

11. The first ten energy levels of an atom are labelled $n = 1, 2, \dots, 10$. Assuming all transitions are possible, find the maximum number of unique photon energies corresponding to transitions between $n = 10$ and $n = 1$.

A 45

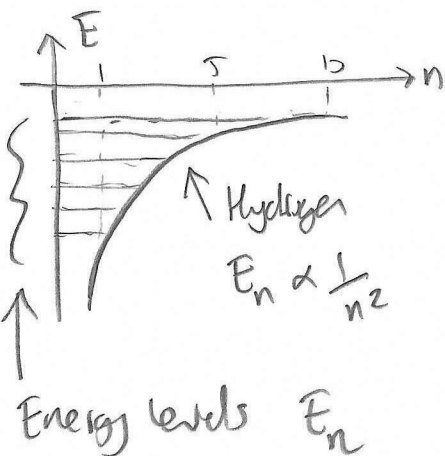
B 55

$\uparrow$
 ΔE

C 90

D 100

E 110



$$E_n + \Delta E_{mn} = E_m$$

$$E_m > E_n \text{ so } \boxed{m > n}$$

ΔE photon energy > 0

ie emit a photon for an energy level change $m \rightarrow n$

$$10 \rightarrow 9, 8, 7, \dots, 1$$

$$9 \rightarrow 8, 7, 6, \dots, 1$$

$$8 \rightarrow 7, 6, \dots, 1$$

$\vdots$

$$2 \rightarrow 1$$

9 transitions

8 "

7

$\vdots$

1

9

So total transitions is $\frac{(1+9)(9)}{2} = \boxed{45}$

If each transition results in a unique ΔE_{mn}

then max # of photon energies is 45.

12. A body, initially at rest, explodes into two fragments of masses m and am where $a > 1$. The total kinetic energy after the explosion is E . Find the kinetic energy of the larger mass.

A $\frac{E}{1+a}$

B $\frac{aE}{1+a^2}$

C $\frac{a^2E}{1+a^2}$

D $\frac{a^3E}{1+a^3}$

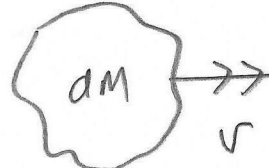
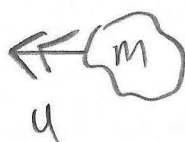
E $\frac{E}{a}$

} E_a

BEFORE

$(1+a)m$

AFTER



Conservation of momentum: $-mu + amv = 0$

$\therefore \boxed{v = \frac{u}{a}}$

$\therefore \boxed{u = av}$

Total KE post explosion is $E = \frac{1}{2}mu^2 + \frac{1}{2}amv^2$

$\uparrow$ E_a

So $E_a = E - \frac{1}{2}ma^2v^2$

Now $E_a = \frac{1}{2}mav^2$ so $\frac{1}{2}ma^2v^2 = aE_a$

$\therefore E_a = E - aE_a \Rightarrow \boxed{E_a = \frac{E}{1+a}}$

13. The pressure p exerted on two closely spaced parallel plates due to quantum effects is dependent only upon Planck's constant h , the speed of light c and the plate separation r .

Find the proportionality relation between p and r .

A $p \propto \frac{1}{r}$

B $p \propto \frac{1}{r^2}$

C $p \propto \frac{1}{r^3}$

D $p \propto \frac{1}{r^4}$

E $p \propto \frac{1}{r^5}$

let $p = k h^A c^B r^C$

where k is a dimensionless constant

de Broglie: $mv = \frac{h}{\lambda}$
 $\uparrow$ momentum $\quad \nwarrow$ wavelength

$\therefore [h] = \text{kg m}^2 \text{s}^{-1}$

$[P] = [F/A] = \left[\frac{m a}{A} \right] = \text{kg m s}^{-2} \text{m}^{-2} = \text{kg m}^{-1} \text{s}^{-2}$

$\therefore$ comparing dimensions $[P] = [h^A] [c^B] [r^C]$

$\therefore \text{kg m}^{-1} \text{s}^{-2} = \text{kg}^A \text{m}^{2A-A} \text{s}^{-A} \text{m}^B \text{s}^{-B} \text{m}^C$

kg: $1 = A \Rightarrow \boxed{A = 1}$

m: $-1 = 2A + B + C \Rightarrow B + C = -3$

s: $-2 = -A - B \Rightarrow \boxed{B = 1}$

$\therefore \boxed{C = -4}$

so $p \propto \frac{hc}{r^4}$

[A bit like the force between magnets
 Field strength $\propto \frac{1}{r^3}$
 and force $\propto$ field gradient $\propto \frac{1}{r^4}$]

14. A thin uniform circular biscuit of radius b is balanced horizontally on the thin circular rim of a teacup, which has radius $3b/2$ positioned as far as possible from the cup's centre. It is then slowly pushed inwards towards the centre of the teacup. What is the maximum distance it can be pushed before it falls?

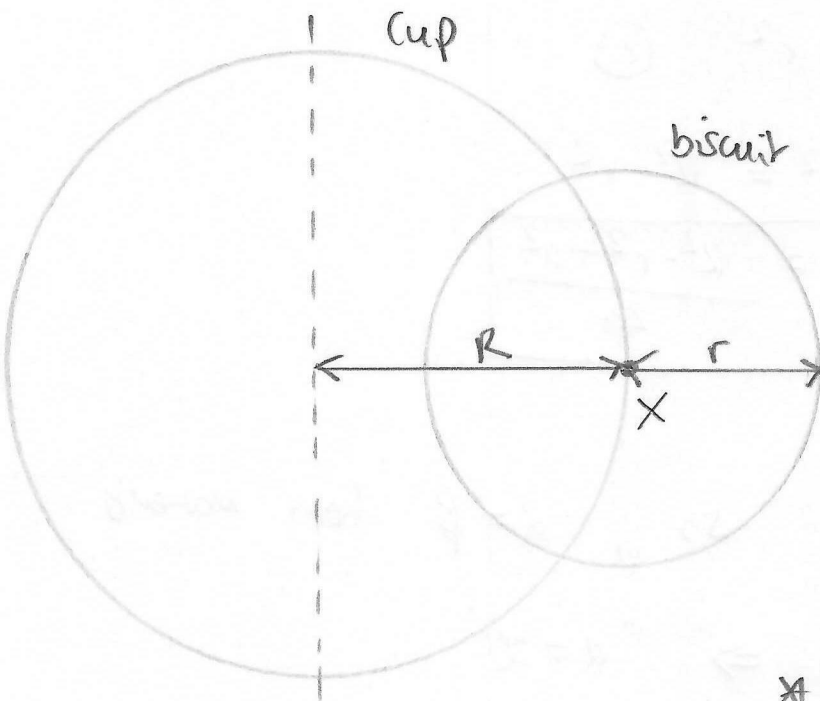
A $\frac{\sqrt{3}-1}{2}b$

B $\frac{5-\sqrt{3}}{5}b$

C $\frac{\sqrt{5}-2}{3}b$

D $\frac{3-\sqrt{5}}{2}b$

E $\frac{\sqrt{3}-1}{3}b$



* Furthest point of balance is when biscuit C.O.M. is on the rim of the cup.

* Normal contact force at point X balances weight W of biscuit, and no turning moment about X.

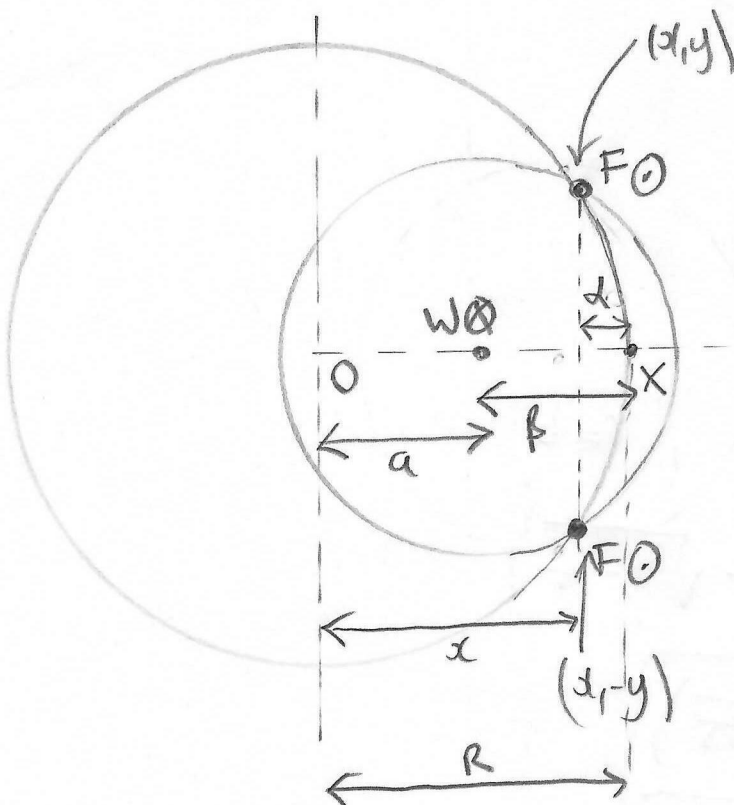
* Continued EQ can occur if turning moment of contact forces at (x, y) and $(x, -y)$ about balance $W\beta$, i.e. turning moment of biscuit weight about X.

Also $\boxed{W = 2F}$ (free balance).

$$\text{so } 2F\alpha = W\beta$$

$$\Rightarrow \boxed{\alpha = \beta} \quad (\text{Note})$$

in diagram $\beta > \alpha$ so biscuit would fall into the cup).



Distance pushed by biscuit from rim scenario is β .

Now $x^2 + y^2 = R^2$ ①

$(x-a)^2 + y^2 = r^2$ ②

$a + \beta = R$ so $\beta = R - a$.

$\therefore x^2 - 2ax + a^2 + y^2 = r^2$ ③

so ① - ③ : $2ax - a^2 = R^2 - r^2$

$\Rightarrow \boxed{x = \frac{R^2 - r^2 + a^2}{2a}}$

Now $R - x = \alpha$ so if $\alpha = \beta$ for moments

$\Rightarrow R - a = R - x \Rightarrow a = x$

$2a^2 = R^2 - r^2 + a^2$

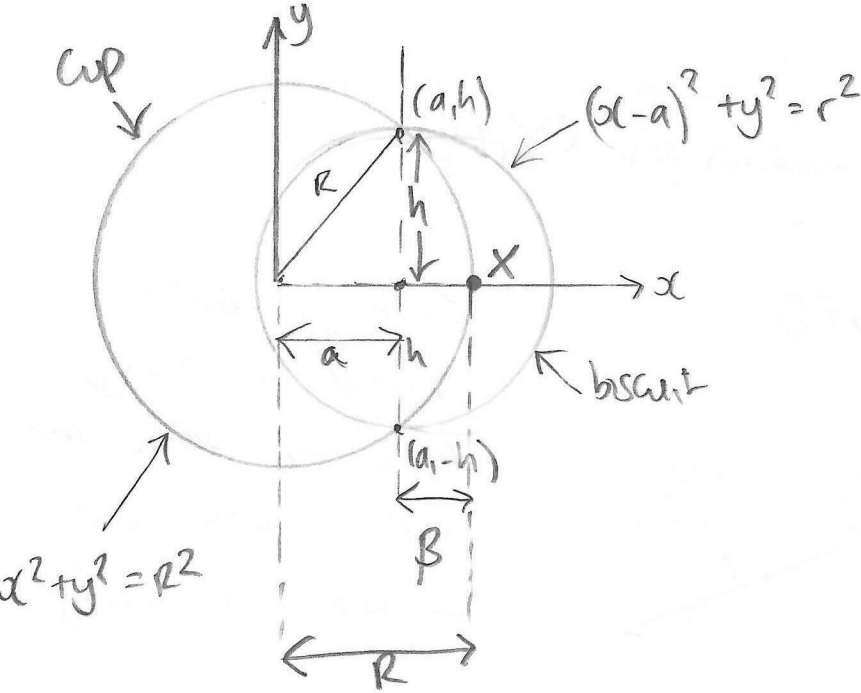
$\therefore \boxed{a = \sqrt{R^2 - r^2}}$

$\therefore \boxed{\beta = R - \sqrt{R^2 - r^2}}$

In example : $R = \frac{3}{2}b$, $r = b$

$\therefore \beta = \frac{b}{2} (3 - \sqrt{9 - 4})$

$\therefore \boxed{\beta = \frac{b}{2} (3 - \sqrt{5})}$



* Might be easier simply to start from this diagram, where rim contacts and biscuit C.O.M are on a vertical line.

* Shift required from rim of biscuit COM is $\boxed{\beta = R - a}$

a substitute

$$\begin{aligned} a^2 + h^2 &= R^2 \\ h^2 &= r^2 \end{aligned}$$

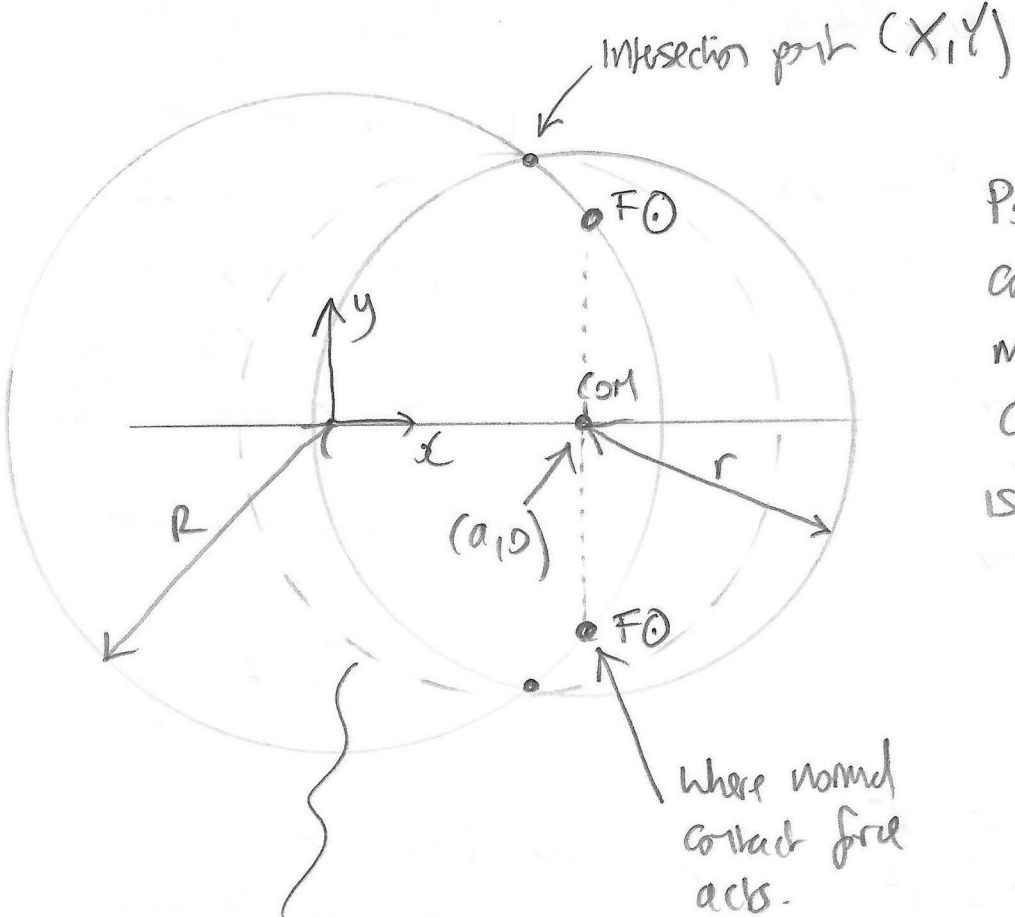
{ i.e. insert (a, h) into Cartesian equations for circles }

$$\text{So } a = \sqrt{R^2 - r^2}$$

$$\therefore \boxed{\beta = R - \sqrt{R^2 - r^2}}$$

So expect EQ for $\boxed{0 \leq \beta \leq R - \sqrt{R^2 - r^2}}$

Within this range, always a possibility for turning moments to balance, so stable.



Point of normal contact can always move $\rightarrow$ until over COM, until COM is over rim itself.

Extreme case of $\beta = R - \sqrt{R^2 - r^2}$ when COM lies under intersection point of circles.

So another way of thinking about this is the COM must be between the circle intersection or coordinate and $x = R$ (the rim) for stability.

Intersection

$$X^2 + Y^2 = R^2$$

$$(X - a)^2 + Y^2 = r^2 \Rightarrow X^2 - 2aX + a^2 + Y^2 = r^2$$

$$\Rightarrow X = \frac{R^2 - r^2 + a^2}{2a}$$

So for stability: $a \geq X$ and $a \leq R$.

Using $a \geq X$

$$\Rightarrow 2a^2 \geq R^2 - r^2 + a^2 \Rightarrow a \geq \sqrt{R^2 - r^2} \therefore \boxed{\beta \leq R - \sqrt{R^2 - r^2}}$$

15. An insulated cup contains 500 g of water at 20°C . Identical ice cubes, each of mass 25 g and at 0°C , are added to the cup. What is the maximum number of cubes that can be added so that, at equilibrium, the mixture is entirely liquid?

Specific heat capacity of water = $4 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$

Specific latent heat of fusion of ice = $3 \times 10^5 \text{ J kg}^{-1}$

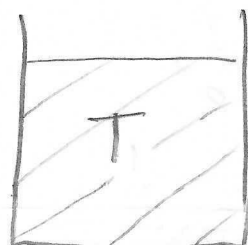
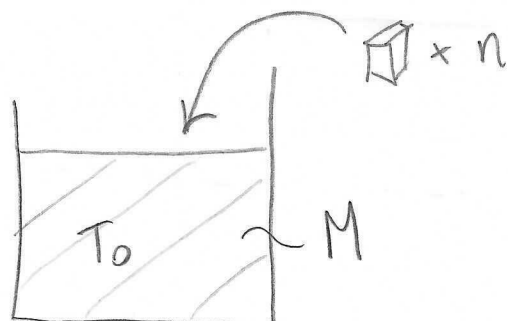
A 4

B 5

C 6

D 7

E 8



All ice cubes melted

Assume no leaks or transfer of thermal energy to surroundings

Energy balance:

$$CM(T_0 - T) = nML + nMCT$$

$\nwarrow$ T is $^\circ\text{C}$
 Thermal energy loss of water

Energy to melt n ice cubes

Energy of nM kg of water raised from 0°C to $T^\circ\text{C}$

$$\Rightarrow n = \frac{CM(T_0 - T)}{m(L + CT)}$$

Now for final state to be liquid water, $T > 0^\circ\text{C}$

So max n is $n_{\text{max}} = \frac{CM T_0}{mL} = \frac{4 \times 10^3 \times 500 \times (20)}{25 \times 3 \times 10^5}$

$= 5.3$ so $n_{\text{max}} = 5$

16. A ray of light is incident on a glass cube of side length a and refractive index $\sqrt{2}$. The angle of incidence is 30° . Find the time taken for the light to travel to the opposite face.

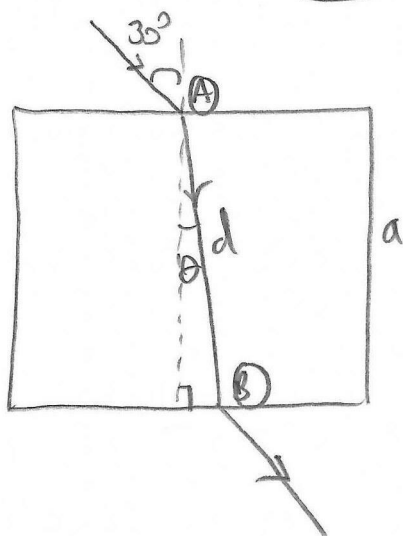
A $\sqrt{\frac{8a}{7c}}$

B $\frac{4a}{\sqrt{7}c}$

C $\frac{\sqrt{2}a}{3c}$

D $\frac{4a}{\sqrt{3}c}$

E $\frac{4a}{\sqrt{2}c}$



Now distance (A) $\rightarrow$ (B) is d

where $d \cos \theta = a$

Snell: $\sqrt{2} \sin \theta = \underbrace{1.0}_{\text{air outside cube}} \sin 30^\circ$

assume
air outside
cube

$\Rightarrow \sin \theta = \frac{1}{2\sqrt{2}}$

Time of flight (A) $\rightarrow$ (B) is $\Delta t = \frac{d}{\left(\frac{c}{\sqrt{2}}\right)}$

Gotcha!
Note speed
in glass is
 $\frac{c}{\sqrt{2}}$

So $\Delta t = \frac{a}{c} \frac{\sqrt{2}}{\cos \theta}$

$\sin^2 \theta + \cos^2 \theta = 1$

$\sin^2 \theta = \frac{1}{8} \quad \therefore \cos^2 \theta = 1 - \frac{1}{8} = \frac{7}{8}$

$\frac{1}{\cos \theta} = \sqrt{\frac{8}{7}}$

$\therefore \Delta t = \frac{a}{c} \sqrt{\frac{8}{7}} \Rightarrow \Delta t = \frac{4a}{c\sqrt{7}}$

17. An uncharged, isolated parallel plate capacitor has capacitance C . Monochromatic light of frequency f is incident on one of the metal plates, which has threshold frequency f_0 . Emitted photoelectrons are then captured by the other plate. Once the capacitor charge has reached a steady value, how many electrons have been transferred between the plates? (h is Planck's constant and e is the magnitude of the electron charge.)

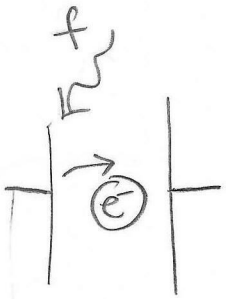
A $\frac{Ch(f+f_0)}{e}$

B $\frac{Cf_0(f+f_0)}{e^2}$

C $\frac{Ch(f-f_0)}{e}$

D $\frac{Cf(f+f_0)}{e^2}$

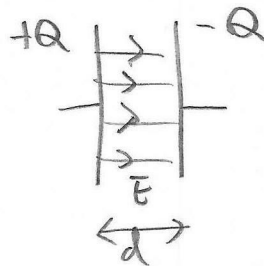
E $\frac{Ch(f-f_0)}{e^2}$



* Max KE of photoelectrons emitted is $h(f-f_0)$

* In steady state, assume voltage V developed across capacitor plates, and charge separated $Q = CV$

Isolated
Capacitor of
Capacitance C



Now electrons deposited on right plate will result in an opposing electric field to incoming electrons. 'Photo-current' between plates ceases when

$$eV = h(f-f_0)$$

↑ max KE

Work/electron to

overcome field $E = \frac{V}{d}$

so $Q = \frac{C \cdot h(f-f_0)}{e} \leftarrow V$

$\therefore$ # electrons transferred is $\frac{Q}{e} = \frac{Ch(f-f_0)}{e^2}$

[You might guess $f-f_0$ factor, and use $Q = CV$ and $V = \text{Energy/charge}$ to guess the correct $\frac{1}{e^2}$ factor]

18. Two particles are projected from ground level at the same speed v , but at two different angles to the horizontal: $(\frac{\pi}{4} + \alpha)$ and $(\frac{\pi}{4} - \alpha)$, where α itself is a small angle in radians. Find the difference between the horizontal ranges of the two particles.

if $\alpha \ll \frac{\pi}{4}$

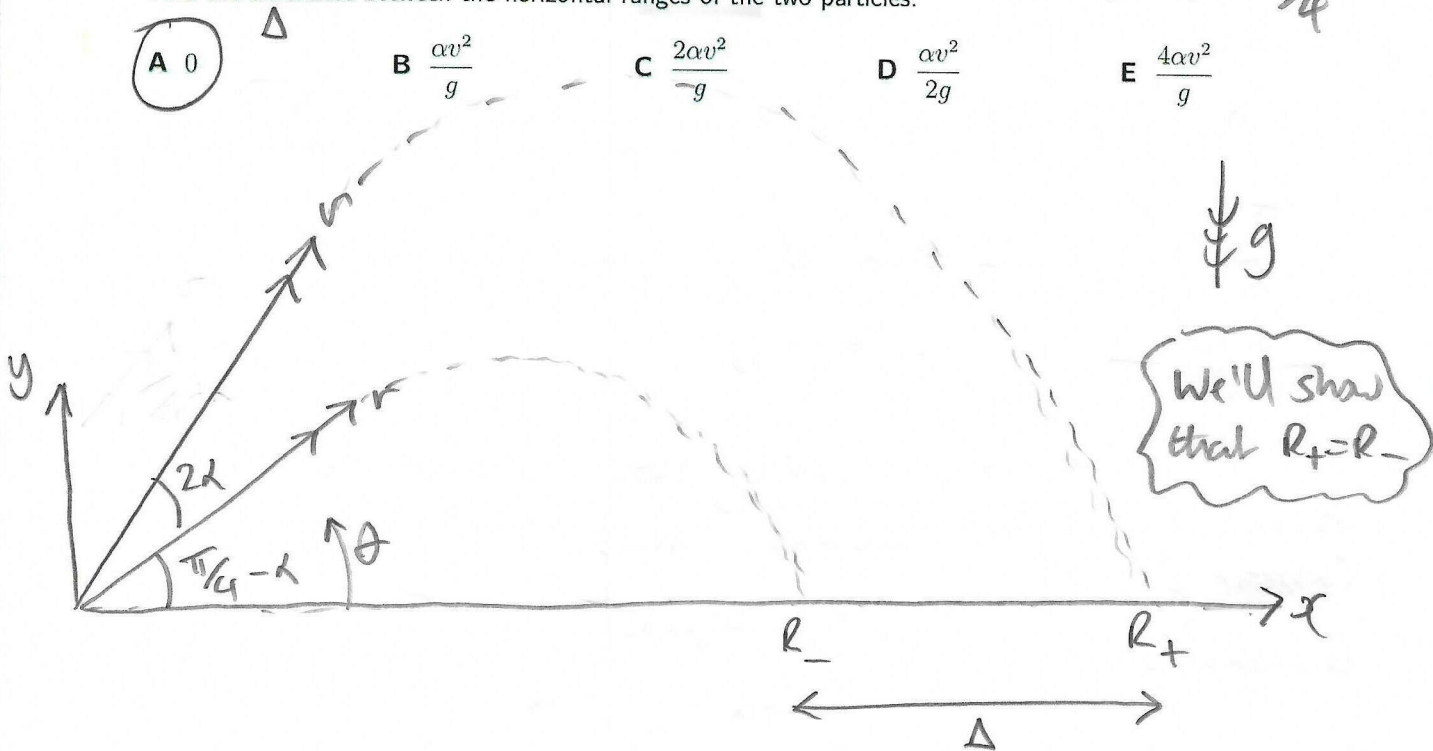
A 0

B $\frac{\alpha v^2}{g}$

C $\frac{2\alpha v^2}{g}$

D $\frac{\alpha v^2}{2g}$

E $\frac{4\alpha v^2}{g}$



Ignoring air resistance:

$$y = vt \sin \theta - \frac{1}{2}gt^2$$

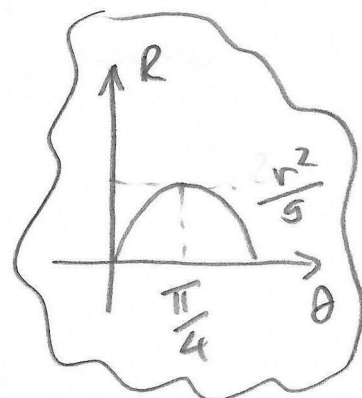
$$x = vt \cos \theta$$

{ projectile landed at elevation angle θ at speed v }

$y=0$ when $t=T$ and $x=R$

$$\therefore 0 = T(v \sin \theta - \frac{1}{2}gT) \Rightarrow T = \frac{2v \sin \theta}{g}$$

$$\therefore R = \frac{2v^2}{g} \sin \theta \cos \theta = \boxed{\frac{v^2}{g} \sin 2\theta}$$



$$\text{So } \Delta = \frac{v^2}{g} \left(\sin \left(\frac{\pi}{2} + 2\alpha \right) - \sin \left(\frac{\pi}{2} - 2\alpha \right) \right)$$

↑ This is the key graph.

$$= \frac{v^2}{g} \left[\sin \frac{\pi}{2} \cos(2\alpha) + \cos \frac{\pi}{2} \sin(2\alpha) - \sin \frac{\pi}{2} \cos(2\alpha) + \cos \frac{\pi}{2} \sin(2\alpha) \right]$$

$$= 0.$$

Don't need this step really!

Note you can see this by symmetry from $R = \frac{v^2}{g} \sin 2\theta$. Same R for $\pm \alpha$ either side of $\frac{\pi}{4}$

19. The half-life of a radioactive substance is T . What is the time taken for one third of the substance to decay?

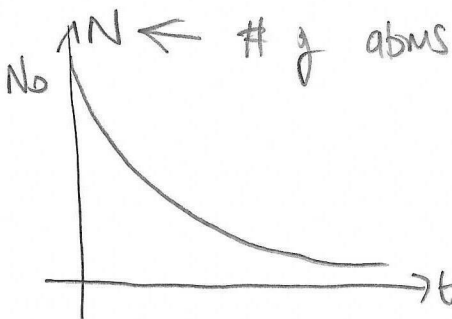
A $\frac{2}{3}T$

B $\sqrt{\frac{2}{3}}T$

C $T \log_2 \left(\frac{3}{2} \right)$

D $T \log_2(3)$

E $T^{\frac{2}{3}}$



$$N = \frac{N_0}{2^{t/T}}$$

ie "divide by 2 every t/T half lives"

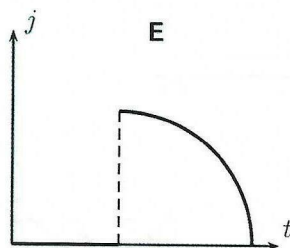
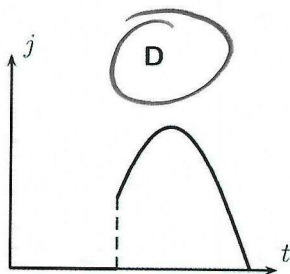
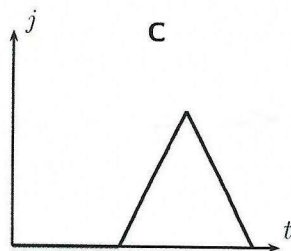
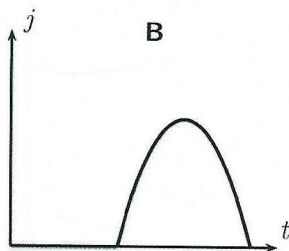
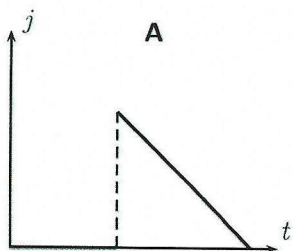
let $N = \frac{2N_0}{3}$ ie $\frac{1}{3} N_0$ has decayed.

$$\therefore \frac{2}{3} N_0 = \frac{N_0}{2^{t/T}} \Rightarrow 2^{t/T} = \frac{3}{2}$$

$$\therefore t = T \log_2 \left(\frac{3}{2} \right)$$

20. Jerk is defined as the rate of change of acceleration with respect to time, $j = \frac{da}{dt}$.

A bungee jumper attached to a slack rope falls from a height. Once the rope is taut, it acts as an ideal spring which subsequently brings the jumper to instantaneous rest. Which of the following graphs shows the magnitude of the jerk j as a function of time t , up to this moment?



* Free fall until rope is taut : $a = g$

$\therefore \frac{da}{dt} = 0$

* As spring extends, restoring force (upwards) is $-kx$
where x is downwards extension of spring

so $m_d = -kx + mg$ (NII)

$$\therefore \frac{da}{dt} = -\frac{k}{m} \left(\frac{dx}{dt} \right) \begin{matrix} +g \\ \uparrow \text{vechaly} \end{matrix}$$

Now jumper still falls due to gravity so magnitude of $v \uparrow$
 $\therefore j \uparrow$, but eventually $\propto$
 large enough to reduce j .

So I must
Start with a value
 > 0 .

← Size jumper only when type tant.

Energy of bungee jumper:

EXTRA!

$$E = \frac{1}{2} m u^2 = \frac{1}{2} m v^2 + \frac{1}{2} k x^2 - m g x$$

KE when
rope taut

i.e. $m g L$ where
 L is length of rope

$$\text{so } 2 g L = v^2 + \frac{k x^2}{m} - 2 g x$$

$$\therefore v^2 = 2 g (L + x) - \frac{k x^2}{m}$$

$$\therefore v = \sqrt{2 g (L + x) - \frac{k x^2}{m}}$$

This is ∇ until $2 g (L + x) = \frac{k x^2}{m}$

$$\Rightarrow x^2 = \frac{2 m g}{k} (L + x)$$

$$\Rightarrow x^2 - \frac{2 m g}{k} x - \frac{2 m g L}{k} = 0$$

$$\Rightarrow \left(x - \frac{m g}{k} \right)^2 - \frac{m^2 g^2}{k^2} - \frac{2 m g L}{k} = 0$$

$$\Rightarrow x = \frac{m g}{k} + \sqrt{\frac{m^2 g^2}{k^2} + \frac{2 m g L}{k}}$$

$$\left[\begin{array}{l} v = \frac{dx}{dt} \\ \therefore t = \int \frac{1}{v} dx \\ \dots \text{might be} \\ \text{analytic!} \end{array} \right.$$

Max extension
when $v = 0$

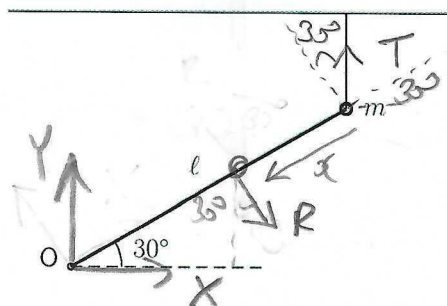
$$\text{so } j = \frac{k}{m} \sqrt{2 g (L + x) - \frac{k x^2}{m}} \quad x=0, j = \frac{k}{m} \sqrt{2 g L}$$

$\uparrow$
upwards

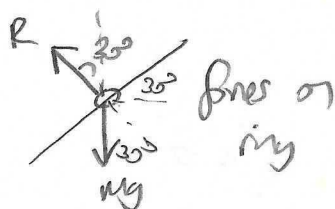
$[j = -\frac{k}{m} v]$

21. A light inextensible string is attached to one end of a rigid rod of negligible weight and of length ℓ , with its other end freely hinged at O. The other end of the string is attached to the ceiling, so that the string is vertical, and the rod makes an angle of 30° to the horizontal. A small smooth ring of mass m is released from rest at the upper end of the rod and slides downwards along it.

Three free
on $\uparrow$ and
 $\rightarrow$ components)



no friction as it
slides



Given that the tension in the string T at time t (while the ring is in motion) is $T = mg(1 - kt^2)$, select the correct expression for k .

☒ A $\frac{g}{4\ell}$

B $\frac{g}{2\ell}$

C $\frac{g}{\ell}$

D $\frac{g}{\sqrt{2}\ell}$

E $\frac{\sqrt{3}g}{2\ell}$

Assume rod remains in equilibrium: taking moments

about O: $0 = T \cos 30^\circ \times \ell - R(\ell - x)$

$\hookrightarrow +$

$\therefore$

$$T = \frac{R(\ell - x)}{\ell \sqrt{3}/2}$$

$$= \frac{2R}{\sqrt{3}} \frac{\ell - x}{\ell}$$

Forces on ring:

NIH // rod: $M\ddot{x} = mg \sin 30^\circ$

$$\Rightarrow \ddot{x} = \frac{g}{2}$$

$$\Rightarrow \dot{x} = \frac{gt}{2}$$

$$\Rightarrow x = \frac{1}{4}gt^2$$

$\perp$ rod: $0 = R - mg \cos 30^\circ$

$$\therefore R = mg \frac{\sqrt{3}}{2}$$

so $T = mg \left(1 - \frac{x}{\ell}\right)$

$$\therefore T = mg \left(1 - \frac{\frac{1}{4}gt^2}{\ell}\right)$$

$$\therefore k = \frac{g}{4\ell}$$

22. A conical pendulum consists of a bob attached to a light inextensible string of length ℓ , with the upper end fixed. The bob moves in a horizontal circle so that the string makes an angle of 30° to the vertical. By what factor must the angular frequency be increased for this angle to double to 60° ?

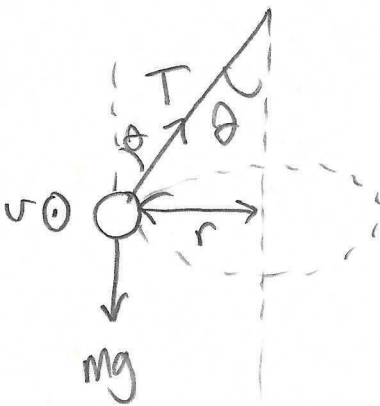
A $\sqrt{\sqrt{3}}$

B $\sqrt{2}$

C $\sqrt{3}$

D 2

E 3



Net: $T \cos \theta = mg$

(vertical)

$mr\omega^2 = T \sin \theta$

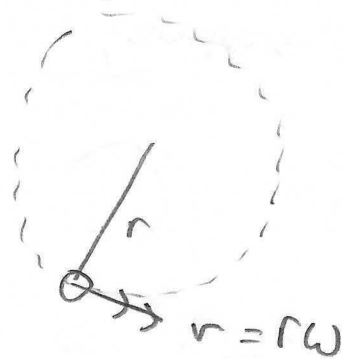
(radially inwards)

So $T = mg / \cos \theta$

$\therefore mr\omega^2 = mg \tan \theta$

$\therefore \omega^2 = \frac{g}{r} \tan \theta$

$\therefore \omega = \sqrt{\frac{g}{r} \tan \theta}$



Now assume string length is fixed

so $\ell \sin \theta = r$

$\therefore \omega = \sqrt{\frac{g \tan \theta}{\ell \sin \theta}} = \boxed{\sqrt{\frac{g}{\ell} \frac{1}{\cos \theta}}}$

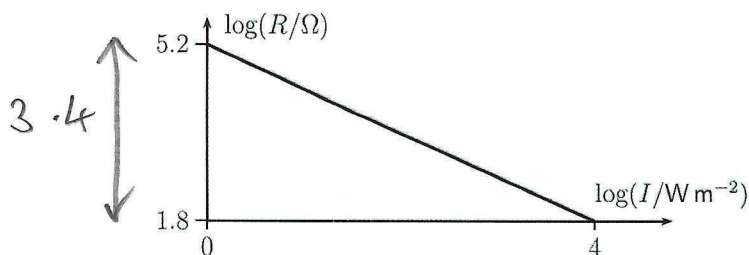


$\omega_0 = \sqrt{\frac{g}{\ell}} \sqrt{\frac{1}{\cos 30^\circ}}$

So $\frac{\omega_1}{\omega_0} = \sqrt{\frac{\cos 30^\circ}{\cos 60^\circ}} = \sqrt{\frac{\sqrt{3}/2}{1/2}} = \boxed{\sqrt{\sqrt{3}}}$

$\omega_1 = \sqrt{\frac{g}{\ell}} \sqrt{\frac{1}{\cos 60^\circ}}$

23. The resistance R of a light-dependent resistor (LDR) depends on the light intensity I . A logarithmic plot relating these variables is shown below.



A point light source placed a distance d from the LDR illuminates it, and its resistance is measured to be R_0 . Which of the following is a good approximation for the LDR resistance when the distance to the light source is halved?

A $0.1R_0$

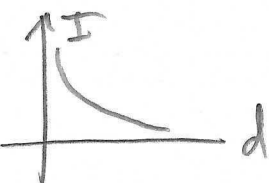
B $0.3R_0$

C $0.5R_0$

D $0.7R_0$

E $0.9R_0$

Assume inverse-square law for light $I = \frac{k}{d^2}$



$$\text{so } \log R_0 = 5.2 - \frac{3.4}{4} \log \left(\frac{k}{d^2} \right)$$

$$\log R_0 = 5.2 - 0.85 \log k + 1.7 \log d$$

let $d \rightarrow d/2$, $R_0 \rightarrow R$

$$\therefore \log R = 5.2 - 0.85 \log k + 1.7 \log d - 1.7 \times \log 2$$

$$\text{so } \log R - \log R_0 = -1.7 \log 2$$

$$\therefore \log \left(\frac{R}{R_0} \right) = \log (2^{-1.7})$$

$$\therefore R \approx 0.31 R_0$$

24. A uniform ladder of mass m rests against a wall in static equilibrium at an angle of 45° to the vertical. The base of the ladder is pushed a small distance a towards the wall. Which of these options gives the best approximation for the change in gravitational potential energy of the ladder?

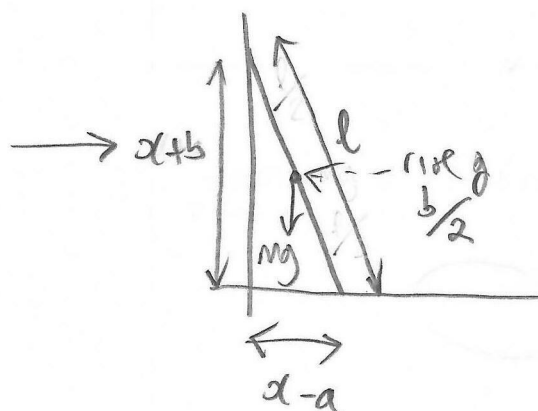
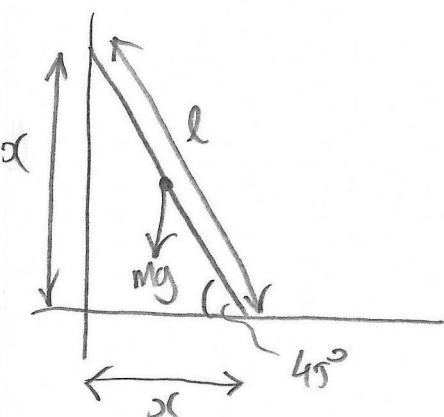
A $\frac{1}{2}mga$

B $\frac{1}{\sqrt{2}}mga$

C mga

D $\sqrt{2}mga$

E $2mga$



Push ladder towards wall by a

tip rises by b .

Pythagoras: $l^2 = 2x^2 \quad \therefore x = \frac{l}{\sqrt{2}}$

$[2x^2 = l^2]$

$l^2 = (x+b)^2 + (x-a)^2$

$l^2 = x^2 + 2bx + b^2 + x^2 - 2ax + a^2$

$l^2 = 2x^2 + (2b-2a)x + b^2 + a^2$

So $b^2 + \frac{2bl}{\sqrt{2}} - \frac{2al}{\sqrt{2}} + a^2 = 0$

$\left(b + \frac{l}{\sqrt{2}}\right)^2 - \frac{l^2}{2} - \frac{2al}{\sqrt{2}} + a^2 = 0$

$\therefore b = \sqrt{\frac{l^2}{2} + \frac{2al}{\sqrt{2}} - a^2} - \frac{l}{\sqrt{2}}$

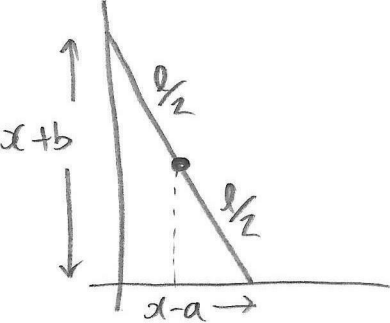
CM is half way along the ladder

and GPE gain is $\boxed{\frac{1}{2}mgb}$ < if $a \ll l$ ignore a^2 term

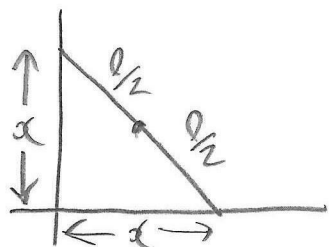
then $b \approx \frac{l}{\sqrt{2}} \left(\left(1 + \frac{4a}{l\sqrt{2}}\right)^{\frac{1}{2}} - 1 \right) \approx \frac{l}{\sqrt{2}} \left(\frac{2a}{l\sqrt{2}} \right) \approx a$

↑ Binomially expand

So GPE gain is $\boxed{\frac{1}{2}mga}$



COM at $\left(\frac{x}{2} - \frac{a}{2}, \frac{x}{2} + \frac{b}{2}\right)$



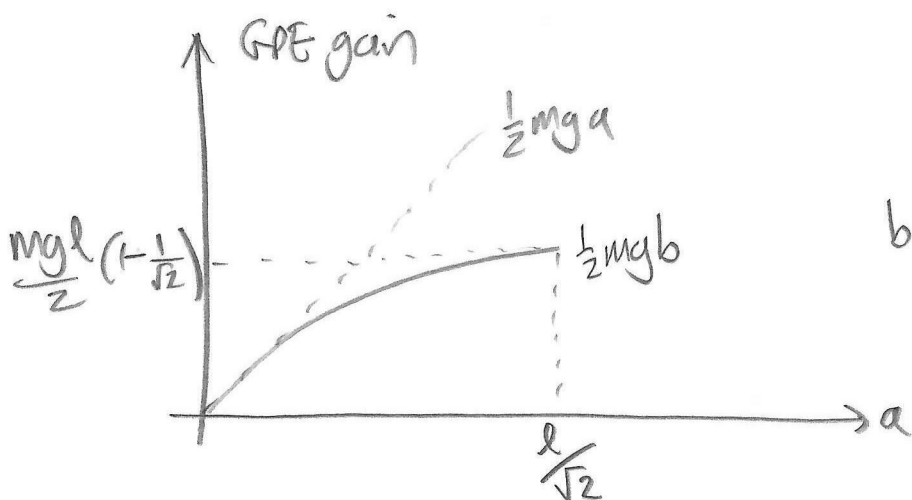
COM at $\left(\frac{x}{2}, \frac{x}{2}\right)$

$x = \frac{l}{\sqrt{2}}$

So rise of $\bullet$ is $\frac{b}{2}$, not b .

So actually this is the insight which yields the $\frac{1}{2}mga$ (rather than mga).

In the limit of small a , $b \approx a$ is a sensible guess

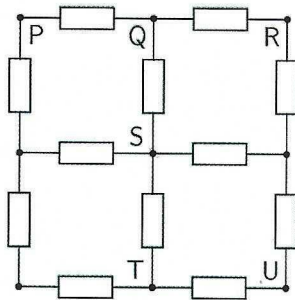


$$b = \sqrt{\frac{l^2}{2} + \frac{2al}{\sqrt{2}} - a^2} - \frac{l}{\sqrt{2}}$$

when $a = \frac{l}{\sqrt{2}}$,
(ie vertical at wall)

COM is at $\frac{l}{2}$. Height gain is $\frac{l}{2} - \frac{l}{2\sqrt{2}} \Rightarrow$ Max GPE gain is $\frac{mgl}{2} \left(1 - \frac{1}{\sqrt{2}}\right)$

25. Consider the arrangement of 12 identical resistors below. The equivalent resistance is measured between the following pairs of points: PR, PS, PU, QS, QT. Which measurement gives the median (middle value) resistance?



A PR

B PS

C PU

D QS

E QT