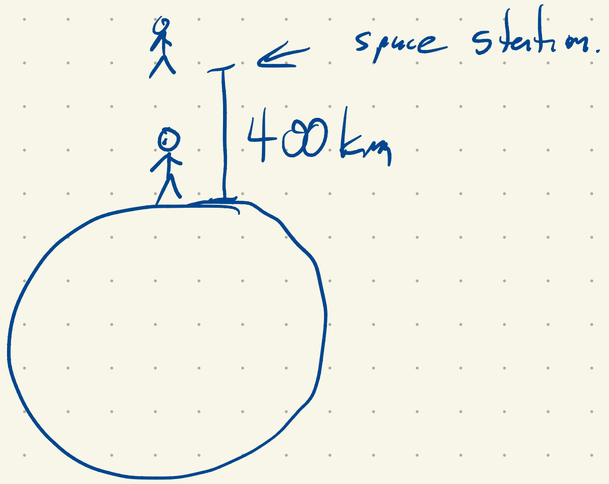
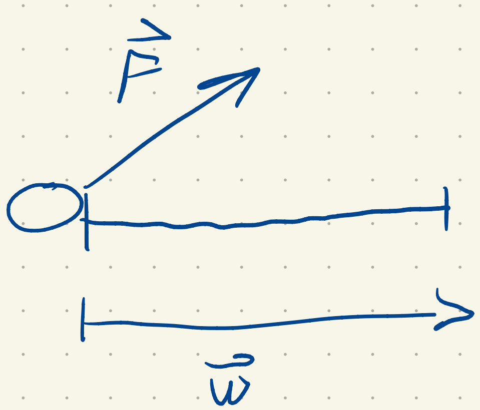
Let's put David in space



How much work?



work done by force:

$\vec{F} \cdot \vec{w}$

$$m \cdot g = 100\,kg \quad 9.8 \frac{m}{s^2} \approx 1000\,N$$

Work done by gravity $\approx -400\,km \cdot 1000\,N$

$$= -4 \times 10^{5}\,\text{m} \cdot 1 \times 10^{3}\,\text{N}$$

$$= \sim 4 \times 10^{8}\ \underbrace{\text{Nm}}_{\text{J}}$$

$1\ \text{kWh} = 3.6 \times 10^{6}\ \text{J}$

So ~100 kWh, roughly

(work you put in has to compensate and it's 100 kWh)

(10 days at our household energy)

But this isn't exact. It should be less because force of gravity is less as you go up.

• 8.68

8.94 •

• 200 $\quad g_{200} = 9.218$

9.5 •

•

$$-9.8 \cdot 100 \cdot 200 \times 10^{3} + (-9.22 \cdot 100 \cdot 200 \times 10^{3})$$

$\sum F(h_i^*)\Delta h \leftarrow$ total work done.

C

the work done on me by gravity going up the curve is the negative of the work going down the curve.

I need to tell you about a different kind of line integral that depends on the orientation of the curve.

$$\int_C dx$$

(using coordinates)

$$\vec{r}(t) = \langle x(t), y(t), z(t) \rangle$$

$$\Delta x \approx x'(t)\,\Delta t$$

$$\sum \Delta x \approx \sum x'(t_i^*)\,\Delta t$$

$$\rightarrow \int_{t_0}^{t_1} \frac{dx}{dt}\,dt$$

$$x(t_1) - x(t_0) \text{ by FTC}$$

This doesn't depend on $\vec{r}$

<u>except</u> if we go backwards,

the sign changes!

More generally

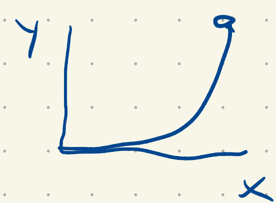
$$\int_C \rho(x,y,z)\,dx = \int_{t_0}^{t_1} \rho(\vec{r}(t))\,\frac{dx}{dt}\,dt$$

$$\int_C \left(M\,dx + N\,dy + P\,dz\right)$$

$$= \int_{t_0}^{t_1} \left(M(\vec{r}(t))\,\frac{dx}{dt} + \cdots + P(\vec{r}(t))\,\frac{dz}{dt}\right) dt$$

e.g. $\vec{r}(t) = t\hat{i} + t^2\hat{j} + t^3\hat{k}$

$0 \le t \le 1$



$$\vec{r}\,'(t) = \langle 1, 2t, 3t^2 \rangle$$

$$\int_C xy\,dx + 3zx\,dy + 5x^2yz\,dz$$

$$= \int_0^1 t^3 + 6t^5 - 15t^9\,dt = -\frac{1}{4}$$

$$GM = 3.98 \times 10^{14}$$

$$GM \cdot m \left(\frac{1}{r_1} - \frac{1}{r_0} \right) =$$

$$-3.69 \times 10^{8}\ J$$