IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 7, Issue 2 Ver. I (Mar. - Apr. 2015), PP 139-150
www.iosrjournals.org

Run Or Walk In The Rain? (Orthogonal Projected Area of Ellipsoid)

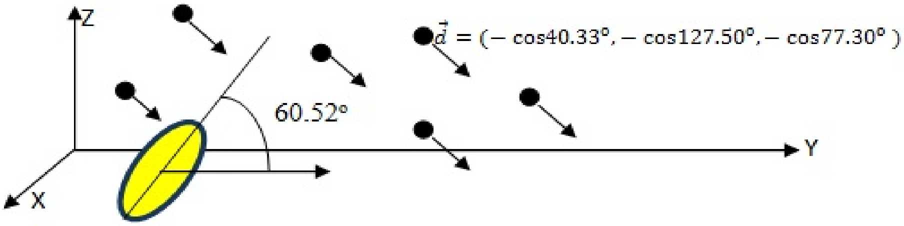
Seongtaek Seo
Faculty of Medicine, University Santiago de Compostela, Spain

Abstract : *Although there have been many articles about this problem, still many people want to know about the conclusion of it. That is because the previous articles were made with the too much complicated ways and there was no clear formulas for explaining well. In fact, this problem does not need a high level of mathematical knowledge. In this paper, it is used a simple method considering the various bodies types, the speed & angle of body and rain even the acceleration. And it is also considered in the cases; the body moves in a time as well as in the same distance. At least in theory, I expect this paper will show the final conclusion.*
Keywords -*Run or walk in the rain, orthogonal projected area of ellipsoid, cylinder and rectangular*

I. Introduction

There have been many papers about the rain problem; Walk or Run? All the previous papers about this problem had been made by assumption that the object moved standing vertically in a given distance. The latest author [1] Bocci considered the slanted model but he only thought about the slated plane. Now we will consider the slanted bodies - rectangular, ellipse and cylinder. And then we will find the formulas and if we can, the optimal speeds too. And we will check how the best strategy in the rain can be different in the two cases; in a given distance and in a given time. In fact this problem is not limited only to the rain. For example,

In the three-dimensional space, a space shuttle looked like an ellipsoid ($x^2/A^2+ y^2/B^2+ z^2/C^2=1$, where A=52.07m, B=73.43m, C=254.31m) travels through a straight line (y-axis). The space shuttle leans forward as much as 60.52^o from y-axis to the direction of movement and its speed is 38.85 m/s. Very small rocks are evenly spread in the space and their speed is 57.85m/s, their direction vector is ($-\cos 40.33^o$,$-\cos 127.50^o$, $-\cos 77.30^o$) and the density is 7.7656/km^3. If the space shuttle travels as much as 1053.90 km, how many do you expect the small rocks will hit the space shuttle during its trip? And if it travels for 2.16 days, how many? In the given angle of the space shuttle (60.52^o), does an optimal speed exist? If it exists, find the optimal speed and the number of small rocks that will hit the space shuttle in two cases; when it travels in the given distance and in the given time.



II. Method

1. Orthogonal projection

1-1 Two-dimensional model

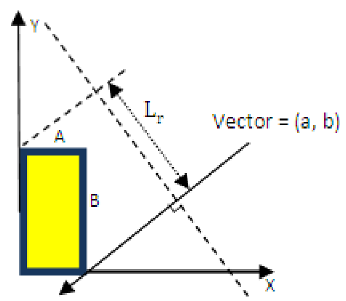


Figure 1 Rectangle

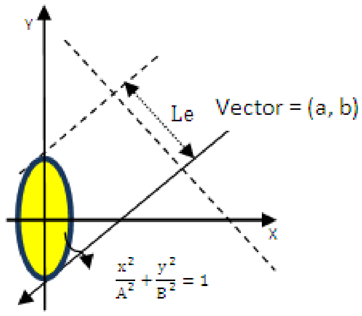


Figure 2 Ellipse

The projected length to the line that is vertical to the vector (a, b)

1-1-1 Rectangle

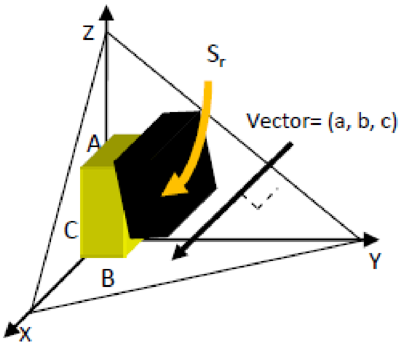
$L_r=\frac{A|b|+B|a|}{\sqrt{a^2+b^2}}$(Proof is omitted) **(1)**

1-1-2 Ellipse

$Le=\frac{2\sqrt{(Ab)^2+(Ba)^2}}{\sqrt{a^2+b^2}}$(Proof is omitted) **(2)**

1-2. Three-dimensional models

1-2-1. Rectangular



The projected area to the plane that is vertical to the vector (a, b, c)

$S_r=\frac{AB|c|+BC|a|+CA|b|}{\sqrt{a^2+b^2+c^2}}$(Proof is omitted) **(3)**

Figure 3 Rectangular

1-2-2 Ellipsoid

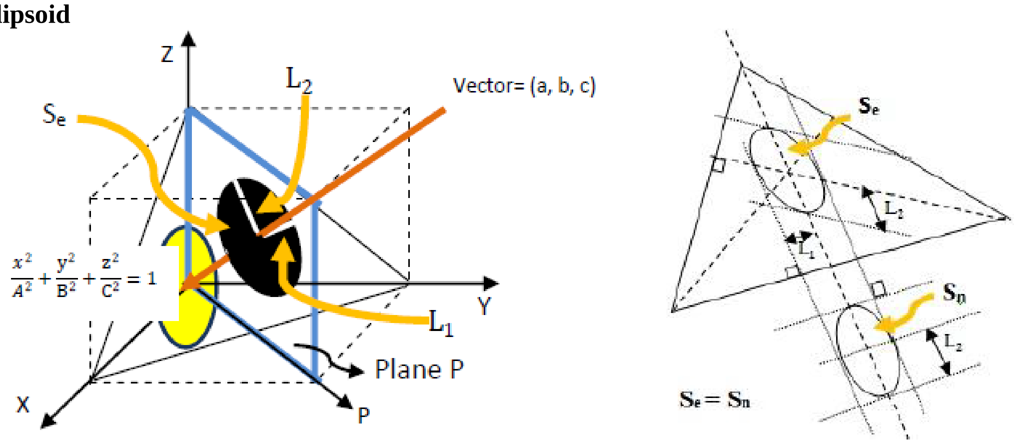


Figure 4 Ellipsoid (1)

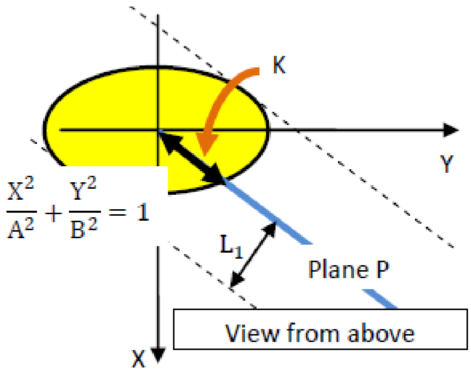


Figure 5 Ellipsoid (2)

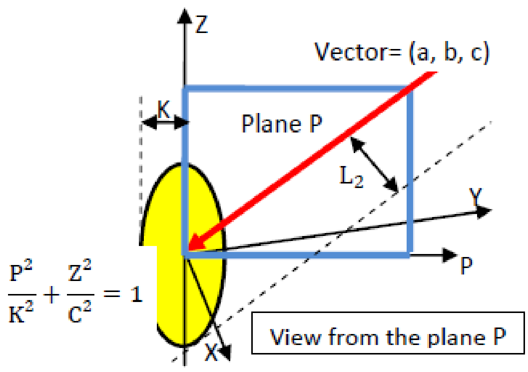


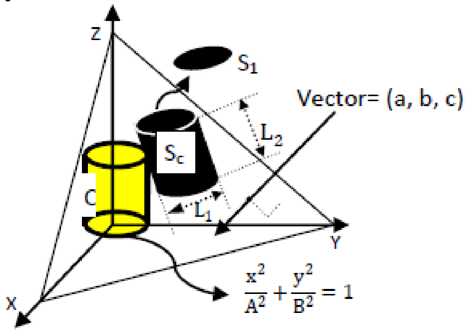
Figure 6 Ellipsoid (3)

On the figure 4, the projected area is also ellipse.

$L_1=\frac{\sqrt{(Ab)^2+(Ba)^2}}{\sqrt{a^2+b^2}}$, $K^2=\frac{(a^2+b^2)A^2B^2}{(Ab)^2+(Ba)^2}$, $L_2=\frac{\sqrt{K^2c^2+C^2(a^2+b^2)}}{\sqrt{a^2+b^2+c^2}}$, $S_e=\pi\ L_1\ L_2=\pi\frac{\sqrt{(ABc)^2+(BCa)^2+(CAb)^2}}{\sqrt{a^2+b^2+c^2}}$**(4)**

For making the formula (4), there can be another method, for example using matrix but I think the way in this paper is the easiest.

1-2-3 Cylinder



$$S_1=\frac{\pi AB|c|}{\sqrt{a^2+b^2+c^2}},$$

$$L_1=\frac{2\sqrt{(Ab)^2+(Ba)^2}}{\sqrt{a^2+b^2}},\ L_2=\frac{C\sqrt{a^2+b^2}}{\sqrt{a^2+b^2+c^2}}$$

$$S_c=S_1+L_1L_2=\frac{\pi AB|c|+2\sqrt{(BCa)^2+(CAb)^2}}{\sqrt{a^2+b^2+c^2}} \quad \textbf{(5)}$$

Figure 7 Cylinder

2. Application

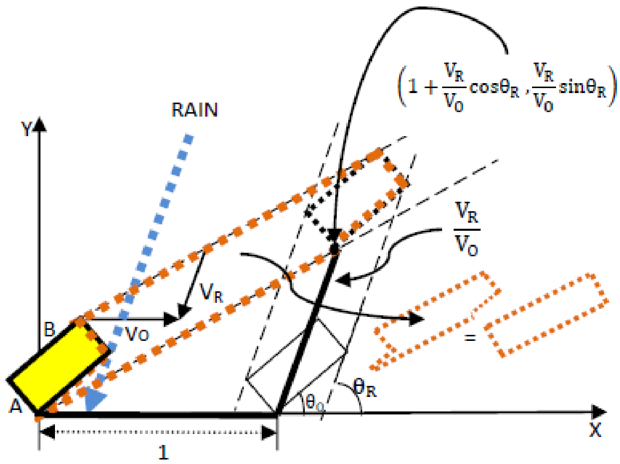


Figure 8 The object moves in the rain

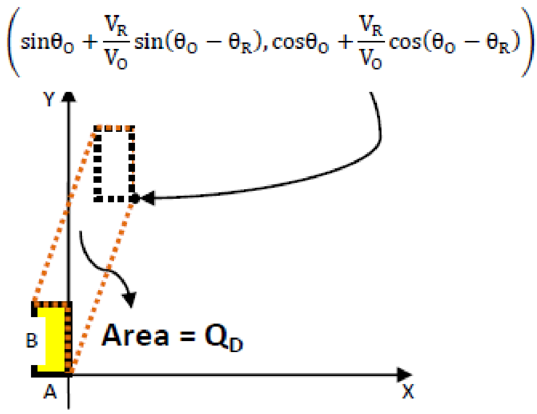


Figure 9 Rotation of the object

2-1 Terms and assumption

V_R =The speed of the rain, V_O = The speed of the object (V_R and V_O cannot be zero at the same time)
θ_R=The angle between the horizon and the rain to the direction of movement ($0 \le \theta_R \le 180^o$)
θ_O=The angle between the horizon and the object to the direction of movement ($0 \le \theta_O \le 180^o$)
ρ =The number of raindrops per unit area or volume (1×1 or $1\times 1 \times 1$)
Q_D =The swept area or volume in the rain field when the object moves in the distance 1
Q_T =The swept area or volume in the rain field when the object moves in the time 1

On the Figure 8, the outer side of the virtual object floating in the air represents the boundary of the last raindrops that will hit the object when it reaches the point (1, 0). That is, the raindrops in the region between the object on the zero point and the floating one will hit the object. The position of the object floating in the air is determined by the ratio of the two speeds; V_R/V_O and the angle of the rain;θ_R.

The key is to find the area of the region. The area of the region is equal to the area of the rectangle that has the same width and height of the region. Because the object is slated, in order to simplify the problem we make the object stand vertically. In other words, we rotate the objects as much as 90^o-θ_O. Using the length of orthogonal projection we found, formula (1), it can be found the area of the region.

The area of the rectangle=$\frac{A|b|+B|a|}{\sqrt{a^2+b^2}}\sqrt{a^2+b^2} = A|b| + B|a|$

2-2 Rain Formulas

In the rectangle model,

Area=Q_D=$A\left|cos\theta_O + \frac{V_R}{V_O}cos(\theta_O-\theta_R)\right| + B\left|sin\theta_O + \frac{V_R}{V_O}sin(\theta_O-\theta_R)\right|$

The total number of raindrops that will hit the object when it moves in the distance D is

$Total_D$ =$\rho D\left[A\left|cos\theta_O + \frac{V_R}{V_O}cos(\theta_O-\theta_R)\right| + B\left|sin\theta_O + \frac{V_R}{V_O}sin(\theta_O-\theta_R)\right|\right]$

The total amount of rain that will hit the object is obtained by multiplying the volume of a raindrop to the Total_D.

How it will be if the object moves in a given time?

When it moves with the speed V_O in the time 1, the distance of movement is V_O, so we can find Q_T as,

$Q_T = V_O Q_D = A|V_O cos\theta_O + V_R cos(\theta_O - \theta_R)| + B|V_O sin\theta_O + V_R sin(\theta_O - \theta_R)|$

$\text{Total}_T = \rho T[A|V_O cos\theta_O + V_R cos(\theta_O - \theta_R)| + B|V_O sin\theta_O + V_R sin(\theta_O - \theta_R)|]$

By applying the same way, in the two-dimensional elliptic model,

$$Q_D = 2\sqrt{A^2\left(cos\theta_O + \frac{V_R}{V_O}cos(\theta_O - \theta_R)\right)^2 + B^2\left(sin\theta_O + \frac{V_R}{V_O}sin(\theta_O - \theta_R)\right)^2}$$

We can find the optimal speed in the given angles by differential,

$$\text{Optimal speed} V_O = -V_R \frac{A^2 \cos^2(\theta_O - \theta_R) + B^2 \sin^2(\theta_O - \theta_R)}{A^2 \cos(\theta_O - \theta_R) \cos\theta_O + B^2 \sin(\theta_O - \theta_R) \sin\theta_O}$$

$$Q_T = 2\sqrt{A^2\left(V_O cos\theta_O + V_R cos(\theta_O - \theta_R)\right)^2 + B^2\left(V_O sin\theta_O + V_R sin(\theta_O - \theta_R)\right)^2}$$

$$\text{Optimal speed } V_O = -V_R \frac{A^2 \cos\theta_O \cos(\theta_O - \theta_R) + B^2 \sin\theta_O \sin(\theta_O - \theta_R)}{A^2 \cos^2\theta_O + B^2 \sin^2\theta_O}$$

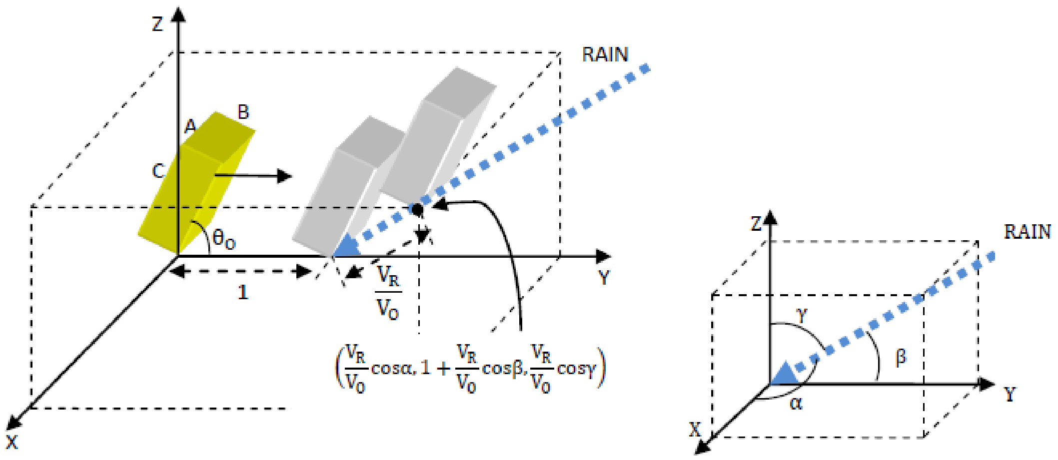


Figure 10 Three-dimensional rectangular

The three-dimensional models are thought as the same way of two-dimensional models. The object moves from zero point by one to the positive direction of y-axis. And we find the swept volume between the object on the origin and the virtual object floating in the air. In order to simplify, we make the object stand vertically as we did in the two-dimensional models. If we rotate the object as much as $90^o - \theta_O$, the point$\left(\frac{V_R}{V_O}cos\alpha, 1 + \frac{V_R}{V_O}cos\beta, \frac{V_R}{V_O}cos\gamma\right)$will be converted into

$$\left(\frac{V_R}{V_O}\cos\alpha, \frac{V_R}{V_O}(\cos\beta\sin\theta_O - \cos\gamma\cos\theta_O) + \sin\theta_O, \frac{V_R}{V_O}(\cos\beta\cos\theta_O + \cos\gamma\sin\theta_O) + \cos\theta_O\right)$$

We substitute the point to the formulas; **(3), (4), (5)** and then we multiply them to the distance between two figures.

In the rectangular parallelepiped model,

$Q_D =$

$$AB\left|\frac{V_R}{V_O}(\cos\beta\cos\theta_O + \cos\gamma\sin\theta_O) + \cos\theta_O\right| + BC\left|\frac{V_R}{V_O}\cos\alpha\right| + CA\left|\frac{V_R}{V_O}(\cos\beta\sin\theta_O - \cos\gamma\cos\theta_O) + \sin\theta_O\right|$$

$Q_T =$

$$AB|V_R(\cos\beta\cos\theta_O + \cos\gamma\sin\theta_O) + V_O\cos\theta_O| + BC|V_R\cos\alpha| + CA|V_R(\cos\beta\sin\theta_O - \cos\gamma\cos\theta_O) + V_O\sin\theta_O|$$

In the elliptic model,

$Q_D =$

$$\pi\sqrt{A^2B^2\left(\frac{V_R}{V_O}(\cos\beta\cos\theta_O + \cos\gamma\sin\theta_O) + \cos\theta_O\right)^2 + B^2C^2\left(\frac{V_R}{V_O}\cos\alpha\right)^2 + C^2A^2\left(\frac{V_R}{V_O}(\cos\beta\sin\theta_O - \cos\gamma\cos\theta_O) + \sin\theta_O\right)^2}$$

$$V_O = -V_R \frac{A^2B^2(\cos\beta\cos\theta_O + \cos\gamma\sin\theta_O)^2 + B^2C^2(\cos\alpha)^2 + C^2A^2(\cos\beta\sin\theta_O - \cos\gamma\cos\theta_O)^2}{A^2B^2\cos\theta_O(\cos\beta\cos\theta_O + \cos\gamma\sin\theta_O) + C^2A^2\sin\theta_O(\cos\beta\sin\theta_O - \cos\gamma\cos\theta_O)}$$

$Q_T=$
$\pi\sqrt{A^2B^2(V_R(\cos\beta\cos\theta_O+\cos\gamma\sin\theta_O)+V_O\cos\theta_O)^2+B^2C^2(V_R\cos\alpha)^2+C^2A^2(V_R(\cos\beta\sin\theta_O-\cos\gamma\cos\theta_O)+V_O\sin\theta_O)^2}$
$V_O=-V_R\frac{A^2B^2\cos\theta_O(\cos\beta\cos\theta_O+\cos\gamma\sin\theta_O)+C^2A^2\sin\theta_O(\cos\beta\sin\theta_O-\cos\gamma\cos\theta_O)}{A^2B^2\cos^2\theta_O+C^2A^2\sin^2\theta_O}$
In the cylindrical model with the elliptic bottom,
$Q_D=$
$\pi AB\left|\frac{V_R}{V_O}(\cos\beta\cos\theta_O+\cos\gamma\sin\theta_O)+\cos\theta_O\right|+2\sqrt{B^2C^2\left(\frac{V_R}{V_O}\cos\alpha\right)^2+C^2A^2\left(\frac{V_R}{V_O}(\cos\beta\sin\theta_O-\cos\gamma\cos\theta_O)+\sin\theta_O\right)^2}$
$Q_T=$
$\pi AB|V_R(\cos\beta\cos\theta_O+\cos\gamma\sin\theta_O)+V_O\cos\theta_O|+2\sqrt{B^2C^2(V_R\cos\alpha)^2+C^2A^2(V_R(\cos\beta\sin\theta_O-\cos\gamma\cos\theta_O)+V_O\sin\theta_O)^2}$
If the object does not move in a constant speed but with acceleration, how can we find the formulas?

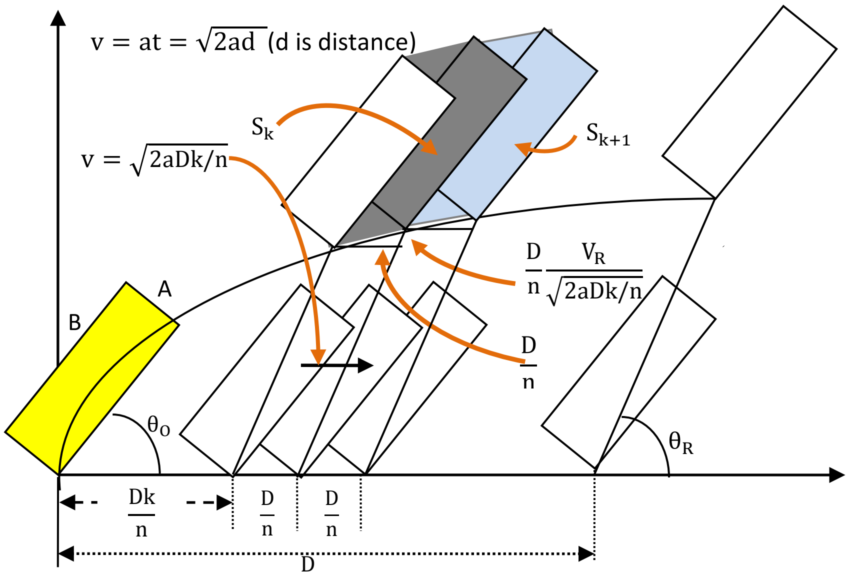


Figure 11 The object moves with a constant acceleration; a

When it moves in a distance D
$S_k=\frac{D}{n}\left[A\left|\cos\theta_O+\frac{V_R}{\sqrt{2aDk/n}}\cos(\theta_O-\theta_R)\right|+B\left|\sin\theta_O+\frac{V_R}{\sqrt{2aDk/n}}\sin(\theta_O-\theta_R)\right|\right]$
$Q=\sum_{k=1}^{n=\infty}S_k=D\int_0^1 A\left|\cos\theta_O+\frac{V_R}{\sqrt{2aDx}}\cos(\theta_O-\theta_R)\right|+B\left|\sin\theta_O+\frac{V_R}{\sqrt{2aDx}}\sin(\theta_O-\theta_R)\right|dx$
Total number of raindrops $=\rho Q$
When it moves in a time T, $D=\frac{1}{2}aT^2$
$Q=\frac{1}{2}aT^2\int_0^1 A\left|\cos\theta_O+\frac{V_R}{aT\sqrt{x}}\cos(\theta_O-\theta_R)\right|+B\left|\sin\theta_O+\frac{V_R}{aT\sqrt{x}}\sin(\theta_O-\theta_R)\right|dx$
Other models (2, 3- dimensional) are the same,

1. When it moves in a distance D
$Q=D\int_0^1 Q_{D^*}\,dx \quad (in\ Q_D, V_0\rightarrow\sqrt{2aDx})$
2. When it moves in a time T
$Q=\frac{1}{2}aT^2\int_0^1 Q_{D^{**}}\,dx \quad (V_0\rightarrow aT\sqrt{x})$

As we see until now, once we know the orthogonal projection area or length, the rain formulas can be made easily by a simple principle. It will be more complicated if we make a formula by the vector sum of the speeds of rain and object from the point of view of the object. But when a third person looks at the rain and the object, their directions and speeds will not be changed. And it is no need to divide the direction of rain into “the speed of cross wind”, “the speed of head wind” etc.

The main parameters are the ratio of speeds between the rain and the body, the sharp and size of the body and the angles of rain and object. The distance or time of travel, the volume of a rain drop and the density are just proportional constants.

III. Result And Conclusion

Previous conclusions

1. Generally, to a slim body, running with the maximum speed is not always the best option while a fat body should run as fast as possible. That is, a slim one has a higher probability of taking an optimal speed. [1]Bocci,[2]Bailey
2. If the rain comes from the back of a rectangular object, the optimal speed is the horizontal speed of the rain.[2]Bailey
3. If the rain comes from the back of an elliptic object, the optimal speed is bigger than the horizontal speed of rain.[3]Hailman&Torrents
4.With a headwind (when it rains from ahead), the object also can have the optimal speed. [1] Bocci

The previous conclusions are excellent, but they are not enough for the secret of rain.
Let us find new conclusions looking at the following Excel tables.
And we assume that the body´s width is shorter than the height in the following examples to think simply.

1. Two-dimensional rectangle model

1-1 When it rains from ahead

Table 1-1-1 A=0.5m, B=1.7m, θ_R=60°, D=1m, V_R =8m/s, ρ=1

90		11,96	6,83	5,12	4,84	4,27	4,11	3,75	3,41	3,17	2,98	2,73	2,56	2,38	2,38	2,21	1,99	1,91	1,80	1,71
80		10,17	5,97	4,56	4,33	3,86	3,74	3,44	3,16	2,96	2,81	2,60	2,46	2,32	2,32	2,18	2,00	1,93	1,85	1,77
70		8,07	4,92	3,87	3,69	3,34	3,25	3,03	2,82	2,67	2,56	2,40	2,29	2,19	2,19	2,08	1,95	1,89	1,83	1,77
60		5,72	3,72	3,06	2,94	2,72	2,66	2,52	2,39	2,29	2,22	2,12	2,06	1,99	1,99	1,92	1,84	1,80	1,76	1,73
50		5,32	2,41	2,15	2,11	2,02	1,99	1,94	1,89	1,85	1,82	1,78	1,76	1,73	1,73	1,70	1,67	1,66	1,64	1,63
43,61		6,86	3,03	1,75	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53
40		7,70	3,50	2,09	1,86	1,39	1,27	1,30	1,33	1,35	1,36	1,39	1,40	1,42	1,42	1,43	1,45	1,46	1,47	1,47
30		9,85	4,72	3,00	2,72	2,15	1,99	1,64	1,29	1,05	0,87	0,95	1,01	1,06	1,06	1,12	1,19	1,22	1,25	1,28
20		11,69	5,79	3,82	3,50	2,84	2,66	2,25	1,86	1,57	1,36	1,07	0,87	0,68	0,67	0,77	0,89	0,94	0,99	1,05
10		13,19	6,69	4,53	4,17	3,44	3,25	2,80	2,36	2,05	1,82	1,50	1,28	1,06	1,06	0,85	0,57	0,63	0,71	0,78
0		14,28	7,39	5,09	4,71	3,94	3,74	3,26	2,80	2,47	2,22	1,88	1,65	1,42	1,42	1,19	0,89	0,78	0,64	0,51
	0	1,00	2,00	3,00	3,27	4,00	4,26	5,00	6,00	7,00	8,00	10,00	12,00	15,00	15,04	20,00	35,29	50,00	100	1000

Table 1-1-2 A=0.5m, B=1.7m, θ_R=60°, T=1/8 second, V_R=8m/s,ρ=1

90	1,28	1,50	1,67	1,71	1,92	1,98	2,13	2,19	2,35	2,77	2,98	3,41	4,05	4,26	4,47	4,48	5,44	5,53	22,53	214
80	1,05	1,27	1,45	1,49	1,71	1,77	1,93	1,99	2,15	2,59	2,81	3,25	3,91	4,13	4,35	4,36	5,36	5,45	23,06	221
70	0,79	1,01	1,19	1,23	1,45	1,51	1,67	1,73	1,89	2,34	2,56	3,00	3,66	3,88	4,10	4,11	5,11	5,21	22,89	222
60	0,50	0,72	0,89	0,93	1,15	1,20	1,36	1,42	1,58	2,01	2,22	2,65	3,30	3,51	3,73	3,74	4,71	4,81	22,03	216
50	0,79	0,66	0,57	0,60	0,81	0,86	1,01	1,06	1,21	1,62	1,82	2,23	2,84	3,04	3,24	3,25	4,17	4,26	20,49	203
40	1,05	0,96	0,89	0,87	0,79	0,76	0,70	0,67	0,81	1,18	1,36	1,73	2,29	2,47	2,66	2,66	3,50	3,58	18,34	184
30	1,28	1,23	1,19	1,18	1,13	1,11	1,07	1,06	1,02	0,92	0,87	1,19	1,67	1,83	1,99	1,99	2,72	2,79	15,62	160
20	1,48	1,46	1,45	1,45	1,43	1,43	1,42	1,42	1,41	1,38	1,36	1,34	1,29	1,28	1,27	1,27	1,86	1,92	12,43	131
16,39	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,53	1,59	11,18	119
10	1,62	1,65	1,67	1,67	1,70	1,70	1,72	1,73	1,75	1,80	1,82	1,87	1,94	1,97	1,99	1,99	2,11	2,12	8,86	97
0	1,72	1,78	1,84	1,85	1,91	1,93	1,97	1,99	2,03	2,16	2,22	2,35	2,53	2,60	2,66	2,66	2,94	2,97	7,97	64
	0	1,00	1,81	2,00	3,00	3,27	4,00	4,26	5,00	7,00	8,00	10,00	13,00	14,00	15,00	15,04	19,56	20,00	100	1000

On the table the vertical axis represents the angle of the object θ_o and the horizontal axis represents the speed of the object V_o. The values on the table represent the number of rain drops that will hit the object. And in the table 1-1-2, using the time 1/8 instead of 1second is for reducing the number size.

Maybe some people will be more interested in this case. Because usually they experiment in real; a man moves in the rain, the direction of the rain is nearly vertical ("when it rains vertically" is also included in this case **1-1**). In the TV programs; Korean television "Heaven of the Curiosity (2002)" and American television "Mythbusters (2006)" ,they experimented about this problem. In Heaven of the Curiosity, the conclusion was running in order to get wet less and in the Mythbusters, the first conclusion was walking and later they modified as running. Let us look at this case mathematically.

When it moves in a given distance, there is a certain section in which the amount of wetting is constant regardless of the moving speed of the object, where θ_o(critical angle)= $\theta_R - tan^{-1}(A/B)$. This means that if you are thin and it rains nearly vertically, you have a higher possibility of being in the critical angle even if you lean forward a little. In real test, if the results of running and walking are not different, it is possible that the body looks like a rectangle and its angle and speed are in that section. And if we divide this into three cases,

1) If it leans its body less than the critical angle, there will not be an optimal speed, so in order to get wet less, it should run as quickly as possible.
2) If it is in the critical angle, if it runs more quickly than a certain speed, the amount of wetting is constant.
3) If it leans its body more than the critical angle, it will always have an optimal speed. In this case, it should control its speed in order to get wet only the top of body.

The optimal speed exists when the rain hits only the top of the object, $V_O = -V_R \frac{sin(\theta_O-\theta_R)}{sin\,\theta_O}$. When it moves leaning its body completely forward with the maximum speed, the amount of rain is the least.
When it moves in a given time, there also exists a constant section where $\theta_o = tan^{-1}(A/B)$. The optimal speed is $V_O = -V_R \frac{sin(\theta_O-\theta_R)}{sin\,\theta_O}$. It is natural that the object should not move and leans its body as the same angle of rain in other to get wet the least.

1-2 When it rains from the back

Table 1-2-1 A=0.5m, B=1.7m, θ_R=170°, D=1m, V_R =8m/s, ρ=1

180		5,8008	0,7406	0,6514	0,5125	0,4386	0,3904	0,3546	0,3254	0,3159	0,2998	0,3058	0,3118	0,3159	0,3183	0,3256	0,3345	0,3466	0,3651	0,3999	0,4222	0,4369	0,4998
170		3,8028	0,5904	0,5337	0,4456	0,3987	0,3681	0,3453	0,3268	0,3207	0,3105	0,2952	0,3105	0,3207	0,3268	0,3453	0,3681	0,3987	0,4456	0,5337	0,5904	0,6276	0,7872
160		5,2496	0,4222	0,3999	0,3651	0,3466	0,3345	0,3256	0,3183	0,3159	0,3118	0,3058	0,2998	0,3159	0,3254	0,3546	0,3904	0,4386	0,5125	0,6514	0,7406	0,7992	1,0507
153,61		6,4714	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3193	0,3549	0,3985	0,4572	0,5473	0,7164	0,8251	0,8965	1,2027
150		7,1272	0,3729	0,2539	0,2735	0,2840	0,2908	0,2959	0,3000	0,3014	0,3037	0,3071	0,3105	0,3128	0,3141	0,3531	0,4009	0,4653	0,5639	0,7493	0,8684	0,9466	1,2822
140		8,7883	0,5451	0,3999	0,1737	0,2128	0,2383	0,2573	0,2727	0,2778	0,2863	0,2991	0,3118	0,3204	0,3254	0,3409	0,3992	0,4778	0,5981	0,8244	0,9697	1,0652	1,4747
130		10,182	0,7008	0,5337	0,2735	0,1351	0,1785	0,2108	0,2371	0,2457	0,2602	0,2819	0,3037	0,3182	0,3268	0,3531	0,3854	0,4757	0,6142	0,8744	1,0416	1,1514	1,6225
120		11,267	0,8352	0,6514	0,3651	0,2128	0,1133	0,1579	0,1943	0,2062	0,2262	0,2563	0,2863	0,3064	0,3183	0,3546	0,3992	0,4593	0,6116	0,8979	1,0819	1,2027	1,7209
110		12,009	0,9442	0,7493	0,4455	0,2840	0,1785	0,1003	0,1455	0,1604	0,1854	0,2228	0,2602	0,2852	0,3000	0,3453	0,4009	0,4757	0,5904	0,8941	1,0892	1,2174	1,7671
100		12,387	1,0246	0,8244	0,5125	0,3466	0,2383	0,1579	0,0924	0,1097	0,1389	0,1826	0,2262	0,2554	0,2727	0,3256	0,3904	0,4778	0,6116	0,8631	1,0635	1,1951	1,7596
96,39		12,431	1,0460	0,8454	0,5329	0,3667	0,2582	0,1777	0,1120	0,0905	0,1210	0,1666	0,2122	0,2427	0,2608	0,3160	0,3837	0,4749	0,6147	0,8774	1,0462	1,1780	1,7437
90		12,388	1,0738	0,8744	0,5639	0,3987	0,2908	0,2108	0,1455	0,1242	0,0882	0,1368	0,1854	0,2178	0,2371	0,2959	0,3681	0,4653	0,6142	0,8941	1,0740	1,1920	1,6987
80		12,013	1,0903	0,8979	0,5981	0,4386	0,3345	0,2573	0,1943	0,1736	0,1389	0,0868	0,1389	0,1736	0,1943	0,2573	0,3345	0,4386	0,5981	0,8979	1,0905	1,2170	1,7596
70		12,319	1,0738	0,8941	0,6142	0,4653	0,3681	0,2959	0,2371	0,2178	0,1854	0,1368	0,0882	0,1242	0,1455	0,2108	0,2908	0,3987	0,5639	0,8744	1,0740	1,2050	1,7671
63,61		12,431	1,0460	0,8774	0,6147	0,4749	0,3837	0,3160	0,2608	0,2427	0,2122	0,1666	0,1210	0,0905	0,1120	0,1777	0,2582	0,3667	0,5330	0,8454	1,0462	1,1780	1,7437
60		12,426	1,0633	0,8631	0,6116	0,4778	0,3904	0,3256	0,2727	0,2554	0,2262	0,1826	0,1389	0,1097	0,0924	0,1579	0,2383	0,3466	0,5125	0,8244	1,0248	1,1563	1,7208
50		12,154	1,0891	0,8941	0,5904	0,4757	0,4009	0,3453	0,3000	0,2852	0,2602	0,2228	0,1854	0,1604	0,1455	0,1003	0,1785	0,2840	0,4456	0,7493	0,9444	1,0726	1,6223
40		11,514	1,0817	0,8979	0,6116	0,4593	0,3992	0,3546	0,3183	0,3064	0,2863	0,2563	0,2262	0,2062	0,1943	0,1579	0,1133	0,2128	0,3651	0,6514	0,8354	0,9562	1,4745
30		10,523	1,0415	0,8744	0,6142	0,4757	0,3854	0,3531	0,3268	0,3182	0,3037	0,2819	0,2602	0,2457	0,2371	0,2108	0,1785	0,1351	0,2735	0,5337	0,7010	0,8108	1,2818
20		9,2128	0,9696	0,8244	0,5981	0,4778	0,3992	0,3409	0,3254	0,3204	0,3118	0,2991	0,2863	0,2778	0,2727	0,2573	0,2383	0,2128	0,1736	0,3999	0,5453	0,6407	1,0503
10		7,6226	0,8683	0,7493	0,5639	0,4653	0,4009	0,3531	0,3141	0,3128	0,3105	0,3071	0,3037	0,3014	0,3000	0,2959	0,2908	0,2840	0,2735	0,2539	0,3730	0,4512	0,7868
6,39		6,9888	0,8250	0,7164	0,5472	0,4572	0,3985	0,3549	0,3193	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3791	0,6853
0		5,8008	0,7406	0,6514	0,5125	0,4386	0,3904	0,3546	0,3254	0,3159	0,2998	0,3058	0,3118	0,3159	0,3183	0,3256	0,3345	0,3466	0,3651	0,3999	0,4222	0,4369	0,4998
	0	1,00	5,08	5,47	6,22	6,71	7,08	7,37	7,63	7,72	7,88	8,12	8,38	8,57	8,68	9,04	9,53	10,28	11,70	15,76	20,28	25,00	1000

If the rain comes from the back, it is more complicated. In reality, it is almost impossible but we suppose that the direction of the rain is 170°. On the horizontal axis, V_O=7.88m/s represents the horizontal speed of the rain to the direction of body's movement ($V_O = -V_R cos\theta_R$, they called it "speed of tail wind" in another articles). Let us look at the Figure 8 and we move the floating object by changing V_O. If an optimal speed exists, there are in following two cases.

1. The rain hits the object only on the top part.

Optimal speed; $V_O = -V_R \frac{sin(\theta_O-\theta_R)}{sin\,\theta_O}$

2. The rain hits the object only on the back part or the front part (when it leans backward)

Optimal speed; $V_O = -V_R \frac{cos(\theta_O-\theta_R)}{cos\,\theta_O}$

(This means that an optimal speed can exist when the rain hits only the larger part of the body as well as when it hits only the shorter part.) But note that even the rain hits only the top or back or front part, an optimal speed does not always exist.
For example, θ_O=90°, an optimal speed can exist if $90^o + tan^{-1}(A/B) \leq \theta_R \leq 180^o$. This means that if it is slim and the angle of the rain is big, it has a higher possibility of being in an optimal speed. And there is the least value and its value is $A\,sin\,\theta_R$ where $\theta_R - \theta_O = 90^o$, $V_O = -V_R \frac{1}{cos\,\theta_R}$

Table 1-2-2 A=0.5m, B=1.7m, θ_R=170°, T=1/8 second, V_R =8m/s,ρ=1

180	0,7876	0,7251	0,5904	0,5337	0,4456	0,3987	0,3681	0,3453	0,3268	0,3207	0,3105	0,2952	0,3105	0,3207	0,3268	0,3453	0,3681	0,3987	0,4456	0,5337	0,5904	1,0528	62,303
170	0,5000	0,4753	0,4222	0,3999	0,3651	0,3466	0,3345	0,3256	0,3183	0,3159	0,3118	0,3058	0,2998	0,3159	0,3254	0,3546	0,3904	0,4386	0,5125	0,6514	0,7407	1,4690	97,951
163,61	0,6861	0,5662	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3193	0,3549	0,3985	0,4572	0,5473	0,7164	0,8252	1,7123	119,236
160	0,7876	0,6562	0,3730	0,2539	0,2735	0,2840	0,2908	0,2959	0,3000	0,3014	0,3037	0,3071	0,3105	0,3128	0,3141	0,3531	0,4009	0,4653	0,5639	0,7492	0,8684	1,8406	130,622
150	1,0513	0,8909	0,5453	0,3999	0,1736	0,2128	0,2383	0,2573	0,2727	0,2778	0,2863	0,2991	0,3118	0,3204	0,3254	0,3409	0,3992	0,4778	0,5981	0,8243	0,9698	2,1563	159,325
140	1,2830	1,0985	0,7010	0,5337	0,2735	0,1351	0,1785	0,2108	0,2371	0,2457	0,2602	0,2819	0,3037	0,3182	0,3268	0,3531	0,3854	0,4757	0,6142	0,8744	1,0417	2,4064	183,187
130	1,4758	1,2728	0,8354	0,6514	0,3651	0,2127	0,1133	0,1579	0,1943	0,2062	0,2262	0,2563	0,2863	0,3064	0,3183	0,3546	0,3992	0,4593	0,6116	0,8978	1,0819	2,5834	201,483
120	1,6237	1,4084	0,9445	0,7493	0,4456	0,2840	0,1785	0,1003	0,1455	0,1604	0,1854	0,2228	0,2602	0,2852	0,3000	0,3453	0,4009	0,4757	0,5904	0,8940	1,0893	2,6819	213,657
110	1,7222	1,5012	1,0248	0,8244	0,5125	0,3466	0,2383	0,1579	0,0924	0,1097	0,1389	0,1826	0,2262	0,2554	0,2727	0,3256	0,3904	0,4778	0,6116	0,8631	1,0636	2,6990	219,339
106,39	1,7451	1,5236	1,0462	0,8454	0,5330	0,3667	0,2582	0,1777	0,1120	0,0905	0,1210	0,1666	0,2122	0,2427	0,2608	0,3160	0,3837	0,4749	0,6147	0,8773	1,0463	2,6849	219,755
100	1,7685	1,5484	1,0740	0,8744	0,5639	0,3987	0,2908	0,2108	0,1455	0,1242	0,0882	0,1368	0,1854	0,2178	0,2371	0,2959	0,3681	0,4653	0,6142	0,8940	1,0740	2,6340	218,356
90	1,7610	1,5485	1,0906	0,8979	0,5981	0,4386	0,3345	0,2573	0,1943	0,1736	0,1389	0,0868	0,1389	0,1736	0,1943	0,2573	0,3345	0,4386	0,5981	0,8978	1,0906	2,6627	210,913
80	1,7000	1,5016	1,0740	0,8941	0,6142	0,4652	0,3681	0,2959	0,2371	0,2178	0,1854	0,1368	0,0882	0,1242	0,1455	0,2108	0,2908	0,3987	0,5639	0,8744	1,0740	2,7025	218,425
73,61	1,7451	1,5236	1,0462	0,8774	0,6147	0,4749	0,3837	0,3160	0,2608	0,2427	0,2122	0,1666	0,1210	0,0905	0,1120	0,1777	0,2582	0,3667	0,5330	0,8454	1,0463	2,6849	219,755
70	1,7610	1,5399	1,0636	0,8631	0,6116	0,4777	0,3904	0,3256	0,2727	0,2554	0,2262	0,1826	0,1389	0,1097	0,0924	0,1579	0,2383	0,3466	0,5125	0,8243	1,0248	2,6602	219,300
60	1,7685	1,5532	1,0893	0,8941	0,5904	0,4757	0,4009	0,3453	0,3000	0,2852	0,2602	0,2228	0,1854	0,1604	0,1455	0,1003	0,1785	0,2840	0,4456	0,7492	0,9445	2,5371	213,512
50	1,7222	1,5193	1,0819	0,8979	0,6116	0,4592	0,3992	0,3546	0,3183	0,3063	0,2863	0,2563	0,2262	0,2062	0,1943	0,1579	0,1133	0,2128	0,3651	0,6514	0,8354	2,3369	201,236
40	1,6237	1,4392	1,0417	0,8744	0,6142	0,4757	0,3854	0,3531	0,3268	0,3182	0,3037	0,2819	0,2602	0,2457	0,2371	0,2108	0,1785	0,1351	0,2735	0,5337	0,7010	2,0657	182,846
30	1,4758	1,3154	0,9698	0,8244	0,5981	0,4777	0,3992	0,3409	0,3254	0,3204	0,3118	0,2991	0,2863	0,2778	0,2727	0,2573	0,2383	0,2128	0,1736	0,3998	0,5453	1,7318	158,901
20	1,2830	1,1516	0,8684	0,7493	0,5639	0,4652	0,4009	0,3531	0,3141	0,3128	0,3105	0,3071	0,3037	0,3014	0,3000	0,2959	0,2908	0,2840	0,2735	0,2539	0,3730	1,3452	130,127
16,39	1,2035	1,0836	0,8251	0,7164	0,5473	0,4572	0,3985	0,3549	0,3193	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	0,3077	1,1949	118,717
10	1,0513	0,9528	0,7407	0,6514	0,5125	0,4386	0,3904	0,3546	0,3254	0,3159	0,2998	0,3058	0,3118	0,3159	0,3183	0,3256	0,3345	0,3466	0,3651	0,3999	0,4222	0,9177	97,399
0	0,7876	0,7251	0,5904	0,5337	0,4456	0,3987	0,3681	0,3453	0,3268	0,3207	0,3105	0,2952	0,3105	0,3207	0,3268	0,3453	0,3681	0,3987	0,4456	0,5337	0,5904	1,0528	62,303
	0	1,00	3,16	4,06	5,47	6,22	6,71	7,08	7,37	7,47	7,63	7,88	8,12	8,29	8,38	8,68	9,04	9,53	10,28	11,70	12,60	20,00	1000

Let us imagine that the rain comes from the back and the object moves in a given time. Interestingly, in order to get wet least, the object should move standing vertically with the horizontal speed of rain.

2. Two-dimensional elliptic model

Table 2-1 A=0.25m, B=0.85m, θ_R=120°, D=1m, V_R =8m/s,ρ=1

180		11,873	2,9445	2,6724	2,4860	2,3401	1,9797	1,6717	1,4933	1,4146	1,3378	1,1945	1,1170	1,0006	0,8666	0,8261	0,7913	0,6710	0,5473	0,4981
170		10,913	2,9036	2,6603	2,4936	2,3632	2,0412	1,7660	1,6066	1,5362	1,4674	1,3388	1,2690	1,1635	1,0405	1,0028	0,9700	0,8527	0,7144	0,5774
160		9,6776	2,7827	2,5745	2,4321	2,3207	2,0462	1,8120	1,6764	1,6166	1,5581	1,4488	1,3894	1,2995	1,1941	1,1616	1,1333	1,0306	0,9039	0,7525
150		8,2286	2,5865	2,4186	2,3039	2,2144	1,9945	1,8077	1,7000	1,6525	1,6063	1,5198	1,4729	1,4020	1,3189	1,2933	1,2708	1,1894	1,0875	0,9584
140		6,6627	2,3233	2,1988	2,1142	2,0484	1,8881	1,7533	1,6764	1,6427	1,6099	1,5490	1,5162	1,4667	1,4091	1,3914	1,3759	1,3199	1,2501	1,1611
130		5,1491	2,0056	1,9251	1,8713	1,8299	1,7313	1,6511	1,6066	1,5874	1,5690	1,5353	1,5174	1,4910	1,4609	1,4518	1,4440	1,4161	1,3827	1,3427
120		4,0286	1,6523	1,6124	1,5875	1,5695	1,5310	1,5051	1,4933	1,4889	1,4850	1,4791	1,4766	1,4739	1,4723	1,4722	1,4723	1,4739	1,4791	1,4927
110		3,8449	1,2948	1,2843	1,2822	1,2834	1,2975	1,3220	1,3413	1,3511	1,3615	1,3827	1,3954	1,4161	1,4429	1,4518	1,4598	1,4910	1,5353	1,6038
100		4,7273	0,9944	0,9847	0,9893	0,9992	1,0468	1,1114	1,1579	1,1805	1,2037	1,2501	1,2770	1,3199	1,3739	1,3914	1,4070	1,4667	1,5490	1,6716
90		6,1652	0,8660	0,8015	0,7775	0,7717	0,8071	0,8887	0,9539	0,9863	1,0199	1,0875	1,1267	1,1894	1,2679	1,2933	1,3159	1,4020	1,5198	1,6932
80		7,7383	0,9944	0,8408	0,7527	0,6977	0,6357	0,6823	0,7475	0,7836	0,8225	0,9039	0,9523	1,0306	1,1295	1,1616	1,1903	1,2995	1,4488	1,6679
70		9,2371	1,2948	1,0751	0,9325	0,8280	0,6195	0,5488	0,5741	0,6005	0,6341	0,7144	0,7660	0,8527	0,9657	1,0028	1,0360	1,1635	1,3388	1,5965
60		10,548	1,6523	1,3909	1,2152	1,0806	0,7700	0,5627	0,5000	0,4929	0,4998	0,5473	0,5896	0,6710	0,7868	0,8261	0,8618	1,0006	1,1945	1,4820
50		11,601	2,0056	1,7174	1,5215	1,3694	1,0030	0,7142	0,5741	0,5248	0,4878	0,4582	0,4674	0,5144	0,6107	0,6474	0,6816	0,8207	1,0231	1,3293
40		12,348	2,3233	2,0195	1,8120	1,6501	1,2544	0,9264	0,7475	0,6738	0,6067	0,5024	0,4633	0,4391	0,4736	0,4972	0,5221	0,6406	0,8352	1,1455
30		12,757	2,5865	2,2769	2,0651	1,8995	1,4923	1,1485	0,9539	0,8701	0,7903	0,6494	0,5803	0,4934	0,4367	0,4330	0,4359	0,4934	0,6494	0,9418
20		12,814	2,7827	2,4768	2,2673	2,1034	1,6992	1,3553	1,1579	1,0716	0,9881	0,8352	0,7550	0,6406	0,5257	0,4972	0,4761	0,4391	0,5023	0,7367
10		12,515	2,9036	2,6105	2,4096	2,2523	1,8642	1,5327	1,3413	1,2571	1,1752	1,0231	0,9415	0,8207	0,6863	0,6474	0,6149	0,5144	0,4580	0,5665
0		11,873	2,9445	2,6724	2,4860	2,3401	1,9797	1,6717	1,4933	1,4146	1,3378	1,1945	1,1170	1,0006	0,8666	0,8261	0,7913	0,6710	0,5473	0,4981
	0	1,00	4,00	4,41	4,74	5,04	5,97	7,11	8,00	8,48	9,00	10,20	11,00	12,52	15,00	16,00	17,00	22,17	37,15	1000

From now, let us consider only the case when it rains from the back. The horizontal speed of the rain is 4m/s. Where θ_O=90^o, the optimal speed is bigger than the horizontal speed of the rain. As the sharp of ellipse is more similar to a round, the gap between the optimal speed and the horizontal speed of the rain is bigger. And the condition of getting wet the least is where$\theta_R - \theta_O = 90^o, V_O = -V_R \frac{1}{\cos\theta_R}$ and its value is$A\sin\theta_R$. (It is the same of rectangle model)

How can we know the above conclusions intuitively without using complicated formulas we made? Let us look at the Figure 8 and assume that $90^o \le \theta_R \le 180^o$. In a givenθ_O,θ_R and V_R, to make the area minimum, we can control the location of the floating object by changing the value V_O.That is, the two figures should be situated on the parallel line (Rains hit only the top or the back or the front part of the body) and in that condition, an optimal speed can exist (not always).

Usually the rectangle model can get an optimal speed when the rain hits only the top part (width is shorter than height) but if θ_R is big enough, as we saw the Table 1-2-1, and if the object is a fatter body, the optimal speed can exist even when the rain hits only the back part or the front part (when it leans backward). On paper, let's paint some pictures of ellipses (one is similar to a rectangle, the other is similar to a round) and rectangles (one is slim and the other is square) and compare them.

In the elliptic model, the floating object should not be situated on the parallel line to make the area minimum; it should be located slightly below the line. If the object is a perfect round, it should be located in a position which makes the distance between the two figures minimum. It means that the optimal speed of the ellipse is bigger than that of the rectangle model and if the body looks more like a round, it should run faster.

Now imagine that we can change even θ_O and we search the minimum value. In other words, now we can change the angle of object as well as the location of the floating object. In this case the minimum condition is that the two objects are located on the same parallel line and the distance of the two figures are minimum. Then we can check the minimum condition;$\theta_R - \theta_O = 90^o, V_O = -V_R \frac{1}{\cos\theta_R}$, which is the same regardless of body type and its value;$A \sin\theta_R$, which is also equal regardless of body type if the widths are the same. But this conclusion cannot be applied to the three dimensions (when the rain comes from the side).

Table 2-2 A=0.25m, B=0.85m, θ_R=120^o, T=1/8 second, V_R =8m/s,ρ=1

180	1,4933	1,4889	1,4791	1,4739	1,4722	1,4739	1,4791	1,4841	1,4889	1,4933	1,5051	1,5193	1,5307	1,5694	1,5872	1,5994	1,6124	1,6249	3,2300	62,267
170	1,3413	1,3512	1,3827	1,4161	1,4518	1,4910	1,5353	1,5644	1,5874	1,6066	1,6511	1,6970	1,7304	1,8298	1,8706	1,8974	1,9251	1,9509	4,1835	72,169
160	1,1579	1,1805	1,2501	1,3199	1,3914	1,4667	1,5490	1,6017	1,6427	1,6764	1,7533	1,8310	1,8867	2,0482	2,1132	2,1555	2,1988	2,2390	5,3724	94,057
150	0,9539	0,9863	1,0875	1,1894	1,2933	1,4020	1,5198	1,5947	1,6525	1,7000	1,8077	1,9156	1,9926	2,2140	2,3025	2,3600	2,4186	2,4729	6,5684	119,81
140	0,7475	0,7836	0,9039	1,0306	1,1616	1,2995	1,4488	1,5435	1,6166	1,6764	1,8120	1,9474	2,0439	2,3203	2,4304	2,5018	2,5745	2,6420	7,6567	145,13
130	0,5741	0,6005	0,7144	0,8527	1,0028	1,1635	1,3388	1,4502	1,5362	1,6066	1,7660	1,9252	2,0385	2,3626	2,4916	2,5751	2,6603	2,7392	8,5696	167,84
120	0,5000	0,4929	0,5473	0,6710	0,8261	1,0006	1,1945	1,3186	1,4146	1,4933	1,6717	1,8498	1,9767	2,3395	2,4837	2,5772	2,6724	2,7606	9,2627	186,58
110	0,5741	0,5248	0,4582	0,5144	0,6474	0,8207	1,0231	1,1546	1,2571	1,3413	1,5327	1,7243	1,8608	2,2517	2,4071	2,5078	2,6104	2,7055	9,7062	200,48
100	0,7475	0,6738	0,5023	0,4391	0,4972	0,6406	0,8352	0,9673	1,0716	1,1579	1,3553	1,5539	1,6958	2,1027	2,2648	2,3698	2,4768	2,5760	9,8824	208,95
90	0,9539	0,8701	0,6494	0,4934	0,4330	0,4934	0,6494	0,7707	0,8701	0,9539	1,1485	1,3465	1,4888	1,8988	2,0625	2,1687	2,2769	2,3773	9,7846	211,65
80	1,1579	1,0716	0,8352	0,6406	0,4972	0,4391	0,5023	0,5909	0,6738	0,7475	0,9264	1,1143	1,2511	1,6494	1,8095	1,9134	2,0195	2,1179	9,4165	208,48
70	1,3413	1,2571	1,0231	0,8207	0,6474	0,5144	0,4582	0,4806	0,5248	0,5741	0,7142	0,8768	1,0000	1,3688	1,5191	1,6172	1,7174	1,8106	8,7926	199,57
60	1,4933	1,4146	1,1945	1,0006	0,8261	0,6710	0,5473	0,5036	0,4929	0,5000	0,5627	0,6722	0,7675	1,0801	1,2131	1,3007	1,3909	1,4752	7,9389	185,26
50	1,6066	1,5362	1,3388	1,1635	1,0028	0,8527	0,7144	0,6436	0,6005	0,5741	0,5488	0,5736	0,6182	0,8276	0,9308	1,0012	1,0751	1,1451	6,8953	166,16
40	1,6764	1,6166	1,4488	1,2995	1,1616	1,0306	0,9039	0,8328	0,7836	0,7475	0,6823	0,6441	0,6357	0,6975	0,7518	0,7937	0,8408	0,8879	5,7212	143,19
30	1,7000	1,6525	1,5198	1,4020	1,2933	1,1894	1,0875	1,0286	0,9863	0,9539	0,8887	0,8363	0,8077	0,7717	0,7773	0,7870	0,8015	0,8188	4,5138	117,73
20	1,6764	1,6427	1,5490	1,4667	1,3914	1,3199	1,2501	1,2097	1,1805	1,1579	1,1114	1,0715	1,0473	0,9993	0,9894	0,9859	0,9847	0,9857	3,4586	92,091
10	1,6066	1,5874	1,5353	1,4910	1,4518	1,4161	1,3827	1,3642	1,3512	1,3413	1,3220	1,3064	1,2977	1,2834	1,2822	1,2827	1,2843	1,2868	2,9170	70,808
0	1,4933	1,4889	1,4791	1,4739	1,4722	1,4739	1,4791	1,4841	1,4889	1,4933	1,5051	1,5193	1,5307	1,5694	1,5872	1,5994	1,6124	1,6249	3,2300	62,267
	0	0,45	1,72	2,89	4,00	5,11	6,28	7,00	7,55	8,00	9,01	10,00	10,70	12,70	13,49	14,00	14,52	15,00	50,00	1000

When it moves in a given time, the object should move standing vertically with the horizontal speed of the rain.

3. Three-dimensional rectangular model

Table 3−1 α =68.61^o, β=150^o, γ= 70^o, A=1m, B=0,5m, C=1.7m, D=1m, V_R =8m/s,ρ=1

180		10,096	2,1489	1,8388	1,7873	1,4811	1,2861	1,1438	1,0293	0,9949	0,9628	0,9311	0,9075	0,8976	0,8649	0,8599	0,8143	0,7539	0,6634	0,6222	0,5037
170		8,4675	1,9690	1,7154	1,6733	1,4228	1,2634	1,1470	1,0534	0,9720	0,9601	0,9482	0,9395	0,9358	0,9236	0,9217	0,9047	0,8822	0,8485	0,8332	0,7890
160		6,6574	1,7480	1,5565	1,5247	1,3355	1,2150	1,1271	1,0564	0,9949	0,9377	0,9455	0,9512	0,9537	0,9617	0,9629	0,9741	0,9890	1,0112	1,0213	0,9885
150		6,7418	1,4928	1,3669	1,3460	1,2216	1,1424	1,0846	1,0381	0,9977	0,9601	0,9228	0,9425	0,9508	0,9781	0,9822	1,0203	1,0709	1,1465	1,1809	1,2799
140		8,5448	1,2111	1,1524	1,1427	1,0847	1,0478	1,0209	0,9992	0,9804	0,9628	0,9455	0,9326	0,9271	0,9723	0,9791	1,0420	1,1255	1,2503	1,3071	1,4203
131,23		9,9761	1,2880	0,9490	0,9490	0,9490	0,9490	0,9490	0,9490	0,9490	0,9490	0,9490	0,9490	0,9490	0,9490	0,9579	1,0403	1,1495	1,3129	1,3873	1,6014
130		10,164	1,3231	0,9782	0,9209	0,9289	0,9341	0,9378	0,9408	0,9434	0,9458	0,9482	0,9500	0,9508	0,9532	0,9536	1,0385	1,1511	1,3195	1,3961	1,5745
120		11,549	1,5955	1,2072	1,1427	0,7591	0,8046	0,8379	0,8647	0,8879	0,9096	0,9311	0,9470	0,9537	0,9757	0,9791	1,0099	1,1469	1,3520	1,4452	1,7139
110		12,659	1,8383	1,4161	1,3460	0,9289	0,6635	0,7242	0,7731	0,8157	0,8553	0,8945	0,9235	0,9358	0,9761	0,9822	1,0385	1,1131	1,3467	1,4529	1,7590
100		13,459	2,0440	1,5986	1,5247	1,0847	0,8046	0,6003	0,6690	0,7288	0,7844	0,8395	0,8804	0,8976	0,9543	0,9629	1,0420	1,1469	1,3039	1,4190	1,7507
90		13,926	2,2065	1,7492	1,6733	1,2216	0,9341	0,7242	0,5554	0,6299	0,6993	0,7680	0,8189	0,8403	0,9110	0,9217	1,0203	1,1511	1,3467	1,4357	1,6921
80		14,045	2,3208	1,8633	1,7873	1,3355	1,0478	0,8379	0,6690	0,5221	0,6024	0,6819	0,7409	0,7657	0,8475	0,8599	0,9741	1,1255	1,3520	1,4550	1,7518
70		13,813	2,3834	1,9374	1,8633	1,4228	1,1424	0,9378	0,7731	0,6299	0,4967	0,5840	0,6487	0,6759	0,7658	0,7794	0,9047	1,0709	1,3195	1,4326	1,7584
60		13,831	2,3924	1,9692	1,8990	1,4811	1,2150	1,0209	0,8647	0,7288	0,6024	0,4772	0,5453	0,5738	0,6683	0,6826	0,8143	0,9890	1,2503	1,3691	1,7117
50		14,047	2,3475	1,9579	1,8932	1,5084	1,2634	1,0846	0,9408	0,8157	0,6993	0,5840	0,4984	0,4625	0,5579	0,5724	0,7056	0,8822	1,1465	1,2666	1,6130
40		13,913	2,3713	1,9210	1,8462	1,5039	1,2861	1,1271	0,9992	0,8879	0,7844	0,6819	0,6058	0,5738	0,4683	0,4523	0,5820	0,7539	1,0112	1,1282	1,4653
30		13,430	2,3953	1,9647	1,8932	1,4679	1,2824	1,1470	1,0381	0,9434	0,8553	0,7680	0,7032	0,6760	0,5861	0,5724	0,4471	0,6079	0,8485	0,9579	1,2733
20		12,615	2,3654	1,9654	1,8990	1,5039	1,2525	1,1438	1,0564	0,9804	0,9096	0,8395	0,7875	0,7657	0,6936	0,6826	0,5820	0,4486	0,6634	0,7611	1,0426
10		11,492	2,2824	1,9230	1,8633	1,5084	1,2824	1,1175	1,0534	0,9977	0,9458	0,8945	0,8563	0,8403	0,7874	0,7794	0,7056	0,6079	0,4615	0,5436	0,7803
0		10,096	2,1489	1,8388	1,7873	1,4811	1,2861	1,1438	1,0293	0,9949	0,9628	0,9311	0,9075	0,8976	0,8649	0,8599	0,8143	0,7539	0,6634	0,6222	0,5037
	0	1,00	4,00	4,53	4,63	5,35	5,93	6,45	6,93	7,41	7,92	8,51	9,00	9,22	10,05	10,19	11,67	14,45	22,45	30,00	1000

When it rains from side and back, like a two-dimensional rectangle model, if there is an optimal speed, the condition should be one of the following two cases.

1. When the rain hits only the upper and side part of the body;
Optimal speed; $V_O = -V_R \frac{\cos\beta \sin\theta_O - \cos\gamma \cos\theta_O}{\sin\theta_O}$ and
2. When it hits only the back and side part or the front and side part (when it leans backward)
Optimal speed; $V_O = -V_R \frac{\cos\beta \cos\theta_O + \cos\gamma \sin\theta_O}{\cos\theta_O}$.

But it does not always exist. If it is slimmer (case 1), α is closer to 90° and β is closer to 180°, it will have more possibility of being in an optimal speed. In the Figure10, imagine a rectangular in the various rain direction and then we can easily understand this conclusion.

And when it rains from side way, there is also a section that makes the amount of wetting constant. The minimum value exists where θ_O =30° and V_0=11.67m/s.

Table 3-2 α =68.61°, β =150°, γ= 70°, A=1m, B=0.5m, C=1.7m, T=1/8 second, V_R =8m/s,ρ=1

180	1,3245	1,2620	1,1876	1,0952	1,0349	0,9902	0,9537	0,9417	0,9216	0,8914	0,9216	0,9417	0,9537	0,9584	0,9902	1,0349	1,0952	1,1876	1,3613	1,4728	3,5834	62,96
170	1,0831	1,0584	1,0291	0,9927	0,9689	0,9512	0,9369	0,9321	0,9242	0,9123	0,9004	0,9321	0,9509	0,9584	1,0084	1,0789	1,1739	1,3195	1,5930	1,7687	5,0934	98,62
163,61	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9390	0,9481	1,0090	1,0949	1,2106	1,3879	1,7211	1,9350	5,9848	119,91
160	0,8182	0,8322	0,8488	0,8694	0,8828	0,8928	0,9010	0,9036	0,9081	0,9149	0,9216	0,9261	0,9288	0,9387	1,0055	1,0996	1,2264	1,4207	1,7858	2,0202	6,4580	131,30
150	1,0031	0,8427	0,6520	0,7291	0,7794	0,8167	0,8471	0,8571	0,8739	0,8990	0,9242	0,9410	0,9510	0,9549	0,9814	1,0962	1,2510	1,4881	1,9337	2,2198	7,6357	159,99
140	1,2526	1,0681	0,8488	0,5761	0,6617	0,7252	0,7770	0,7939	0,8225	0,8653	0,9081	0,9367	0,9537	0,9604	1,0055	1,0690	1,2470	1,5197	2,0322	2,3614	8,5909	183,84
130	1,4734	1,2704	1,0291	0,7291	0,5332	0,6211	0,6926	0,7161	0,7556	0,8147	0,8739	0,9134	0,9368	0,9462	1,0084	1,0962	1,2146	1,5146	2,0785	2,4406	9,2945	202,11
120	1,6589	1,4436	1,1876	0,8694	0,6617	0,5075	0,5967	0,6259	0,6751	0,7488	0,8225	0,8718	0,9010	0,9126	0,9902	1,0996	1,2470	1,4729	2,0710	2,4551	9,7251	214,24
110	1,8034	1,5823	1,3195	0,9927	0,7794	0,6211	0,4920	0,5261	0,5835	0,6696	0,7556	0,8131	0,8471	0,8607	0,9512	1,0789	1,2510	1,5146	2,0100	2,4044	9,8697	219,88
100	1,9025	1,6824	1,4207	1,0952	0,8828	0,7252	0,5967	0,5546	0,4837	0,5794	0,6751	0,7391	0,7770	0,7920	0,8928	1,0349	1,2264	1,5197	2,0710	2,4250	9,7237	218,84
90	1,9533	1,7408	1,4881	1,1739	0,9689	0,8167	0,6926	0,6520	0,5835	0,4810	0,5835	0,6520	0,6926	0,7088	0,8167	0,9689	1,1739	1,4881	2,0785	2,4576	9,6338	211,51
80	1,9541	1,7557	1,5197	1,2264	1,0349	0,8928	0,7770	0,7391	0,6751	0,5794	0,4837	0,5546	0,5967	0,6134	0,7252	0,8828	1,0952	1,4207	2,0322	2,4250	9,8586	218,98
70	1,9049	1,7266	1,5146	1,2510	1,0789	0,9512	0,8471	0,8131	0,7556	0,6696	0,5835	0,5261	0,4920	0,5088	0,6211	0,7794	0,9927	1,3195	1,9337	2,3281	9,7933	219,80
60	1,9441	1,7289	1,4729	1,2470	1,0996	0,9902	0,9010	0,8718	0,8225	0,7488	0,6751	0,6259	0,5967	0,5851	0,5075	0,6617	0,8694	1,1876	1,7858	2,1699	9,4399	213,96
50	1,9589	1,7559	1,5146	1,2146	1,0962	1,0084	0,9369	0,9134	0,8739	0,8147	0,7556	0,7161	0,6927	0,6833	0,6211	0,5332	0,7291	1,0291	1,5930	1,9552	8,8091	201,62
40	1,9235	1,7391	1,5197	1,2470	1,0690	1,0055	0,9537	0,9367	0,9081	0,8653	0,8225	0,7939	0,7770	0,7703	0,7252	0,6617	0,5761	0,8488	1,3613	1,6904	7,9200	183,17
30	1,8392	1,6788	1,4881	1,2510	1,0962	0,9814	0,9510	0,9410	0,9242	0,8990	0,8739	0,8571	0,8471	0,8432	0,8167	0,7794	0,7291	0,6520	1,0976	1,3838	6,7997	159,16
20	1,7083	1,5769	1,4207	1,2264	1,0996	1,0055	0,9288	0,9261	0,9216	0,9149	0,9081	0,9036	0,9010	0,8999	0,8928	0,8828	0,8694	0,8488	0,8100	1,0445	5,4822	130,32
16,39	1,6504	1,5305	1,3879	1,2106	1,0949	1,0090	0,9390	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	0,9161	4,9656	118,89
10	1,5350	1,4365	1,3195	1,1739	1,0789	1,0084	0,9510	0,9321	0,9004	0,9123	0,9242	0,9321	0,9369	0,9387	0,9512	0,9689	0,9927	1,0291	1,0976	1,1416	4,0076	97,54
0	1,3245	1,2620	1,1876	1,0952	1,0349	0,9902	0,9537	0,9417	0,9216	0,8914	0,9216	0,9417	0,9537	0,9584	0,9902	1,0349	1,0952	1,1876	1,3613	1,4728	3,5834	62,96
	0	1,00	2,19	3,67	4,63	5,35	5,93	6,12	6,45	6,93	7,41	7,73	7,92	8,00	8,51	9,22	10,19	11,67	14,45	16,23	50,00	1000

Like other models, when it moves in a given time and it rains from the back, the object should move standing vertically with the horizontal speed of the rain.

And as we see the formulas of this model, when it moves in a given distance, the amount of wetting of the side part depends on the speed of the body (an author ignored this point) but when it moves in a given time, it is constant irrespective of the speed of body in a given rain condition.

4. Three-dimensional elliptic model

Table 4-1 α =68.61°,β =150°, γ= 70°, A=0.5m, B=0.5m, C=0.85m, D=1m, V_R =8m/s,ρ=1

180		7,0853	1,4537	0,7709	0,6758	0,6595	0,6556	0,6543	0,6432	0,6390	0,6289	0,6131	0,6100	0,5970	0,5818	0,5778	0,5686	0,5585	0,5580	0,5568	0,5525	0,5506	0,5503	0,5501	0,7800
170		6,6862	1,3842	0,7673	0,6867	0,6732	0,6699	0,6689	0,6598	0,6564	0,6482	0,6356	0,6332	0,6230	0,6113	0,6083	0,6016	0,5946	0,5943	0,5936	0,5911	0,5905	0,5905	0,5908	0,8026
160		6,4667	1,3218	0,7569	0,6911	0,6806	0,6782	0,6773	0,6706	0,6680	0,6621	0,6532	0,6515	0,6448	0,6378	0,6361	0,6328	0,6307	0,6306	0,6306	0,6314	0,6334	0,6340	0,6356	0,8631
150		6,4719	1,2757	0,7408	0,6886	0,6812	0,6795	0,6789	0,6744	0,6728	0,6691	0,6642	0,6633	0,6604	0,6585	0,6583	0,6591	0,6626	0,6630	0,6638	0,6688	0,6741	0,6755	0,6787	0,9479
140		6,7008	1,2534	0,7205	0,6795	0,6748	0,6738	0,6735	0,6711	0,6703	0,6688	0,6676	0,6676	0,6683	0,6715	0,6730	0,6779	0,6874	0,6882	0,6899	0,6994	0,7084	0,7108	0,7159	1,0424
130		7,1063	1,2589	0,6982	0,6645	0,6620	0,6616	0,6614	0,6608	0,6607	0,6611	0,6632	0,6639	0,6679	0,6759	0,6788	0,6876	0,7030	0,7042	0,7068	0,7207	0,7334	0,7367	0,7436	1,1341
120		7,6162	1,2912	0,6766	0,6453	0,6441	0,6440	0,6440	0,6446	0,6450	0,6467	0,6513	0,6525	0,6593	0,6712	0,6754	0,6876	0,7081	0,7097	0,7130	0,7310	0,7471	0,7512	0,7599	1,2138
110		8,1558	1,3446	0,6585	0,6238	0,6228	0,6229	0,6229	0,6239	0,6246	0,6269	0,6330	0,6346	0,6431	0,6578	0,6629	0,6777	0,7023	0,7042	0,7082	0,7295	0,7484	0,7533	0,7634	1,2750
100		8,6605	1,4108	0,6464	0,6025	0,6006	0,6005	0,6005	0,6011	0,6017	0,6039	0,6101	0,6117	0,6208	0,6368	0,6425	0,6588	0,6861	0,6882	0,6926	0,7163	0,7373	0,7427	0,7540	1,3132
90		9,0799	1,4807	0,6422	0,5842	0,5802	0,5796	0,5794	0,5787	0,5788	0,5800	0,5848	0,5863	0,5946	0,6103	0,6159	0,6325	0,6608	0,6630	0,6676	0,6924	0,7146	0,7203	0,7322	1,3259
80		9,3777	1,5459	0,6464	0,5714	0,5643	0,5629	0,5625	0,5597	0,5590	0,5583	0,5603	0,5612	0,5673	0,5807	0,5858	0,6012	0,6285	0,6306	0,6352	0,6598	0,6820	0,6878	0,6998	1,3124
70		9,5304	1,5995	0,6585	0,5661	0,5553	0,5530	0,5522	0,5468	0,5451	0,5418	0,5397	0,5398	0,5424	0,5515	0,5555	0,5682	0,5923	0,5943	0,5984	0,6213	0,6424	0,6479	0,6595	1,2734
60		9,5269	1,6365	0,6766	0,5691	0,5546	0,5513	0,5503	0,5420	0,5391	0,5331	0,5261	0,5252	0,5233	0,5267	0,5290	0,5376	0,5563	0,5580	0,5614	0,5809	0,5995	0,6045	0,6149	1,2116
50		9,3673	1,6537	0,6982	0,5800	0,5624	0,5583	0,5570	0,5462	0,5422	0,5335	0,5217	0,5198	0,5132	0,5099	0,5102	0,5137	0,5254	0,5265	0,5289	0,5436	0,5585	0,5626	0,5713	1,1313
40		9,0635	1,6495	0,7205	0,5970	0,5774	0,5727	0,5712	0,5585	0,5538	0,5430	0,5273	0,5245	0,5137	0,5041	0,5024	0,5005	0,5043	0,5049	0,5062	0,5150	0,5253	0,5282	0,5346	1,0394
30		8,6394	1,6244	0,7408	0,6178	0,5973	0,5924	0,5908	0,5772	0,5721	0,5601	0,5419	0,5386	0,5247	0,5103	0,5070	0,5006	0,49716	0,49718	0,4973	0,5003	0,5056	0,5073	0,5113	0,9450
20		8,1320	1,5804	0,7569	0,6395	0,6194	0,6145	0,6129	0,5994	0,5943	0,5821	0,5632	0,5596	0,5445	0,5275	0,5232	0,5139	0,5053	0,5049	0,5042	0,5025	0,5037	0,5043	0,5060	0,8607
10		7,5922	1,5216	0,7673	0,6595	0,6410	0,6364	0,6349	0,6223	0,6175	0,6060	0,5880	0,5845	0,5698	0,5526	0,5481	0,5379	0,5271	0,5265	0,5253	0,5212	0,5198	0,5197	0,5200	0,8012
0		7,0853	1,4537	0,7709	0,6758	0,6595	0,6556	0,6543	0,6432	0,6390	0,6289	0,6131	0,6100	0,5970	0,5818	0,5778	0,5686	0,5585	0,5580	0,5568	0,5525	0,5506	0,5503	0,5501	0,7800
	0	1,00	4,00	6,93	8,00	8,25	8,31	8,34	8,53	8,61	8,81	9,17	9,25	9,62	10,17	10,34	10,83	11,61	11,67	11,79	12,47	13,09	13,26	13,60	1000

Like two-dimensional elliptic model, whereθ_O=90^o, the optimal speed is bigger than the horizontal speed of the rain. In the given rain condition, the two-dimensional models (there is no side wind) will have the same minimum condition regardless of body type. However, when it rains side way, the minimum condition depends on the body type. In this example, the ellipsoid should move more slowly than the rectangular to get wet the least. On the table, θ_O =30^o and V_0=11.67m/s are the minimum condition of rectangular.

Table 4-2 α =68.61^o,β =150^o, γ= 70^o, A=0.5m, B=0.5m, C=0.85m, T=1/8 second, V_R =8m/s,ρ=1

180	0,9531	0,8857	0,7710	0,7269	0,6841	0,6822	0,6808	0,6780	0,6738	0,6726	0,6704	0,6683	0,6676	0,6676	0,6683	0,6704	0,6726	0,6738	0,6758	0,6780	0,6808	0,6822	0,6841	4,2809	97,50
170	0,9014	0,8358	0,7292	0,6921	0,6627	0,6618	0,6612	0,6602	0,6592	0,6591	0,6595	0,6612	0,6645	0,6655	0,6692	0,6754	0,6804	0,6827	0,6867	0,6906	0,6954	0,6977	0,7007	4,4806	100,32
160	0,8790	0,8083	0,6968	0,6609	0,6389	0,6387	0,6387	0,6389	0,6404	0,6412	0,6437	0,6487	0,6555	0,6573	0,6640	0,6740	0,6817	0,6852	0,6911	0,6968	0,7037	0,7068	0,7111	4,8625	107,88
150	0,8909	0,8090	0,6790	0,6379	0,6154	0,6155	0,6157	0,6166	0,6195	0,6208	0,6247	0,6320	0,6415	0,6440	0,6530	0,6663	0,6765	0,6810	0,6886	0,6960	0,7047	0,7087	0,7142	5,3479	118,49
140	0,9344	0,8376	0,6792	0,6267	0,5953	0,5952	0,5952	0,5959	0,5988	0,6002	0,6045	0,6129	0,6240	0,6268	0,6374	0,6531	0,6651	0,6705	0,6795	0,6882	0,6985	0,7033	0,7097	5,8607	130,30
130	1,0007	0,8883	0,6975	0,6295	0,5814	0,5805	0,5801	0,5797	0,5810	0,5821	0,5856	0,5935	0,6047	0,6077	0,6188	0,6357	0,6488	0,6546	0,6645	0,6742	0,6856	0,6909	0,6981	6,3397	141,76
120	1,0783	0,9520	0,7303	0,6456	0,5759	0,5739	0,5725	0,5703	0,5687	0,5688	0,5706	0,5764	0,5860	0,5887	0,5993	0,6159	0,6291	0,6351	0,6453	0,6553	0,6673	0,6729	0,6804	6,7401	151,73
110	1,1567	1,0195	0,7722	0,6723	0,5797	0,5762	0,5738	0,5693	0,5636	0,5625	0,5615	0,5637	0,5703	0,5724	0,5812	0,5960	0,6083	0,6140	0,6238	0,6336	0,6454	0,6509	0,6584	7,0305	159,38
100	1,2272	1,0826	0,8172	0,7054	0,5921	0,5872	0,5838	0,5767	0,5666	0,5641	0,5598	0,5574	0,5598	0,5610	0,5669	0,5785	0,5889	0,5938	0,6025	0,6114	0,6223	0,6274	0,6344	7,1905	164,15
90	1,2831	1,1350	0,8597	0,7404	0,6113	0,6052	0,6007	0,5915	0,5772	0,5734	0,5658	0,5586	0,5561	0,5563	0,5586	0,5658	0,5734	0,5772	0,5842	0,5915	0,6007	0,6052	0,6113	7,2100	165,74
80	1,3199	1,1722	0,8954	0,7729	0,6344	0,6274	0,6223	0,6114	0,5938	0,5889	0,5785	0,5669	0,5598	0,5589	0,5574	0,5598	0,5641	0,5666	0,5714	0,5767	0,5838	0,5872	2,4155	1,4995	164,05
70	1,3349	1,1913	0,9209	0,7998	0,6584	0,6509	0,6454	0,6336	0,6140	0,6083	0,5960	0,5812	0,5703	0,5684	0,5637	0,5615	0,5625	0,5636	0,5661	0,5693	0,5738	0,5762	0,5797	6,8314	159,18
60	1,3270	1,1909	0,9341	0,8183	0,6804	0,6729	0,6673	0,6553	0,6351	0,6291	0,6159	0,5993	0,5860	0,5834	0,5764	0,5706	0,5688	0,5687	0,5691	0,5703	0,5725	0,5739	0,5759	6,4584	151,45
50	1,2967	1,1709	0,9339	0,8268	0,6981	0,6909	0,6856	0,6742	0,6546	0,6488	0,6357	0,6188	0,6047	0,6019	0,5935	0,5856	0,5821	0,5810	0,5800	0,5797	0,5801	0,5805	0,5814	5,9970	141,42
40	1,2463	1,1329	0,9203	0,8248	0,7097	0,7033	0,6985	0,6882	0,6705	0,6651	0,6531	0,6374	0,6240	0,6212	0,6129	0,6045	0,6002	0,5988	0,5970	0,5959	0,5952	0,5952	0,5953	5,4881	129,92
30	1,1798	1,0799	0,8945	0,8122	0,7142	0,7087	0,7047	0,6960	0,6810	0,6765	0,6663	0,6530	0,6415	0,6392	0,6320	0,6247	0,6208	0,6195	0,6178	0,6166	0,6157	0,6155	0,6154	4,9882	118,13
20	1,1030	1,0165	0,8586	0,7902	0,7111	0,7068	0,7037	0,6968	0,6852	0,6817	0,6740	0,6640	0,6555	0,6538	0,6487	0,6437	0,6412	0,6404	0,6395	0,6389	0,6387	0,6387	0,6389	4,5699	107,59
10	1,0240	0,9490	0,8159	0,7608	0,7007	0,6977	0,6954	0,6906	0,6827	0,6804	0,6754	0,6692	0,6645	0,6636	0,6612	0,6595	0,6591	0,6592	0,6595	0,6602	0,6612	0,6618	0,6627	4,3136	100,15
0	0,9531	0,8857	0,7710	0,7269	0,6841	0,6822	0,6808	0,6780	0,6738	0,6726	0,6704	0,6683	0,6676	0,6676	0,6683	0,6704	0,6726	0,6738	0,6758	0,6780	0,6808	0,6822	0,6841	4,2809	97,50
	0	1,00	3,00	4,00	5,41	5,50	5,57	5,72	6,00	6,09	6,31	6,62	6,93	7,00	7,24	7,55	7,76	7,85	8,00	8,14	8,29	8,36	8,45	50	1000

Like other models, when it moves in a given time, the object should move standing vertically with the horizontal speed of the rain.

5. Three-dimensional cylindrical model

Table 5-1 α =68.61^o, β =150^o, γ= 70^o, A=0.5m, B=0.5m, C=1.7m, D=1m, V_R =8m/s,ρ=1

180		11,456	5,3353	3,2950	2,2749	1,6629	1,2548	0,9815	0,9795	0,9552	0,9363	0,9213	0,9089	0,9018	0,8986	0,8899	0,8824	0,8760	0,8533	0,8307	0,8126	0,7868
170		10,669	5,0240	3,1457	2,2090	1,6488	1,2767	1,0284	1,0120	0,9283	0,9345	0,9400	0,9450	0,9481	0,9496	0,9538	0,9577	0,9613	0,9763	0,9966	1,0187	1,0655
160		10,156	4,7779	3,0051	2,1321	1,6176	1,2813	1,0604	1,0458	0,8868	0,9174	0,9439	0,9670	0,9810	0,9875	1,0058	1,0222	1,0370	1,0935	1,1586	1,2177	1,3140
150		10,169	4,6946	2,9180	2,0649	1,5783	1,2717	1,0774	1,0649	0,9182	0,8843	0,9302	0,9707	0,9951	1,0065	1,0383	1,0667	1,0921	1,1874	1,2924	1,3833	1,5225
140		10,701	4,8153	2,9194	2,0291	1,5422	1,2528	1,0809	1,0702	0,9492	0,8652	0,8981	0,9538	0,9874	1,0032	1,0471	1,0861	1,1210	1,2504	1,3900	1,5081	1,6848
130		11,493	5,0818	3,0086	2,0381	1,5206	1,2308	1,0736	1,0643	0,9658	0,9052	0,8667	0,9156	0,9569	0,9763	1,0301	1,0781	1,1208	1,2786	1,4469	1,5877	1,7960
120		12,288	5,3948	3,1500	2,0884	1,5210	1,2129	1,0594	1,0510	0,9690	0,9291	0,9111	0,9044	0,9036	0,9257	0,9871	1,0418	1,0906	1,2703	1,4610	1,6196	1,8525
110		12,922	5,6736	3,2990	2,1620	1,5432	1,2050	1,0434	1,0350	0,9613	0,9373	0,9369	0,9473	0,9569	0,9621	0,9785	0,9949	1,0307	1,2253	1,4315	1,6024	1,8527
100		13,304	5,8664	3,4200	2,2369	1,5797	1,2098	1,0309	1,0218	0,9464	0,9314	0,9444	0,9688	0,9874	0,9970	1,0254	1,0526	1,0781	1,1781	1,3592	1,5369	1,7967
90		13,381	5,9426	3,4892	2,2941	1,6189	1,2257	1,0261	1,0158	0,9291	0,9147	0,9351	0,9695	0,9951	1,0080	1,0462	1,0824	1,1160	1,2459	1,3894	1,5108	1,6904
80		13,131	5,8858	3,4920	2,3201	1,6496	1,2472	1,0309	1,0191	0,9150	0,8920	0,9123	0,9512	0,9810	0,9961	1,0412	1,0840	1,1238	1,2776	1,4468	1,5893	1,7993
70		12,549	5,6901	3,4212	2,3066	1,6630	1,2675	1,0434	1,0305	0,9086	0,8695	0,8811	0,9177	0,9481	0,9639	1,0120	1,0585	1,1021	1,2725	1,4610	1,6197	1,8536
60		12,582	5,4316	3,2747	2,2492	1,6529	1,2800	1,0594	1,0462	0,9123	0,8542	0,8492	0,8754	0,9018	0,9164	0,9625	1,0089	1,0533	1,2313	1,4316	1,6013	1,8516
50		13,149	5,7385	3,2799	2,1468	1,6159	1,2794	1,0736	1,0609	0,9247	0,8512	0,8259	0,8341	0,8512	0,8620	0,8997	0,9408	0,9821	1,1565	1,3600	1,5345	1,7933
40		13,385	5,9075	3,4242	2,1918	1,5510	1,2621	1,0809	1,0695	0,9416	0,8617	0,8194	0,8063	0,8099	0,8144	0,8360	0,8652	0,8977	1,0529	1,2491	1,4216	1,6805
30		13,293	5,9379	3,4929	2,2768	1,5537	1,2263	1,0774	1,0678	0,9577	0,8819	0,8322	0,8033	0,7935	0,7910	0,7917	0,8019	0,8184	0,9306	1,1040	1,2666	1,5166
20		12,899	5,8377	3,4881	2,3169	1,6177	1,1716	1,0604	1,0531	0,9679	0,9054	0,8595	0,8263	0,8099	0,8032	0,7882	0,7801	0,7775	0,8151	0,9359	1,0757	1,3067
10		12,255	5,6254	3,4172	2,3143	1,6537	1,2142	1,0284	1,0237	0,9679	0,9254	0,8922	0,8658	0,8512	0,8447	0,8277	0,8139	0,8028	0,7748	0,7886	0,8643	1,0571
0		11,456	5,3353	3,2950	2,2749	1,6629	1,2548	0,9815	0,9795	0,9552	0,9363	0,9213	0,9089	0,9018	0,8986	0,8899	0,8824	0,8760	0,8533	0,8307	0,8126	0,7868
	0	1,00	2,00	3,00	4,00	5,00	6,00	6,93	7,00	8,00	9,00	10,00	11,00	11,67	12,00	13,00	14,00	15,00	20,00	30,00	50,00	1000

In this example, the cylinder should move more quickly than the rectangular in the given rain condition in order to get wet the least.

Table 5-2 α =68.61°, β =150°, γ= 70°, A=0.5m, B=0.5m, C=1.7m, T=1/8 second, V_R =8m/s,ρ=1

180	1,5302	1,4320	1,3338	1,2356	1,1375	1,0393	0,9411	0,8500	0,8570	0,9552	1,0534	1,1516	1,2497	1,3152	1,3479	1,4461	1,5443	1,6424	2,1333	3,1151	98,34
170	1,4128	1,3337	1,2560	1,1796	1,1045	1,0305	0,9575	0,8906	0,8855	0,9283	1,0513	1,1750	1,2994	1,3827	1,4243	1,5499	1,6759	1,8025	2,4408	3,7371	133,19
160	1,3525	1,2695	1,1945	1,1269	1,0661	1,0110	0,9609	0,9183	0,9151	0,8868	1,0321	1,1798	1,3297	1,4306	1,4813	1,6344	1,7888	1,9444	2,7338	4,3446	164,25
150	1,3856	1,2711	1,1737	1,0943	1,0325	0,9864	0,9538	0,9330	0,9318	0,9182	0,9948	1,1628	1,3347	1,4512	1,5098	1,6872	1,8667	2,0477	2,9685	4,8466	190,32
140	1,4908	1,3376	1,2038	1,0948	1,0146	0,9639	0,9396	0,9361	0,9364	0,9492	0,9734	1,1226	1,3115	1,4401	1,5049	1,7015	1,9007	2,1019	3,1259	5,2124	210,61
130	1,6192	1,4366	1,2704	1,1282	1,0191	0,9504	0,9231	0,9297	0,9313	0,9658	1,0184	1,0833	1,2590	1,3955	1,4644	1,6740	1,8866	2,1016	3,1964	5,4259	224,49
120	1,7360	1,5360	1,3487	1,1812	1,0442	0,9506	0,9097	0,9174	0,9196	0,9690	1,0453	1,1388	1,2436	1,3178	1,3885	1,6040	1,8231	2,0449	3,1757	5,4787	231,56
110	1,8221	1,6153	1,4184	1,2371	1,0810	0,9645	0,9038	0,9035	0,9057	0,9613	1,0544	1,1711	1,3025	1,3955	1,4432	1,5900	1,7412	1,9325	3,0632	5,3681	231,59
100	1,8672	1,6630	1,4666	1,2825	1,1184	0,9873	0,9074	0,8927	0,8941	0,9464	1,0478	1,1805	1,3321	1,4401	1,4955	1,6663	1,8421	2,0214	2,9452	5,0969	224,59
90	1,8661	1,6727	1,4856	1,3084	1,1470	1,0118	0,9193	0,8886	0,8888	0,9291	1,0290	1,1689	1,3331	1,4512	1,5120	1,7001	1,8943	2,0925	3,1147	5,2104	211,30
80	1,8166	1,6414	1,4715	1,3095	1,1601	1,0310	0,9354	0,8927	0,8917	0,9150	1,0035	1,1403	1,3079	1,4306	1,4942	1,6919	1,8970	2,1071	3,1940	5,4257	224,92
70	1,7192	1,5687	1,4225	1,2829	1,1533	1,0394	0,9507	0,9036	0,9017	0,9086	0,9782	1,1014	1,2619	1,3826	1,4459	1,6445	1,8524	2,0665	3,1812	5,4787	231,70
60	1,7915	1,5728	1,3579	1,2280	1,1246	1,0331	0,9600	0,9174	0,9154	0,9123	0,9609	1,0615	1,2037	1,3152	1,3746	1,5640	1,7655	1,9749	3,0782	5,3687	231,45
50	1,8559	1,6437	1,4346	1,2300	1,0734	1,0100	0,9595	0,9297	0,9283	0,9247	0,9576	1,0324	1,1468	1,2414	1,2930	1,4620	1,6464	1,8414	2,8912	5,1001	224,16
40	1,8720	1,6731	1,4769	1,2841	1,0959	0,9693	0,9466	0,9361	0,9358	0,9416	0,9694	1,0242	1,1087	1,1811	1,2216	1,3586	1,5141	1,6832	2,6323	4,6840	210,06
30	1,8408	1,6616	1,4845	1,3098	1,1384	0,9710	0,9197	0,9330	0,9344	0,9577	0,9922	1,0403	1,1046	1,1572	1,1865	1,2865	1,4033	1,5346	2,3266	4,1401	189,58
20	1,7666	1,6123	1,4594	1,3080	1,1585	1,0111	0,8787	0,9183	0,9215	0,9679	1,0186	1,0744	1,1362	1,1811	1,2048	1,2809	1,3651	1,4579	2,0376	3,5097	163,34
10	1,6578	1,5318	1,4064	1,2815	1,1572	1,0336	0,9107	0,8906	0,8958	0,9679	1,0410	1,1152	1,1905	1,2414	1,2671	1,3450	1,4243	1,5052	1,9370	2,9571	132,14
0	1,5302	1,4320	1,3338	1,2356	1,1375	1,0393	0,9411	0,8500	0,8570	0,9552	1,0534	1,1516	1,2497	1,3152	1,3479	1,4461	1,5443	1,6424	2,1333	3,1151	98,34
	0	1,00	2,00	3,00	4,00	5,00	6,00	6,93	7,00	8,00	9,00	10,00	11,00	12,00	13,00	14,00	15,00	20,00	30,00	50,00	1000

When it rains from the back and the object should move in a given time, the rectangular, elliptic and cylindrical models have a best strategy when it moves standing vertically or totally leaning forward with the horizontal speed of the rain. To prove it by using formulas is not easy.

But let´s look at the Figures 8 and 10. When they move in a given time 1 with a speed V_O , the points in the sky will be $(V_O + V_R\cos\theta_R , V_R\sin\theta_R)$ and $(V_R\cos\alpha, V_O + V_R\cos\beta, V_R\cos\gamma)$ respectively.We can imagine how the floating objects move in the givenspeed and angle of rain. And we can find easily the condition to make the area or volume minimum.

The floating objects move on the parallel line to the x-axis and y-axis respectively. To make the swept area or volume minimum, they should stand vertically; θ_O=90° or lean forward totally; θ_O=0° and they should be located just above the zero point, it means that the optimal speeds are the horizontal speed of rain;$V_O + V_R\cos\theta_R = 0$, $V_O + V_R\cos\beta = 0$.

Solution of quiz in the introduction

When it travels 1053.90 km

60,52		24479,920	2325,0951	1109,6892	716,9055	546,6635	427,3903	275,2350	264,0700	258,7355	258,7349	258,7352	300,1805
	0	1	10	20	30	38,85	50	100	120	161	161,57	162	100000

When it travels 2.16 days

60,52	4355,9377	4111,2207	3923,7300	3754,1729	3752,2570	3751,2482	3777,5241	3876,2768	4043,1340	4270,1197	4548,2403	4868,7407	51101,664
	0	10	20	38,85	40	41,63	50	60	70	80	90	100	1000

Acknowledge

I thank to Prof. Franco Bocci for providing a motive of making this paper and his words of encouragement.

Reference

[1]. Bocci, F. (2012).Whether or not to run in the rain.European Journal of Physics, 33(5), 1321-1332

[2]. Bailey, H. (2002).On running in the rain.College Mathematics Journal, 33(2), 88-92.

[3]. Hailman, D., & Torrents, B. (2009).Keeping dry: The mathematics of running in the rain.Mathematics Magazine, 82(4), 266-277

[4]. S. Seo (2012). The best strategy in rain.International Journal of Fundamental Physical Sciences, Vol. 2, No.4, 64-71.