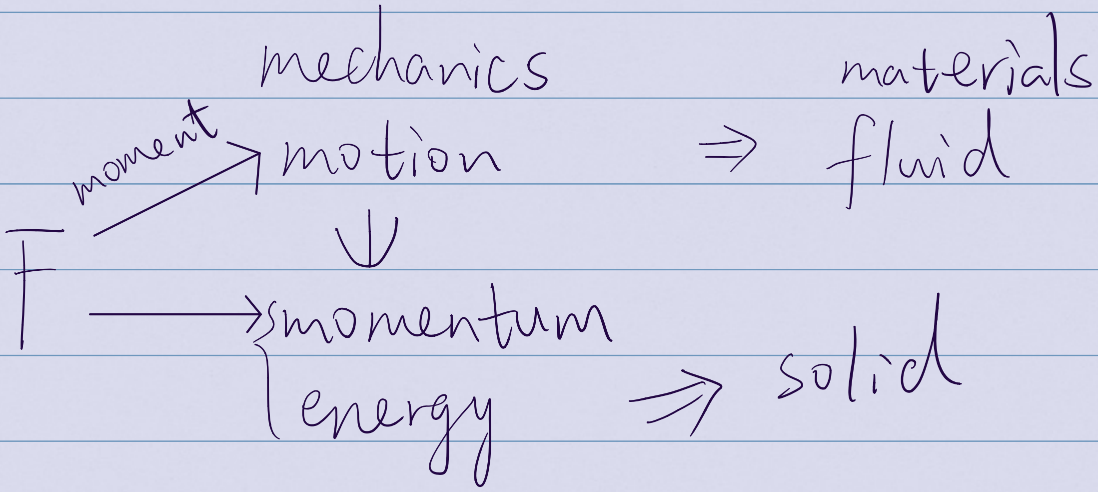
Unit 1



explain how/why → reason

explain sth → describe + reason

● 实际运用类题 答题技巧

① 简化思想 ⇒ 图文合一

② 模型归一 ⇒ 常见运动模型

③ 转化物理量

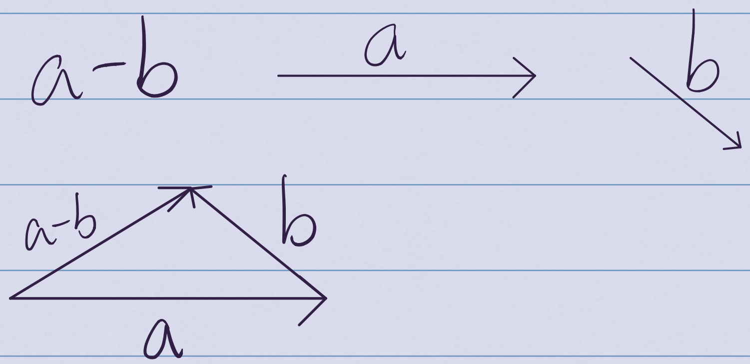
④ 从运动结果入手

⑤ 公式/题目中找影响因素

⑥ 得分点除了逻辑起点和逻辑终点，还有逻辑证据 (ep.公式)

⚛️矢量.标量

- momentum vector
  moment vector
  work (done) scalar
- 图 a-b



- base / derived unit
  注意 unit 和 quantity

Mechanics

- **用于求运动**

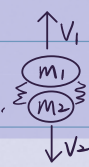
① 大三式　条件：匀加速

② 能量守衡　条件：无heat. friction 的存在

(侧重于转移的过程 ep. KE → GPE)

③ 动量守衡　条件：① 短时间内爆发 (ep. 碰撞)

② 合外力为0

(侧重于转移的状态 ep. 

$m_1V_1 = m_2V_2$)

- **Gravitational field strength**

the gravitational force per unit mass

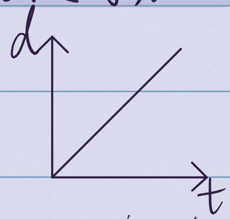
⚛️ 纯运动

- **Calculate** 关注斜率、线下面积

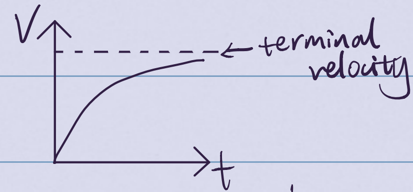
  ↓ (斜率)

  取点：①两点间隔大
  ②关注轴与轴间的信息
  ③尽量取 origin/截距

- **Describe motion** ← 不能提到力



constant velocity
gradient $= v = \frac{\Delta d}{\Delta t}$



accelerate with a decreasing rate

描述方向
- horizontal: s, v, a
- vertical: s, v, a

- **Plot**
  1. 确定起点和终点的两个坐标； 确定斜率； 注意正方向
     选取合适的scale，图形占据坐标纸不少于2/3 的空间
  2. 取点尽量远一点，尽量选原点或截距；gradient是2点的关系
  3. 注意横纵轴的量

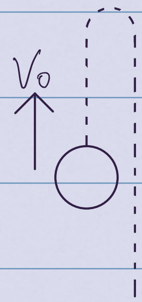
⚛️ 抛体运动

- 题型
  - 计算
    - range 水平位移
    - height
  - 解释 path
    - 无 air resistance
    - 有 air resistance

- 竖抛

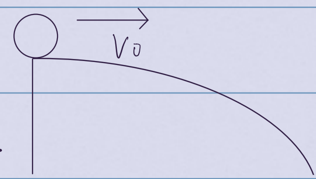
  Hmax $v=0$ $u=v_0$ $a=-g$

  $s=ut+\frac{1}{2}at^2$
  - $s>0$ 上抛
  - $s<0$ 下抛



- 横抛 horizontal V_0 vertical $u=0$

  $s=V_0t$ $s=\frac{gt^2}{2}$



- 斜抛

x: $v_x = v_0\cos\theta$ = constant

y: $u_y = v_0\sin\theta$

$t = \frac{v_0\sin\theta}{g}$

$t_{total} = 2t = \frac{2v_0\sin\theta}{g}$

$Range = v_0\cos\theta \cdot t_{total} = v_0\cos\theta \cdot \frac{2v_0\sin\theta}{g} = \frac{2v_0^2\sin\theta\cos\theta}{g}$

⚛️ 力与运动

- 分析主语.

1. 未知量少
2. 可能自身给自身的力（ep. 气球喷气）
3. 繁杂归一（ep. 多米诺牌）
4. 以物体的一个物理量为主语

- 拉力和位移相同做运动

（适用于 calculate/explain）

- $F_{主动} \rightarrow F_{被动} \rightarrow \Sigma F \rightarrow a/\Delta v \rightarrow v \rightarrow s$

N3
相互作用力

ΣF（合外力）

N1 ↙ 静止/运动状态（explain）

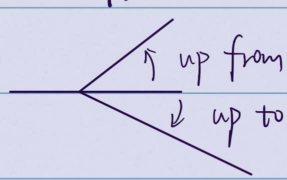
N2 ↘ 运动/$F=ma$（calculate）

- 受力分析及表达

2D：① 受力分析到水平、竖直方向

② ΣF 求和

③ 表示

1. 正北　due to north
   东南　x° east to north
2. 

⚛️ 力矩

F & 力臂 $r_\perp$ — perpendicular distance between force and pivot

(对比 linear motion)

$\vec{M} = \vec{r} \times \vec{F}$
- 大小: $r_\perp$ (level arm) $\times F = rF\sin\theta$
- 方向: + 逆时针, − 逆时针

F	Moment — vector. unit: Nm
↓	↓
ΣF	ΣM (一般为0) — equilibrium
↓	↓
a	α 角加速度
↓	↓
v	ω 角速度
↓	↓
s	θ 角位移

- **力矩平衡计算**

1. 确定杆子
2. 确定 pivot
3. 标记力/力矩
4. 运用 equilibrium of momentum
   a. 合力为0
   b. 合力矩为0

分清重心和支点

重心可以不在物体上，支点必须在

☆ centre of gravity 重心 ←

a point at which all the weight of an object appears to act on

☆ Principal of moment

in equilibrium, the sum of anticlockwise moments = the sum of clockwise moments

⚛ 功能关系

- **F**

↓ 做功

正功 → 运动增加 → 与力的方向夹角 < 90°
负功 → 运动减少 → 与力的方向夹角 > 90°

W ← work / work done / energy → scalar.

$W_F = \Delta E_{chemical}$
$W_f = -\Delta Q$
$W_{weight} = -\Delta GPE$
$W_{el} = -\Delta E_{el}$

} $W_{total\ force} = \Delta E$

↓

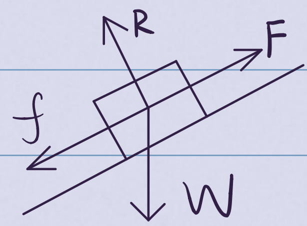
ΔE

↓

conservation

ep. 1. 加速骑车
$\Delta E_{ch}\downarrow = \Delta Q\uparrow + \Delta KE\uparrow$
$W_F = W_f + W_{\Sigma F}$

2. 匀速爬坡



$W_f + 0 + W_W + W_F = 0$
$W_f \rightarrow \Delta Q\uparrow$, $W_W \rightarrow \Delta GPE\downarrow$, $W_F \rightarrow \Delta E_{ch}\downarrow$

- **功率**

匀速状态下，总功 = 0. → 总功率 = 0

↳ ① 把功率当作功来分析 $P = \frac{W}{t} = \frac{Fs}{t}$
② 功率考虑主语

⚛️ 动量

- 转移式 (trans)　$\Delta P_1 = \Delta P_2$ (object 改变)

  $m_1V_1 + m_2V_2 = m_1V_1' + m_2V_2'$

  守衡式 (con)　$\Sigma P = \Sigma P'$ (time 改变)

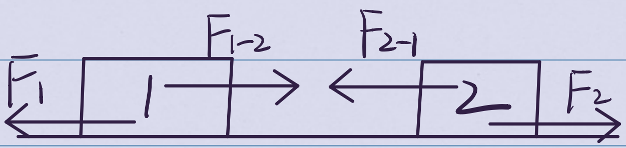
  $m(v_1' - v_1) = -m(V_2' - V_2)$

- $F_1 \xrightarrow{\Delta t} \Delta P_1 \xrightarrow{con} \Delta P_2$

  $\begin{cases} F_{ex} \xrightarrow{\Delta t} \Delta \Sigma P \xrightarrow{con} \Delta P_{ex} \\ F_{in} \xrightarrow{\Delta t} \Delta P \xrightarrow{con} \Delta P_{in} \end{cases}$

- 通过 N_2 N_3 推导动量

  $$\frac{\Delta \Sigma P}{\Delta t} = \frac{\Delta P_1 + \Delta P_2}{\Delta t} \overset{\text{根据}N_2}{=} \Sigma F_1 + \Sigma F_2$$

  $$= F_1 + F_{2-1} + F_{1-2} + F_2$$

  $$= F_1 + F_2 = \Sigma F_{ext}$$

  (根据 N_3)

- 用于求运动

  ① 大三式　　条件：匀加速

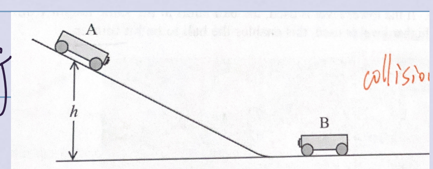
  ② 能量守衡　条件：无 heat. friction 的存在

  ③ 动量守衡　条件：① 短时间内爆发 (ep. 碰撞)

  　　　　　　　　　② 合外力为0

☆ 没有弹开的碰撞一定不能用能量守衡

可以先用能量守衡再用动量守衡



- Conservation of linear momentum
  the sum momentum before a collision is equal to the sum of momentum after a collision, if no external force act.

- Impulse 冲量
  $\sum I = \Delta P = \sum F \times \Delta t$

Materials

⚛️ (物体在流体中运动)

fluids
- solid
- flow (流体运动)

Upthrust — 排斥
- 定义：$F_{浮} = G_{排}$
- $U = \rho_{fluid}\, g\, V_{displaced}$

Drag — 影响因素 (从公式中找答案)
- size
- V_{ball} → ΣF → a → v
- η_{fluid}
- turbulent

$D = 6\pi\eta r v$ 条件：层流 { 小球, 慢速 }

产生条件 { 有速度才有阻力, 与运动方向相反 }

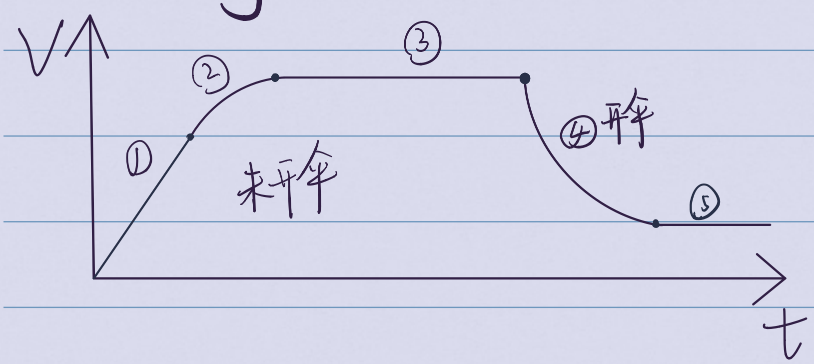
Weight — 地球 $W = \rho_{solid}\, g\, V_{solid}$

分析物体沉浮：直接因素是力，硬ρ

- **Viscosity**
  - gas: $\eta \propto T$ — $T\uparrow \rightarrow \eta\uparrow$ → $D\uparrow \rightarrow \Sigma F \rightarrow$ rate of flow
  - liquid: $\eta \propto \frac{1}{T}$ — $T\uparrow \rightarrow \eta\downarrow$

def. resistance of a fluid to flow

• Drag force 跳伞



① only W act → $a = g$

② v与drag force成正比

③ $D = W$ $a = 0$ terminal velocity

④ $D - W = ma$

tur → v↓ → D↓ → a↓

⑤ $D = W$ $a = 0$ terminal velocity

m↑ → terminal velocity↑

原因：Drag = mg

↳ 与v成正比

逻辑关键：力

力是导致速度变化的根本原因

- Rain consists of droplets of water of different sizes.
  Explain why larger droplets of rain reach the ground more quickly.
  You may assume that the upthrust acting on a rain droplet is negligible.

1 At terminal/constant velocity the resultant force is zero （weight = drag）

2 Larger droplets require a greater air resistance to equal a greater weight
Or as the radius increases, weight increases more rapidly than drag (at a given speed)

3 Drag increases with velocity

4 Larger droplets have a greater terminal velocity

⚛️ Solid.

- $F_{restoring} \rightarrow W\downarrow \rightarrow \Delta EPE \xrightarrow{conservation} \Delta E$

  $W = \Delta EPE$

  W_{res} $= \int_{\square}^{\square} F\,ds$ $= F\text{-}\Delta x$ area
  - before PL: $\frac{1}{2}F\Delta x = \frac{1}{2}k\Delta x^2$
  - after PL: 数格子/近似面积

- Hooke's law
  1. Before PL $F_{restoring} = -k\vec{\Delta x}$
  2. ΣFx. Tx. Wx
  3. Δx
     - $+$: extension 拉伸
     - $-$: compression 压缩
  4. k: spring constant. stiffness.

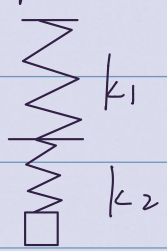
- $F = k\Delta x$

  $k \rightarrow$ stiffness constant Nm^{-1}

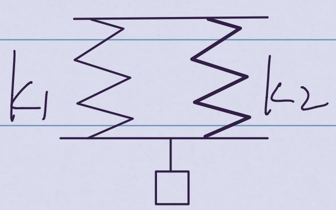
  - k越大，越 stiffer，extension越小
  - F Δx 图像求 area

  看清横纵坐标，ΔW 求与 Δx 轴的面积

  - 串/并联



$$\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2}$$



$$k = k_1 + k_2$$

● 通过图象展开

看一个物体是否能承受大力 ep. concrete

stress when a material is breaking

考点：1. 斜率，2. 区域

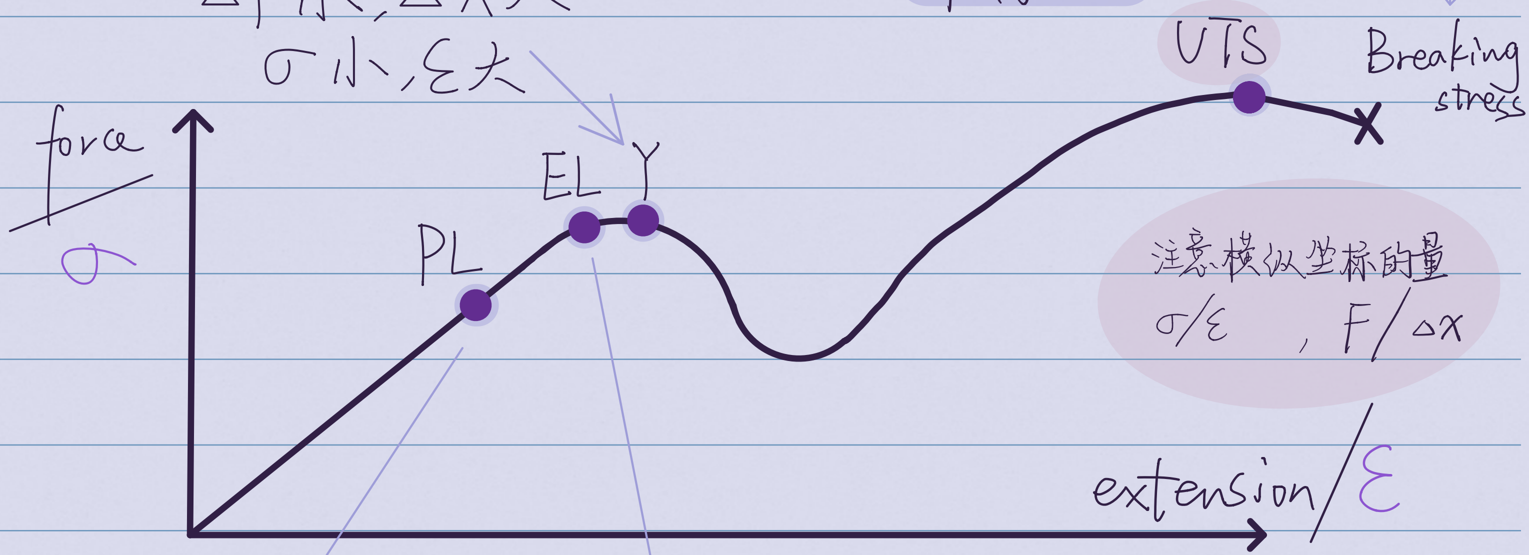
通过求图中区域面积比较 energy per volume

the maximum tensile stress for a material

最高点

ΔF 小，Δx 大

σ 小，ε 大



通过分析 unloading line 判断点在 EL 前/后

before P,

$F_{restoring} = k\,\Delta x$

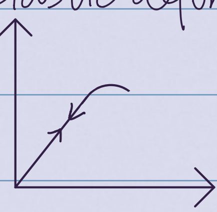
$\div A \downarrow \qquad \downarrow \div x$

$\sigma = E_y\,\varepsilon$

obey Hooke's law

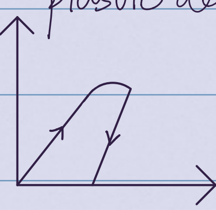
before EL

elastic deformation



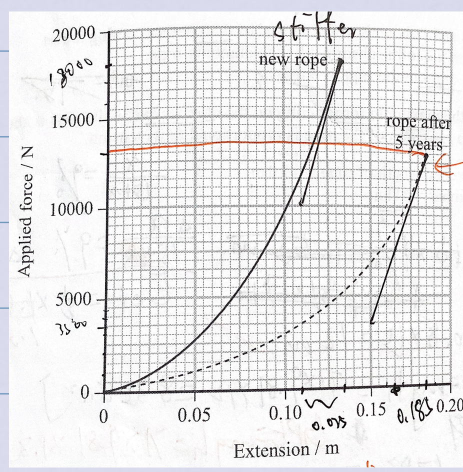
after EL

plastic deformation



典型题：比较两个物体的 stiffness

取同一个力求斜率，作比较



Experiment

- 材料
  - 长度 { ruler
    - micrometer 千分尺
    - screw gauge ep. 导线直径
    - vernier calliper 游标卡尺
    - (more accurate, better precision)
  - 垂直：set square 三角尺
  - 精度：percentage accuracy
  - 保护 { hand – gloves
    - eye – goggles
    - face – mask

- error
  - random error：不可避免 多算几次，取平均值
    - 通过画图法减小差错，求best fitline斜率
  - systematic error：可避免 { zero error 器材未归0
    - parallex error 视差
      - measure sth at eye level

- 求 uncertainty

● accuracy 精确度

提高 accuracy

① measure … at different position

because actural … may not be uniform

② calculate the average

because it can reduce random error

1. 用 digital camera 的好处

① no reaction time

② can be paused

③ can be read every frame

2. 用 data logger 的好处（数据检测器）

① measure 2 data simultaneously

② more readings

● 画图法好处

① greater accuracy

② clearly show the rate varies

● 数据处理

先排除异常值，再求平均