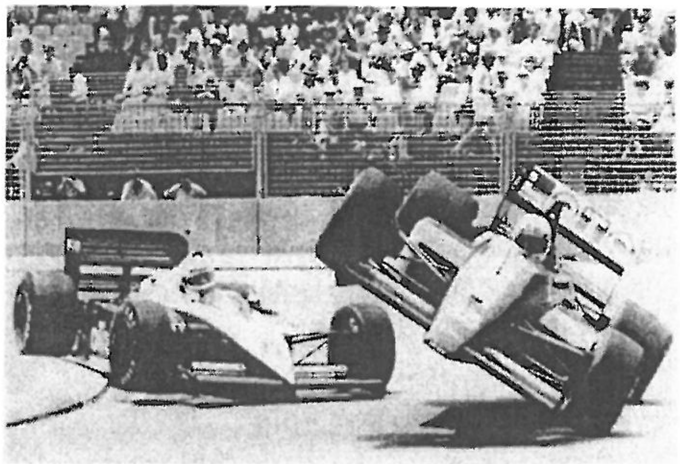
Q1 [4 marks]

Consider the design features of a formula one racing car that help to prevent it from toppling over when taking bends at high speeds.



Carefully describe and explain what happens in terms of STABILITY.

- WIDE BASE / VERY LOW CENTRE OF GRAVITY
- MOST OF THE MASS IS DISTRIBUTED IN SUCH A WAY AS TO CREATE A LOW CENTRE OF GRAVITY.
- SINCE THE WHEELS PROVIDE A WIDE BASE, A VERY LARGE ANGLE OF DEFLECTION WOULD BE REQUIRED TO POSITION THE C.O.G BEYOND THE BASE IN ORDER TO PRODUCE ENOUGH TORQUE TO TOPPLE OVER.
- THE CAR, THEREFORE, TENDS TO TIP (TURN) BACK ONTO ITS PREFERRED BASE (RESTORING TORQUE) SHOULD IT TURN AT HIGH SPEED AS SHOWN (STABLE EQUILIBRIUM)

- THE AERODYNAMIC DESIGN CREATES A DOWNWARD THRUST VIA THE REAR SPOILER ETC, MAKING IT HARDER TO TIP OVER.

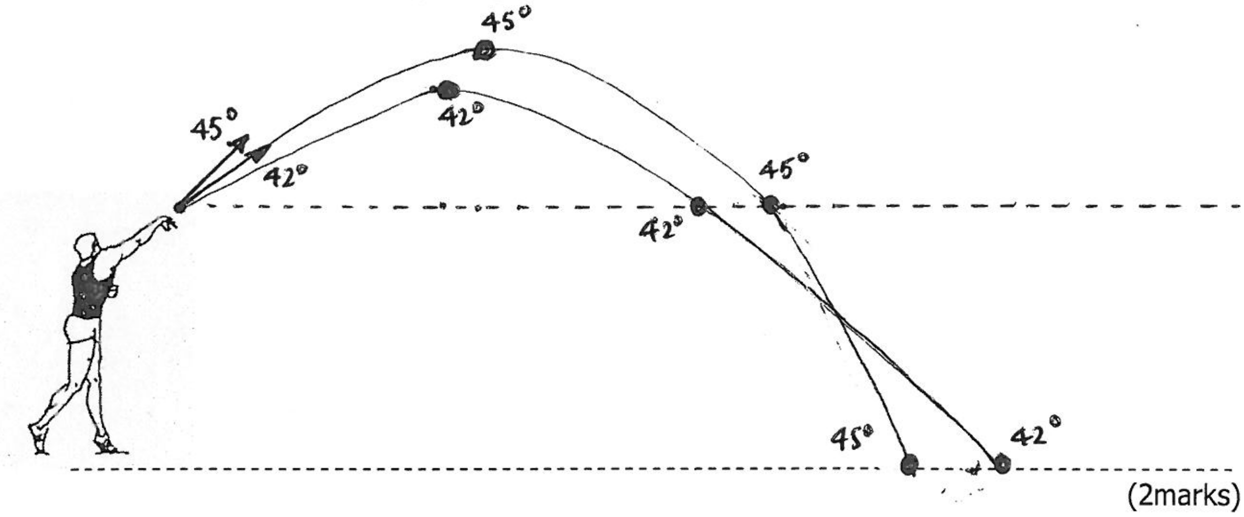
(4marks)

Q2 [6 marks]

Physicists have shown mathematically that when an object is launched from the ground it will cover a maximum distance if it has an elevation of 45° above the horizontal.

However, a shot-putter knows that a maximum distance can be obtained when the shot is released at an angle of 42° above the horizontal.

2a) Ignoring the effects of air resistance, carefully illustrate the trajectories of shots released at 45° and 42° at the same speed (on the diagram below).



(2marks)

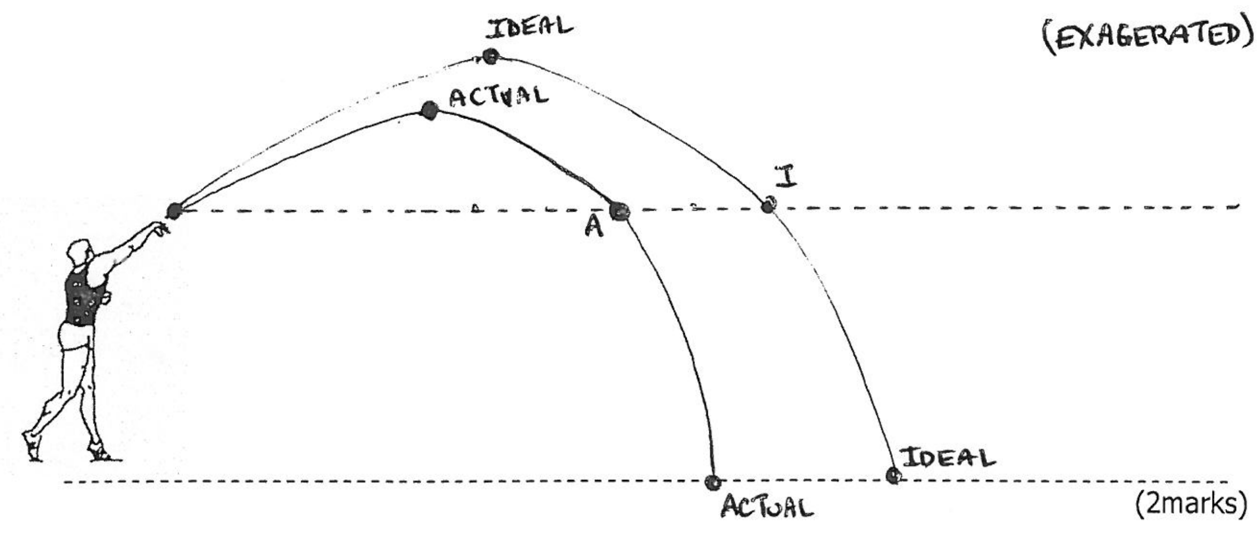
2b) Describe the most significant factors that will influence the optimum angle of release of the shot to achieve the maximum range.

- TIME OF FLIGHT (ENHANCED BY RELEASE ABOVE GROUND)
- HORIZONTAL VELOCITY

(BIOMECHANICAL FACTORS) (AERODYNAMICS)

(2marks)

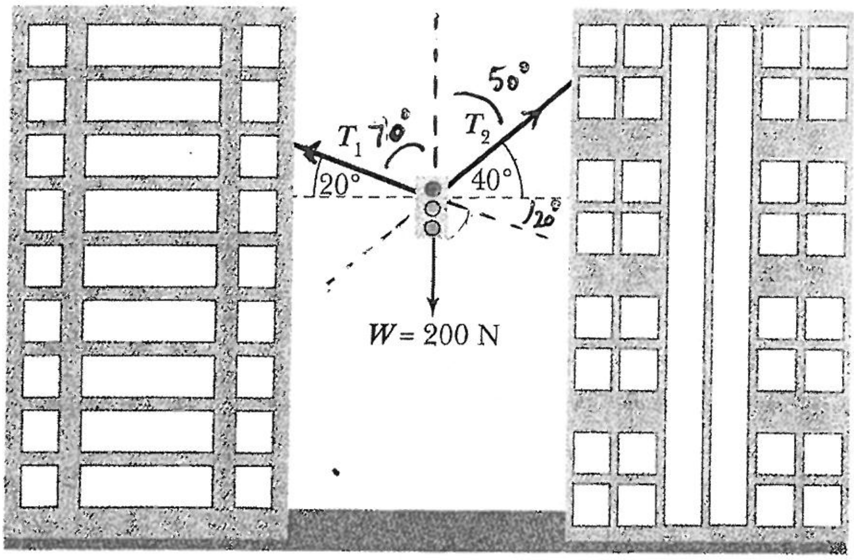
2c) Illustrate the difference that air resistance will have on the trajectory of the shot (i.e carefully construct both the "actual" and "ideal" trajectories on the diagram below).

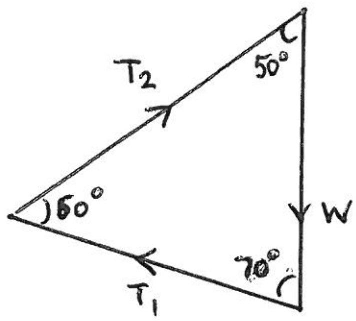


(2marks)

Q3 [6 marks]

A set of traffic lights weighing 200 N is suspended by means of two cables affixed to buildings adjacent to the intersection, as shown in the diagram below:





Calculate the tension in each cable.

USING THE SINE RULE

$$\frac{W}{\sin 60^\circ} = \frac{T_1}{\sin 50^\circ} = \frac{T_2}{\sin 70^\circ}$$

ie $T_1 = \dfrac{W \sin 50^\circ}{\sin 60^\circ}$

$\therefore T_1 = 177$ N

$T_2 = \dfrac{W \sin 70^\circ}{\sin 60^\circ}$

$\therefore T_2 = 217$ N

ALTERNATIVELY!

$\sum$ HORIZONTAL FORCES $= 0$

$\therefore T_1 \cos 20^\circ = T_2 \cos 40^\circ$

$\therefore T_1 = \dfrac{T_2 \cos 40^\circ}{\cos 20^\circ}$

ie $T_1 = 0{\cdot}82\, T_2$ — ①

$\sum$ VERTICAL FORCES $= 0$

$\therefore W = T_1 \sin 20^\circ + T_2 \sin 40^\circ$

$\therefore T_1 = \dfrac{W - T_2 \sin 40^\circ}{\sin 20^\circ}$ — ②

let ① = ②

$0{\cdot}82\, T_2 = \dfrac{200 - T_2 \sin 40^\circ}{\sin 20^\circ}$

$\therefore 0{\cdot}28\, T_2 = 200 - 0{\cdot}64\, T_2$

$\therefore 0{\cdot}92\, T_2 = 200$

$\therefore T_2 = 217$ N

Sub into ①

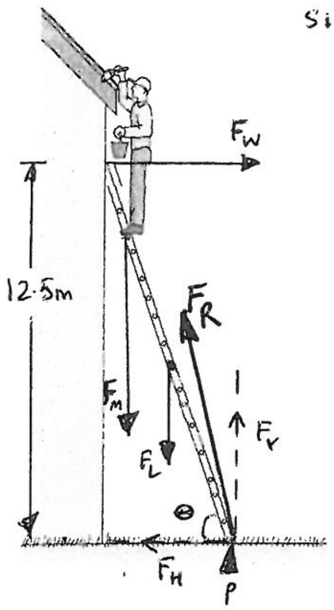
$T_1 = 0{\cdot}82 \times 217$

$\therefore T_1 = 178$ N

(6marks)

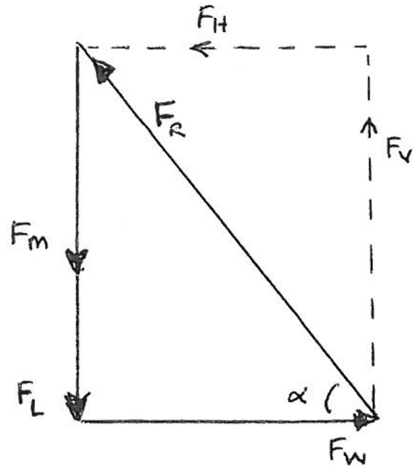
Q4 [16 marks]

A uniform 16 m ladder weighing 35 kg rests against a smooth wall at a point 12.5 m above the ground. A 75 kg man climbs three quarters of the way up the ladder when it just begins to slip.



$\sin\theta = \dfrac{12.5}{16}$

$\theta = 51.4°$



4a) Sketch a vector diagram (in the space above) to illustrate the relationships between the forces acting on the ladder prior to slipping. (2marks)

4b) Determine the force acting on the wall.

TAKING MOMENTS ABOUT P : $\sum M = 0$

$\sum CWM = \sum ACM$

ie $F_W \times r_W = (F_m \times r_m) + (F_L \times r_L)$

ie $F_W = \dfrac{(75 \times 9.8 \times 12 \times \cos 51.4°) + (35 \times 9.8 \times 8 \times \cos 51.4°)}{16 \sin 51.4°}$

$\therefore$ $F_W = 577$ N (FORCE ON LADDER DUE TO WALL)

$\therefore$ FORCE ON WALL $= 577$ N INTO THE WALL (HORIZONTALLY)

(FORCE ON WALL DUE TO LADDER)

(5)

4c) Determine the reaction force acting on the ladder by the ground.

TRANSLATIONAL EQUILIBRIUM: $\sum F = 0$

$\vec{F_R} = \vec{F_V} + \vec{F_H}$ AND $F_V = -(F_m + F_L)$ AND $F_H = -F_W$

THUS $F_R^2 = F_V^2 + F_H^2$

$= ((75+35) \times 9.8)^2 + (577)^2$

$\therefore F_R = 1223$ N

USING $\tan \alpha = \frac{F_V}{F_H} = \frac{1078}{577}$

$\alpha = 61.8°$

ie REACTION FORCE ON LADDER IS 1.22×10^3 N AT AN ANGLE OF 61.8° ABOVE THE HORIZONTAL TOWARDS THE WALL

(4marks)

4d) Determine the limiting friction preventing the ladder from slipping.

LIMITING FRICTION $= -F_W = F_H$ SINCE $\sum F = 0$ HORIZONTALLY

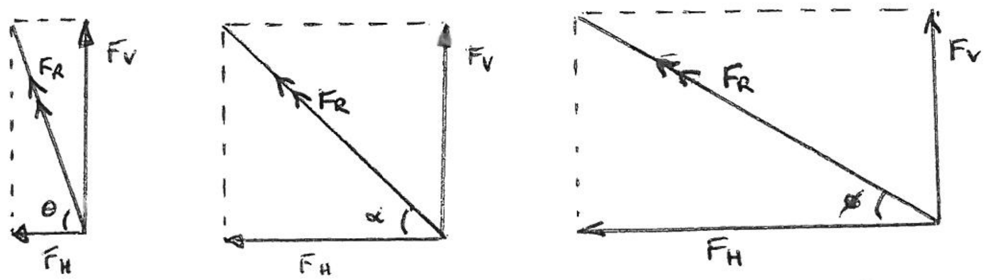
ie 577 N HORIZONTALLY TOWARDS THE WALL.

(2marks)

4e) Use a series of diagrams (or graph) to show how the force on the ladder at the ground varies as the man climbs up the ladder.

THE VERTICAL COMPONENT OF THE REACTION IS FIXED → REMAINS THE SAME

THE HORIZONTAL COMPONENT INCREASES AS MAN CLIMBS UP THE LADDER



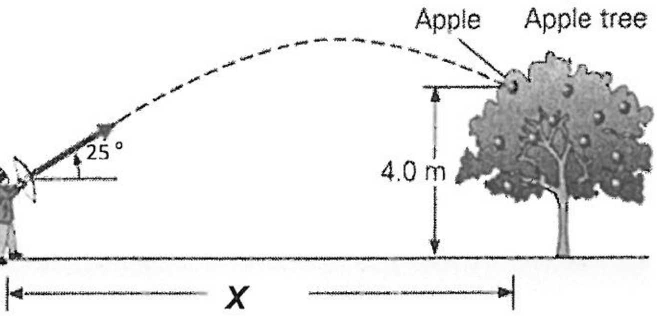
MAGNITUDE OF FORCE INCREASES AND THE DIRECTION (ANGLE) BECOMES CLOSER TO THE HORIZONTAL AND RELYING MORE ON FRICTION.

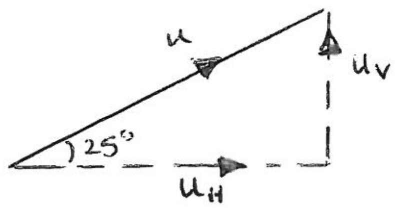
(3marks)

Q5 [6 marks]
An archer fires an arrow at a speed of 33.0 ms^{-1} at an angle of 25° to the horizontal, so that it hits an apple as shown in the diagram below.

Using the information provided, find the horizontal distance, X covered by the arrow.

SIGN CONVENTION





$u_V = u \sin 25°$
$u_H = u \cos 25°$

USING VERTICAL INFORMATION $\Rightarrow t$

$s_V = u_V t + \frac{1}{2} g t^2$

$\therefore (4.0 - 1.0) = (33 \sin 25° t) + (\frac{1}{2}(-9.8)t^2)$

$\therefore \quad 3 = 13.9t - 4.9t^2$

ie $\quad 4.9t^2 - 13.9 + 3 = 0 \quad \Rightarrow$ QUADRATIC FORMULA

$\Rightarrow t = 2.62$ s (NOT 0.234 s)

USING HORIZONTAL INFORMATION

$s_H = u_H \times t$

$= 33 \cos 25° \times 2.62$

$\therefore s_H = 78.4$ m (3SF)