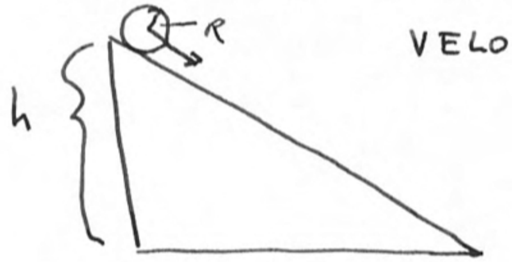
① EXAMPLES

Ball rolls down an incline. WHAT IS ~~IT~~ ITS VELOCITY (CENTER OF MASS)



$$E_i = E_f$$

$$mgh = \underbrace{\tfrac{1}{2} m v_{cm}^2}_{K_{TRANS}} + \underbrace{\tfrac{1}{2} I \omega^2}_{K_{Rot}}$$

$\omega = v/R$ Radius = R

$I = \frac{2}{5} MR^2$ Sphere

$$mgh = \tfrac{1}{2} m v_{cm}^2 + \tfrac{1}{2}\Big[\underbrace{\tfrac{2}{5} MR^2}_{I}\Big] \underbrace{\frac{v_{cm}^2}{R^2}}_{\omega^2}$$

$$mgh = \tfrac{1}{2} m v_{cm}^2 + \tfrac{1}{5} M v_{cm}^2$$

$$= \tfrac{7}{10} m v_{cm}^2 \qquad \boxed{v_{cm} = \left(\tfrac{10}{7} gh\right)^{1/2}}$$

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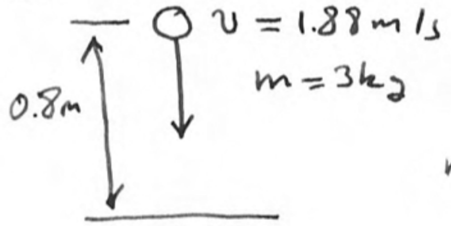
②

How high will ~~be~~ the ball go?



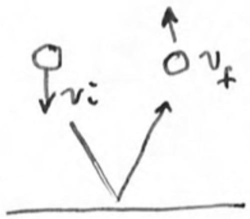
$$E_i = mgh_i + \tfrac{1}{2} m v_i^2 = E_f = \underbrace{mgh_f}_{\text{No K.E.}}$$

$$mgh_i + \tfrac{1}{2} m v_i^2 = mgh_f$$

$$h_f = \cancel{g} h_i + \frac{v_i^2}{2g}$$

$$h_f = 0.8 + \left[\frac{(1.88)^2}{2(9.8)}\right] = 0.8 + 0.1803 = 0.9803 \text{ m}$$

Note:



It's just like reversing the velocity!

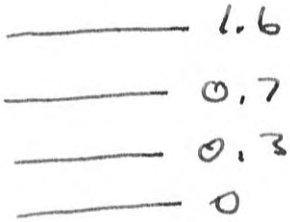
③ An excited atom emits light at

$\boxed{0.3,\ 0.4,\ 0.7,\ 1.3,\ 1.6 \text{ and } 2.0 \text{ eV}}$

What energies will this atom absorb ⇒

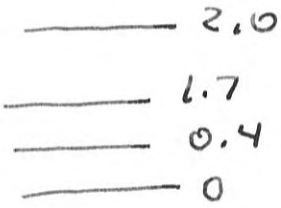
Guess!

(A)



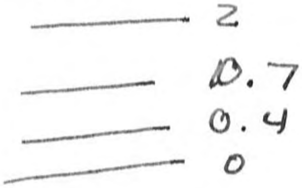
No! Need absorption at 2.0 eV

(B)



No! No transition at 1.3 eV

(C)



Yes
2 eV 0.4 eV 0.7 eV
0.3 eV 1.6 eV
1.3 eV

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④ Is it possible that a nickel will statically "jump" 1μ above a table. (AT T=300K)

$h = 10^{-6}$ m

$mgh = (0.005)(9.8)(10^{-6})$

$= 5 \times 10^{-9}$ J

ΔE ↑h $m = 0.005$ kg

$kT = (1.4 \times 10^{-23} J/K)(300)$

$= 4.2 \times 10^{-21}$

$$\frac{N(\text{Jump})}{N} = \exp\left(-\frac{\Delta E}{kT}\right) = \exp\left(-\frac{5 \times 10^{-9}}{4 \times 10^{-21}}\right)$$

$= \exp(-10^{12})$ ⇒ TOO SMALL FOR MY CALCULATOR!

No, it is Not possible

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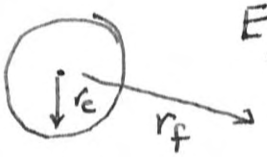
⑤ How much energy does it take to move a object from the earth to 24,000 km above the surface?

~~MASS OF OBJ.~~ MASS OF OBJECT $= 10^3$ kg



$$E_i = K_i + U_i \qquad E_f = U_f$$

$$K_i = U_f - U_i = \frac{-GM_E m_o}{r_f} - \frac{-GM_E m_o}{r_e}$$

$$= \cancel{10} \quad K_i = GM_E m_o\left[\frac{1}{r_e} - \frac{1}{r_f}\right]$$

$$K_i = \left[6.7\times10^{-11}\right]\left[6\times10^{24}\right]\left[10^{3}\right]\left[\frac{1}{r_e} - \frac{1}{r_e+\Delta r}\right]$$

$$= 4.02(10^{\overset{18}{\cancel{15}}})\left[\underbrace{\frac{r_e+\Delta r - r_e}{r_e(r_e+\Delta r)}}\right]$$

$\Delta r = 2.4\times10^{4}\ m$

$r_e = 6.4\times10^{6}\ m$

$$\frac{\Delta r}{r_e(r_e+\Delta r)} \approx \frac{2.4\times10^{4}}{(6.4\times10^{6})^2} = 5.9\times10^{-10}$$

$$\boxed{K_i = 2.36\times10^{\overset{9}{\cancel{8}}}\ J}$$

1 TON TNT $= 4.2\times10^{9}$ J

↳ 1000 lbs ⇒ 2×10^{9} J

<u>TNT</u>

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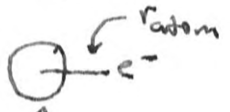
⑥ A typical atom is $\sim 1\times10^{-10}$ m in size. How much ~~is~~ energy does it take to remove an electron (ionization energy)?



Charge +e

Assume $K_i = 0$

$K_f = 0$

~~$K_i + U_i = K_f + U_f + W \qquad E$~~

$$\Delta E_{sys} = W$$

$$K_f + U_f - K_i - U_i = W$$

$$W = U_f - U_i = \frac{-e^2}{4\pi\varepsilon_0}\left[\cancel{\frac{1}{r_\infty}}^{\,0} - \frac{1}{r_{atom}}\right]$$

$$= \underbrace{9\times10^{9}}_{\frac{1}{4\pi\varepsilon_0}}(1.6\times10^{-19})^2\ \frac{1}{1\times10^{-10}} = 2.3\times10^{-18}\ J$$

$$\boxed{1eV = 1.6\times10^{-19}\ J}$$

$$2.3\times10^{-18}\ J \times \frac{1eV}{1.6\times10^{-19}} \approx \underline{\underline{15\ eV}}$$

⑦ How much energy does it take to move an object in orbit from $r = 2R$ to $r = 4R$? (R = radius ot the earth)

$$E_i = \frac{1}{2} m v_i^2 - \frac{G m M_E}{2R} \qquad E_f = \frac{1}{2} m v_f^2 - \frac{G m M_E}{4R}$$

Note: $\frac{mv^2}{r} = \frac{G M_E m}{r^2}$ [General redult for circuler ~~orb~~ orbit]

$$m v^2 = \frac{G M_E m}{r} \qquad \boxed{KE = \frac{1}{2} m v^2 = \frac{G M_E m}{2r}}$$

So

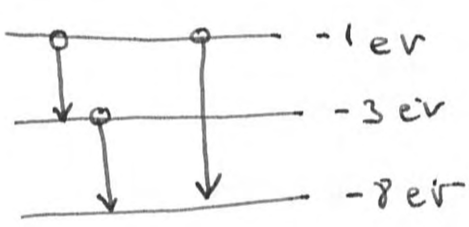
$$E_i = \frac{1}{2} \frac{G M_E m}{2R} - \frac{G m M_E}{2R} = -\frac{1}{4} \frac{G m M_E}{R}$$

$$E_f = \frac{1}{2} \frac{G M_E m}{4R} - \frac{G m M_E}{4R} = -\frac{1}{8} \frac{G m M_E}{R}$$

$$\Delta E = E_f - E_i = -\frac{1}{8} \frac{G m M_E}{R} + \frac{1}{4} \frac{G m M_E}{R} = \frac{1}{8} \frac{G m M_E}{R}$$

$$\boxed{\Delta E = \frac{1}{8} \frac{G m M_E}{R}}$$

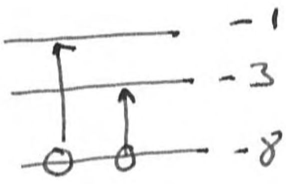
Some Absorption / Emission RULES



Emission at 2 eV, 5eV, 7eV

Atom can emit more than one photon as it decays to ground state

EMISSION



Atom can absorb at 5 eV and 7 eV.

It cannot absorp two photons - say 5 eV and then 2 eV. ENERGETICALLY THIS OK → BUT IMPROBABLE. Atom will decay back to ground state befor absorbing another photon.