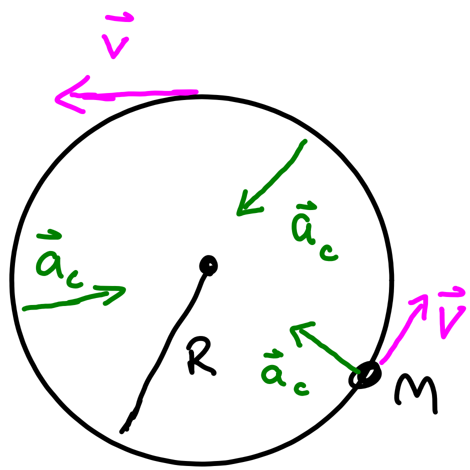
$$9.8\ m/s^2 = \frac{v^2}{R_e + 100{,}000\ m}$$

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

$v = 7962\ m/s$

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

Summary of circular motion



Circular Motion

$\Longleftrightarrow$

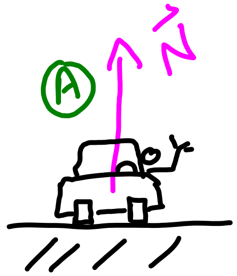
$$|\vec{a}_c| = \frac{|\vec{V}|^2}{R}$$

$F = Ma$

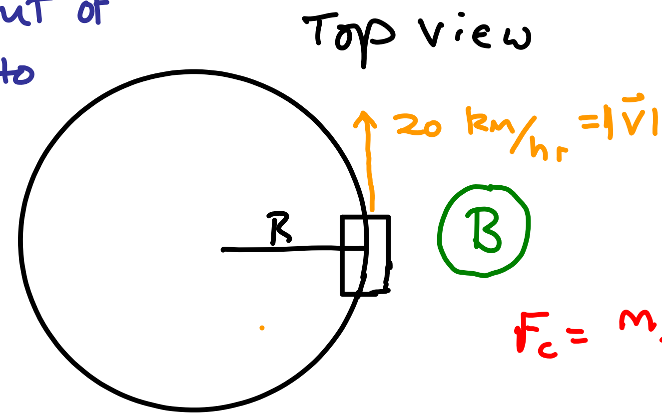
centripetal force

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

Example

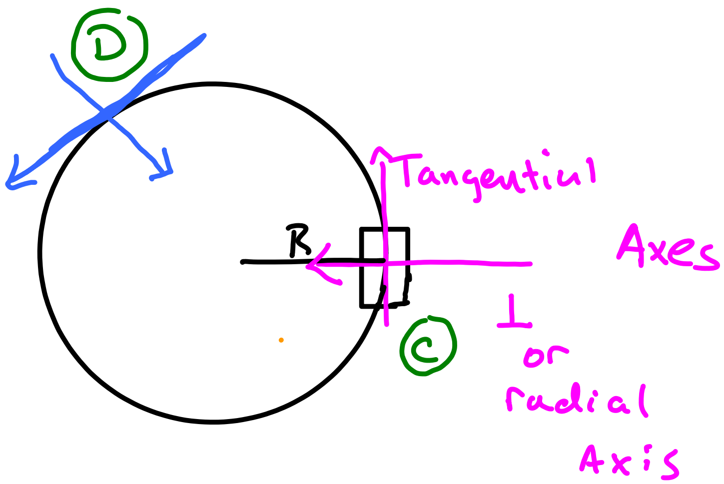


Car driven at 20 km/hour in a circle of radius R = 50 m.
What is minimum Coefficient of Static Friction required to Keep car on road (keep on circle).



$$F_c = m\frac{v^2}{R}$$

Axes Rotate with car

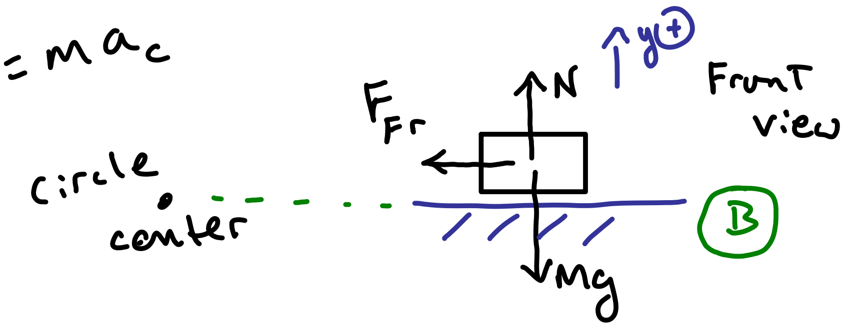


If road is "banked" problem is different. Not banked unless stated otherwise.

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

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 $\perp$ direction (radial direction)

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

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

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 $\equiv$ ~ (Force)(Distance)

What is Energy?

Energy $\equiv$ Ability to do work

Can take different forms:

Kinetic (energy of motion)

heat

light

Sound

Mechanical

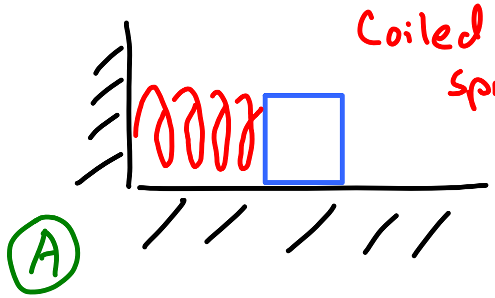
mass ($E=mc^2$)

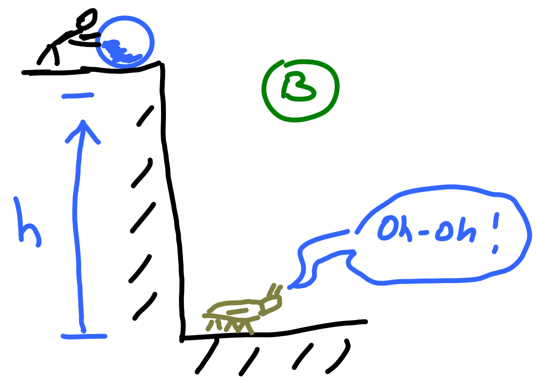
Potential Energy - Stored

Potential to do work

(13)

Coiled spring





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

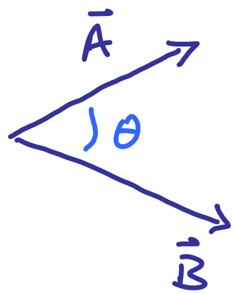
Work = (Force)(Displacement)

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" 15

A

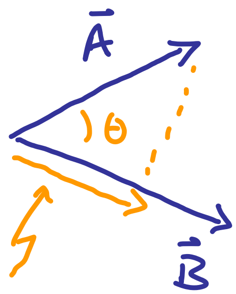


D

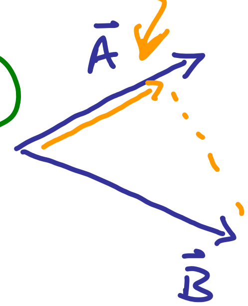
$$\vec{A} \cdot \vec{B} \equiv \text{"A dot B"} = \underbrace{|\vec{A}||\vec{B}| \cos\theta}_{\text{Scalar = Not a vector just a \#}}$$

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

B



C



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

$$\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$$ 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
$$
\begin{aligned}
&= A_xB_x\,\hat{i}\cdot\hat{i} + \cancel{A_xB_y\,\hat{i}\cdot\hat{j}} + \cancel{A_xB_z\,\hat{i}\cdot\hat{k}} \\
&\quad + \cancel{A_yB_x\,\hat{j}\cdot\hat{i}} + A_yB_y\,\hat{j}\cdot\hat{j} + \cancel{A_yB_z\,\hat{j}\cdot\hat{k}} \\
&\quad + \cancel{A_zB_x\,\hat{k}\cdot\hat{i}} + \cancel{A_zB_y\,\hat{k}\cdot\hat{j}} + A_zB_z\,\hat{k}\cdot\hat{k}
\end{aligned}
$$

D Terms $\rightarrow 0$ because unit vectors $\perp$ to each other $\rightarrow$ dot product $= 0$

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

F $\therefore$ $\boxed{\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z}$ useful formula

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

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

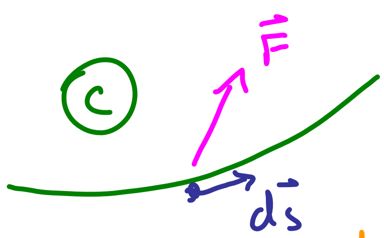
You know – That's Fine and nice but why do I care about all this dot crap ??

Because

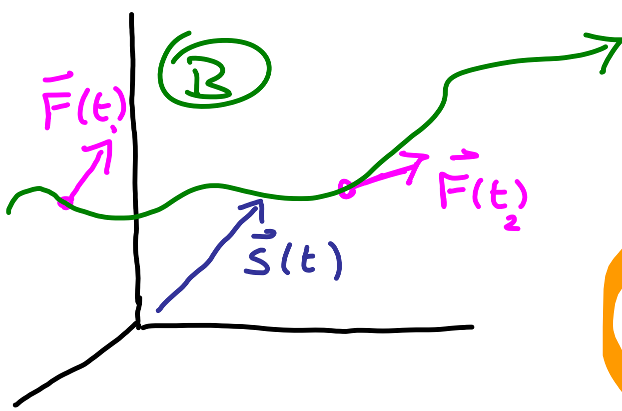
Work is (Force)×(Displacement)
where we multiply the projection of one vector along the other with the Magnitude of the other.

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

(C)



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



(D)

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