Pg 1

Part A:

2.

i) $F_c$ means "centripetal Force:" the force that points in toward the centre of the circle when an object is moving with circular motion.

ii) k is the spring constant: a measure of the stiffness of a spring.

iii) $a_c$ means "centripetal acceleration." $a_c = F_c/m$.

iv) $v_f$ means "final velocity," the 'initial' and 'final' points being defined by the time, $t$.

v) $\Delta E_p$ means "the change in Gravitational Potential Energy" when an object gains or loses height ($\Delta h$).

3. i) $p = 62 \times 3.25 = 201.5 \text{ kgms}^{-1}$

since "62" is 2sf, answer is to 2sf

$p \doteq 200 \text{ kgms}^{-1}$ (2sf)

ii) $F = 2.0 \times 0.2 = 0.4$ N

since "0.2" is 1sf, answer is to 1sf.

$F = 0.4$ N (1sf)

iii) $v_{ave} = 0.34 \mu m / 12 ns = \frac{0.34 \times 10^{-6}}{12 \times 10^{-9}} = 28.333 \text{ ms}^{-1}$

Since both pieces of information are 2sf, answer is to 2sf.

$v_{ave} = 28 \text{ ms}^{-1}$

Part B:

1. i) $t = 8$, $v_i = 0$, $a = 0.3$ $v_f = ?$ use $v_f = v_i + at$

$v_f = 0 + 0.3 \times 8 = 2.4$ s $= 2$ s (1sf)

ii) $d = 6$, $v_i = 0.4$, $v_f = 0.7$, $t = ?$ use $d = \frac{(v_i + v_f)}{2} t$

$d = \frac{v_i + v_f}{2} t \Rightarrow 2d = (v_i + v_f)t \Rightarrow \frac{2d}{v_i + v_f} = t$

$t = \frac{2d}{v_i + v_f} = \frac{2 \times 6}{0.4 + 0.7} = \frac{12}{1.1} = 10.909$

$= 10$ s (1sf)

iii) $a = 0.2$, $d = 11$, $v_f = 2.2$, $v_i = ?$ use $v_f^2 = v_i^2 + 2ad$

$v_f^2 = v_i^2 + 2ad \Rightarrow v_i^2 = v_f^2 - 2ad \Rightarrow v_i = \sqrt{v_f^2 - 2ad}$

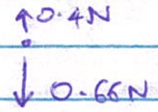
$v_i = \sqrt{(2.2)^2 - 2 \times 0.2 \times 11} = 2.09$

$= 2 \text{ ms}^{-1}$ (1sf)

Pg 2

2\. i) $F_g = mg = 0.067 \times 9.81 = 0.657 = 0.66\,N$ (2sf)

ii)

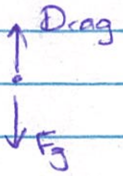



$F_{NET} = 0.66 - 0.4 = 0.26\,N$

iii) $a = F/M = 0.26/0.067 = 3.88$

$= 3.9\,ms^{-2}$ (2sf)

iv)




Eventually the pebble falls at a constant speed. As the pebble accelerates (which happens while $F_g > F_{drag}$), the speed increases. Since drag is proportional to speed, the drag will increase until it is equal to the weight force. Now the forces are balanced and the pebble falls at constant velocity (Newton's first law). This is called the terminal velocity.

v) At terminal velocity, $F_{DRAG} = F_g = 0.66\,N$.

$F = 0.2v^2 \Rightarrow v = \sqrt{\frac{F}{0.2}} = \frac{0.66}{0.2} = 6.58 = 6.6\,ms^{-1}$ (2sf)

*Q3 was taken out*

4\. i) diagram 1: D and E are possible

diagram 2: A and B are possible

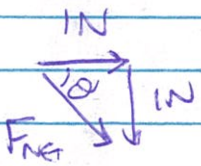
diagram 3: None, since there must be some acceleration downwards, motion fully to the left is not possible.

ii) d1: $F_{NET} = 1N$ right

d2: $F_{NET} = 0N$

d3: $(F_{NET})_x = 1N$ right

$(F_{NET})_y = 1N$ down

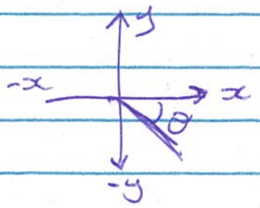



$|F_{NET}| = \sqrt{1^2 + 1^2} = \sqrt{2}\,N$

$\theta = \tan^{-1}(1) = 45°$

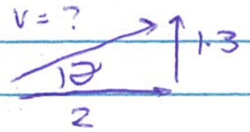
* NOTE: $|F|$ means "size of F"

So $\bar{F}_{NET} = \sqrt{2}\,N$, 45° below the "+ve x" axis



## Part C:

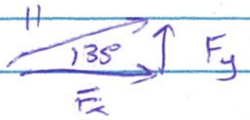
1\. i)




$|V| = \sqrt{2^2 + 1.3^2} = 2.385 = 2.4\ ms^{-1}$ (2sf)

$\theta = \tan^{-1}\left(\frac{1.3}{2}\right) = 32.75 = 33°$ (2sf)

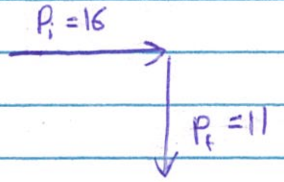
ii)



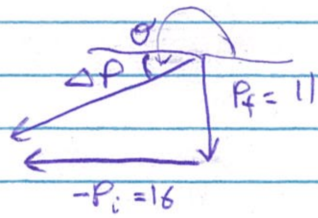

$\sin\theta = F_y/11$ $\qquad F_y = 11 \sin 35 = 6.3N$

$\cos\theta = F_x/11$ $\qquad F_x = 11 \cos 35 = 9.0N$

iii)




$\Delta p = p_f - p_i = p_f + (-p_i)$



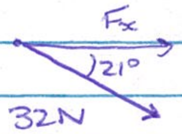

$\Delta p = \sqrt{16^2 + 11^2}$

$= 19.41 = 19\ kgms^{-1}$ (2sf)

$\theta = \tan^{-1}(11/16) = 34°$

(technically $\theta = 214°$, since we conventionally measure anti-clockwise from the "+ve x" axis.

2\. i)




ii) Pushing horizontally means $W = F_x \times d$

$= 32\cos(21) \times 17$

$= 507.87$

$= 510\ J$ (2sf)

Challenge:

without push: $F_s = F_g = 490.5N$

$F_g = mg = 50 \times 9.81 = 490.5N$

with push: $F_s = F_g + F_x = 490.5 + 32\sin(21)$

$= 501.97$

$F_x \quad F_g$

$\frac{(501.97 - 490.5)}{490.5} \times 100 = 2.3\%$

Pg 4.

## Part D:

1. i) $a_x = 0\ ms^{-2}$ (usually the case for projectile motion)

ii) $V_x = \Delta x / \Delta t = 230/6 = 38.3 = 38 ms^{-1}$ (2sf)

iii) $a_y = g = -9.81\ ms^{-2}$ (ALWAYS for projectile motion!)

iv) use $a_y = -9.81$, $(v_f)_y = 0$, $t = 3$ seconds (half time: to top)

i.e $t = 6/2 = 3$ seconds

v) as above, so use $V_f = 0$, ...

vi) therefore $d = V_i t + \frac{1}{2} a t^2$

$V_i$ unknown so can use $d = v_f - \frac{1}{2} a t^2$ ← NOT given but handy to remember

$d = 0 - \frac{1}{2} \times -9.81 \times 3^2$

$= 44.145$

$= 44 m$ (2sf)

*[Alternatively make $V_i = 0$, i.e. top is initial point, landing is final point (as opposed to above, where take-off is initial point, top is final point.) Advantage is you can use $d = v_i t + \frac{1}{2} a t^2$ which is given. You will get a -ve distance to indicate the ball travels the -ve direction (downwards)].*

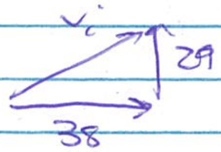
vii) $V_f = 0$; $a = -9.81$; $t = 3$ use $V_f = v_i + at$

$V_i = V_f - at = 0 - (-9.81 \times 3) = 29.43 = 29 ms^{-1}$

(Notice the answer is +ve, for upwards motion).

(could also use answer from vi) and $v_f^2 = v_i^2 + 2ad$).

viii) $(V_i)_x = 38 ms^{-1}$ $(V_i)_y = 29 ms^{-1}$

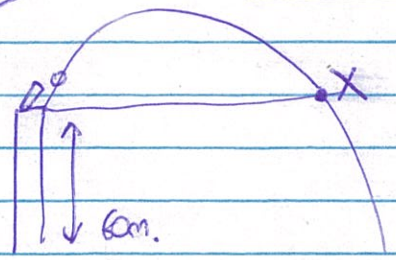


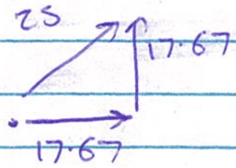

$V_i = \sqrt{38^2 + 29^2} = 47.8 = 48 ms^{-1}$ (2sf)

ix) $\theta = \tan^{-1}(29/38) = 36.8 = 39°$ (2sf)

$\boxed{\text{ANS} = 101\text{M}}$

2.




(NOTE $v_x = v_y$ because 45°)

Step 1: time to point X.

$v_i = 25\,ms^{-1}$ at 45°, so $(v_i)_y = 17.67\,ms^{-1}$.

Time to top: use $v_f = v_i + at$

$t = \dfrac{v_f - v_i}{a} = \dfrac{0 - 17.67}{-9.81}$

$= 1.80$ seconds

$\therefore$ time to point $X = 2t_{top} = 3.60$ seconds

{incidentally, $d = v_i t + \frac{1}{2}at^2 = 17.67 \times 1.8 + \frac{1}{2} \times -9.81 \times 1.8^2$
$= 15.9m$ gives h above cliff, so
$h_{max} = 60 + 15.9 = 75.9m$ }

Step 2: Time from X to ground.

$v_i = -17.67\,ms^{-1}$ (due to symmetry → or can calculate using any number of equations!)

$d = 60$

$a = -9.81$

$t = ?$

use either:

2 equations:

$v_f^2 = v_i^2 + 2ad$

negative (cancel out)

$= (-17.67)^2 + (-9.81 \times 2 \times 60)$

$= -38.59\,ms^{-1}$

(note: -ve since $v_f = \pm\sqrt{v_f^2}$, need to "choose" -ve because you know it's moving down)

now $v_f = v_i + at$

$t = \dfrac{v_f - v_i}{a} = \dfrac{(-38.59 - (-17.67))}{-9.81}$

$= 2.13\,s$

or:

Level 2 algebra:

$d = v_i t + \frac{1}{2}at^2$.

$\frac{1}{2}at^2 + v_i t - d = 0$ (quadratic)

$t = \dfrac{-v_i \pm \sqrt{v_i^2 - 4 \times \frac{1}{2}a \times d}}{a}$

$= \dfrac{-(-17.67) \pm \sqrt{(17.67)^2 - 2 \times -9.81 \times 60}}{-9.81}$

$= 2.13\,s$ (choose the +ve answer)

CAN ALSO SOLVE ON GRAPHIC CALCULATOR

Step 3: $t_{total} = 3.6 + 2.13$
$= 5.73\,s.$

so $d = v_x t = 17.67 \times 5.73$
$= 101.2 = 101M$

Part E:

1. i) $a_c = \frac{v^2}{r}$ $\quad V = 240\ kmh^{-1} = \frac{240}{3.6} = 66.67 ms^{-1}$

$= \frac{(66.67)^2}{11} = 404\ ms^{-2}$ (or 41g. Perhaps not very realistic => should be a larger radius corner)

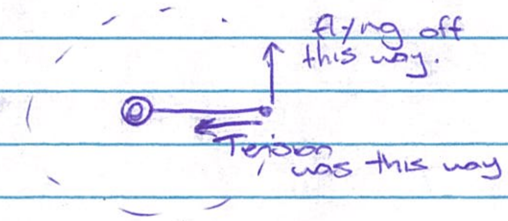
$F_c = \frac{mv^2}{r} = ma_c$

$= 263\ kN.$ (again, unrealistic)

ii) Toward the centre of the corner


iii) Friction between the tyres and the road.

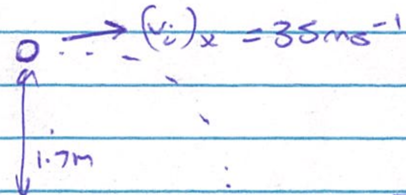
2. i) and ii)




iii) $T = F_c = \frac{mv^2}{r} = \frac{7 \times 18^2}{0.9} = 2.52\ kN$

iv) $V = \sqrt{\frac{F_c r}{m}} = \sqrt{\frac{9500 \times 0.9}{7}} = 34.9 = 35 ms^{-1}$

v) Projectile motion!




vertical:
$v_i = 0$
$a = -9.81$
$d = 1.7$
$t = ?$

use
$d = v_i t + \frac{1}{2}at^2$
thankfully this time, $v_i = 0$ (no quadratic!)

$t = \sqrt{2d/a} = \sqrt{\frac{2 \times -1.7}{-9.81}}$

$= 0.59$ sec.

So $x = v_x t = 35 \times 0.59 = 20.6$ m.

Pg 7.

Part F:

1\. i) $F = -kx = 23 \times 0.04 = -0.92N$ (i.e. opposite to stretch direction, 0.92N)

ii) Right

iii) $E_{spring} = \frac{1}{2}kx^2 = \frac{1}{2} \times 23 \times 0.04^2 = 0.0184 = 0.018J$

2.) $k = \frac{F}{x} = \frac{mg}{x} = \frac{0.250 \times 9.81}{0.02}$

$= 122.63 = 122Nm^{-1}$

3\. i) $E_{GP} = mgh = 65 \times 9.81 \times 43 = 27.418\ kJ$

ii) $x = 43 - 11 = 32m$

iii) At the bottom, all gravitational potential is now elastic potential:

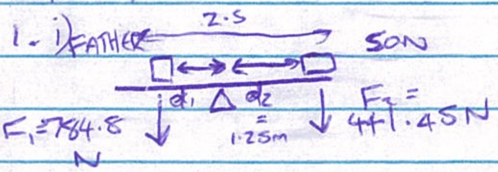
$E_{GP} = E_{E.P.}$

$\frac{1}{2}kx^2 = E_{GP.}$

$k = \frac{2E}{x^2} = \frac{2 \times 27.418 \times 10^3}{32^2} = 53.55 = 54Nm^{-1}$

Part G:

1\. i)




ii) Torque is a force applied at some (perpendicular) distance from a pivot. An unbalanced net torque will cause rotation.

iii) $\tau = 441.45 \times 1.25 = 551.8$ Nm clockwise (by my diagram)

iv) $\tau_F = \tau_S$

$F_1 d_1 = F_2 d_2$

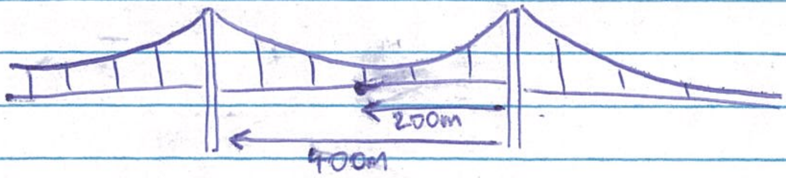
$d_1 = \frac{F_2 d_2}{F_1} = \frac{441.45 \times 1.25}{784.8} = 0.70m = 70cm$

so he moves $1.25 - 0.7 = 0.55$, 55cm forward.

v) For equilibrium, the sum of the total (clockwise and anticlockwise) torques must be equal. So $F_1 d_1 = F_2 d_2$. If dad moves in, $d_2$ decreases, the torque provided by the father decreases, so $\tau_2 > \tau_1$ and the see-saw rotates (clockwise by my diagram.

Pg8.

2. i)




ii) Downward Force $= mg = 5\times10^6$ N

$\therefore$ Total upward Force $= 5\times10^6$ N

so $2.5\times10^6$ N each support.

Can also use torque to work this out:

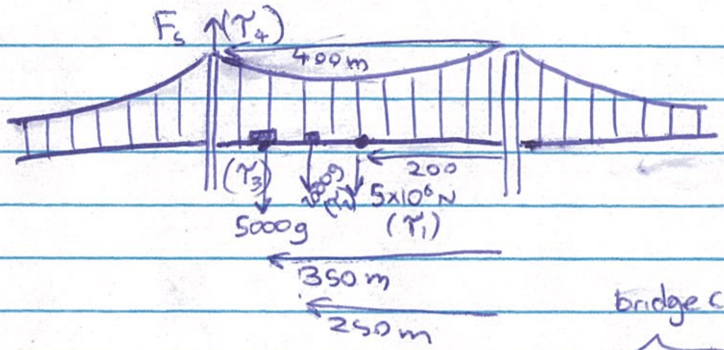
using R.H. Tower as a pivot:

$\tau_{ac}$ (from mass of bridge) $= F.d = 5\times10^6 \times 200 = 10^9$ Nm

$\therefore \tau_c = 10^9$ Nm (from L.H. tower) $= F.d$

$F = \tau_c / d = 10^9/400 = 2.5\times10^6$ N

iii)




Anticlockwise: $\tau_1 + \tau_2 + \tau_3 = \underbrace{5\times10^6\times200}_{\text{bridge C.O.M}} + \underbrace{19620\times250}_{\text{car}} + \underbrace{49050\times350}_{\text{truck}}$

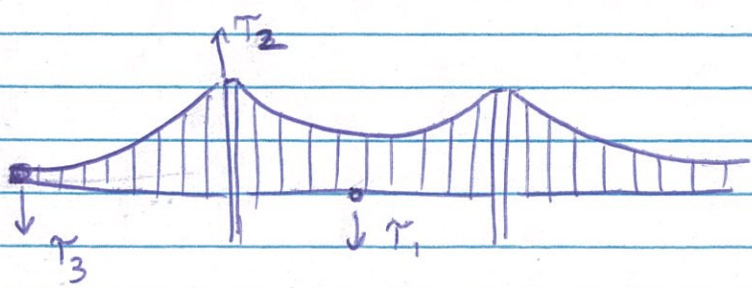
$= 1.02\times10^9$ Nm

Clockwise $= \tau_4 = F_s\times400 = \tau_{anticlockwise}$

$F_s = \tau_a/400$

$= 1.02\times10^9/400 = 2.56\times10^6$ Nm

iv)




Limit: $\tau_1 + \tau_3 = \tau_2$

$\tau_3 = \tau_2 - \tau_1$

$= 6\times10^6\times400 - 5\times10^6\times200$

$= 1.4\times10^9$ Nm

$\therefore F_{max} = \dfrac{1.4\times10^9}{550}$

$= 2.5\times10^6$ kg

$= 2500$T object.

Pg 9.

Part H:

1\. i) $E_K = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.05 \times 25^2 = 15.63 = 15.6J$

ii) $E_{GP} = mgh = 70 \times 9.81 \times 10 = 6.867 \times 10^3 = 6.9kJ$

iii) $E_{EP} = \frac{1}{2}kx^2 = \frac{1}{2} \times 16 \times 0.11^2 = 0.0968 = 0.10 J$ (2sf)

2\. i) Total height $= 25 + 1.5 = 26.5$

$E_{gp} = mgh = 0.140 \times 9.81 \times 26.5$
$= 36.4 J$

ii) Already was at 1.5m, gained 25m.
Thus gained $E_{GP} = mgh = 0.140 \times 9.81 \times 25 = 34.3 J$ of gravitational energy.
This was originally kinetic:

$(E_{GP})_{final} = (E_k)_{initial} = \frac{1}{2}mv^2$

$v_{initial} = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 34.3}{0.14}} = 22.1 ms^{-1}$

iii) From 26.5 to 0.5m, loses 26m.
So $\Delta E_{GP} = 0.14 \times 9.81 \times 26 = 35.7 J$
All converted to kinetic.
$\therefore v = \sqrt{\frac{2 \times 35.7}{0.14}} = 22.6 ms^{-1}$

iv) Smith has a point because the energy gained depends on vertical height gained only: No work is done against gravity to move the ball horizontally, and so the calculations should be the same.
Richardson also has a point because the ball does travel a further distance overall, meaning more energy will be lost overall to heat due to air resistance.
In this case, the correct speed will be slightly less than what was calculated in iii) for the ball going straight up, and slightly less again for the ball going to the boundary.

3\. i) Assume all initial gravitational is converted to elastic energy (via kinetic): gravitational → kinetic → elastic
So $mgh = \frac{1}{2}kx^2$

$k = 2mgh/x^2 = 2 \times 0.2 \times 9.81 \times 1 / 0.1^2$
$= 392.4 \text{ Nm}$

ii) Again, $E_{GP} = E_{EP}$ $\Rightarrow mgh = \frac{1}{2}kx^2$

$$x = \sqrt{\frac{2mgh}{k}} = \sqrt{\frac{2 \times 0.2 \times 9.81 \times 6}{392.4}} = 0.24 \quad (24\text{ cm})$$

iii) Because the assumption that all gravitational potential energy is converted to kinetic and then elastic potential is not correct. Some energy is lost to heat due to air resistance.

Part I:

1. i) $p = mv = 0.06 \times 11 = 0.66\ \text{kgms}^{-1}$

ii) $v = p/m = 0.66/0.045 = 14.67\ \text{ms}^{-1}$

iii) ~~The egg/golf ball~~
Both objects have a momentum of $0.66\ \text{kgms}^{-1}$. Assume that in both cases the object stops dead, i.e. it has no momentum after it hits your face. So $p_f = 0$, so $\Delta p = p_f - p_i = -0.66\ \text{kgms}^{-1}$ for both.
Since impulse is $J = \Delta p$, both have the same impulse. But $J = F\Delta t$. Since the egg breaks but the golf ball is hard, the egg collision lasts longer, meaning a lower force is needed to achieve the same impulse, and it hurts less.

iv) $\Delta p = p_f - p_i = (0.045 \times 12) - 0.66 = -0.12\ \text{kgms}^{-1}$

v) $\Delta p = \text{area under graph} = \frac{1}{2} b \times h = \frac{1}{2} F_{max} \times \Delta t = 0.12$

$$F_{max} = \frac{2 \times 0.12}{4 \times 10^{-3}} = 60$$

$\Rightarrow$ whoops it should be 60N, my bad. $\Leftarrow$

vi) $F_{AVE} = \Delta p / \Delta t = 0.12/0.004 = 30\text{N}$

Pg 11.

2. i) Since there is no friction, there is no net external force involved as the ball rolls → this means that there is no acceleration and speed stays constant. Another way to look at it is that since there are no forces, momentum is conserved, i.e $\Delta p = 0$, so velocity does not change.

ii) No external forces during this collision ($F_{\text{ball on pin}}$ is equal to $F_{\text{pin on ball}}$).
So momentum is conserved / $\Delta p = 0$ / $p_i = p_f$.

Initial: $p_i = (p_i)_{ball} + (p_i)_{pin} = 5 \times 4 + 0 = 20\,kgms^{-1}$

final: $p_f = (p_f)_{ball} + (p_f)_{pin} = 5 \times 2.4 + (p_f)_{pin} = 20$

$(p_f)_{pin} = 20 - 12$
$= 8\,kgms^{-1}$

$(p_f)_{pin} = mv = 1 \times v \therefore v = 8\,ms^{-1}$

iii) The wall is connected the the ground, so that there is a net external Force.