Unit-1 : Assignment

Q1. A two-wheeler with drag coefficient of 0.51 and frontal projection area of 0.72 m^2 has a maximum velocity of 130 Kmph. Calculate the air resistance of the vehicle for the speed from 0-130 Kmph (Take maximum speed increment of 5 Kmph). Also, plot the graph of aerodynamic force Vs the speed.

→ Given,

Drag Coefficient $C_D = 0.51$, Frontal Area = 0.72 m^2

V_{max} = 130 Kmph. Density of air = 1.2 Kg/m^3

We know that

$$F_D = \frac{1}{2} \rho v^2 C_D A$$

Or $F_D = 0.6 \times C_D \times A \times v^2$

where,

F_D = drag force or aerodynamic force

ρ = density of fluid

v = velocity of the object relative to the fluid

C_D = drag coefficient

A = Cross sectional Area

Sl No	Speed (m/s)	Fd (N)
1	$5 \times \frac{5}{18}$	0.43
2	$10 \times \frac{5}{18}$	1.7
3	$15 \times \frac{5}{18}$	3.82
4	$20 \times \frac{5}{18}$	6.8
5	$25 \times \frac{5}{18}$	10.62
6	$30 \times \frac{5}{18}$	15.3

7	$35 \times \frac{5}{18}$	20.83
8	$40 \times \frac{5}{18}$	27.2
9	$45 \times \frac{5}{18}$	34.43
10	$50 \times \frac{5}{18}$	42.5
11	$55 \times \frac{5}{18}$	51.43
12	$60 \times \frac{5}{18}$	61.2
13	$65 \times \frac{5}{18}$	71.83
14	$70 \times \frac{5}{18}$	83.1
15	$75 \times \frac{5}{18}$	95.48
16	$80 \times \frac{5}{18}$	108.64
17	$85 \times \frac{5}{18}$	122.64
18	$90 \times \frac{5}{18}$	137.5
19	$95 \times \frac{5}{18}$	153.2
20	$100 \times \frac{5}{18}$	169.75
21	$105 \times \frac{5}{18}$	187.15
22	$110 \times \frac{5}{18}$	205.4
23	$115 \times \frac{5}{18}$	224.5

24	$120 \times \frac{5}{18}$	244.4
25	$125 \times \frac{5}{18}$	265.2
26	$130 \times \frac{5}{18}$	286.9

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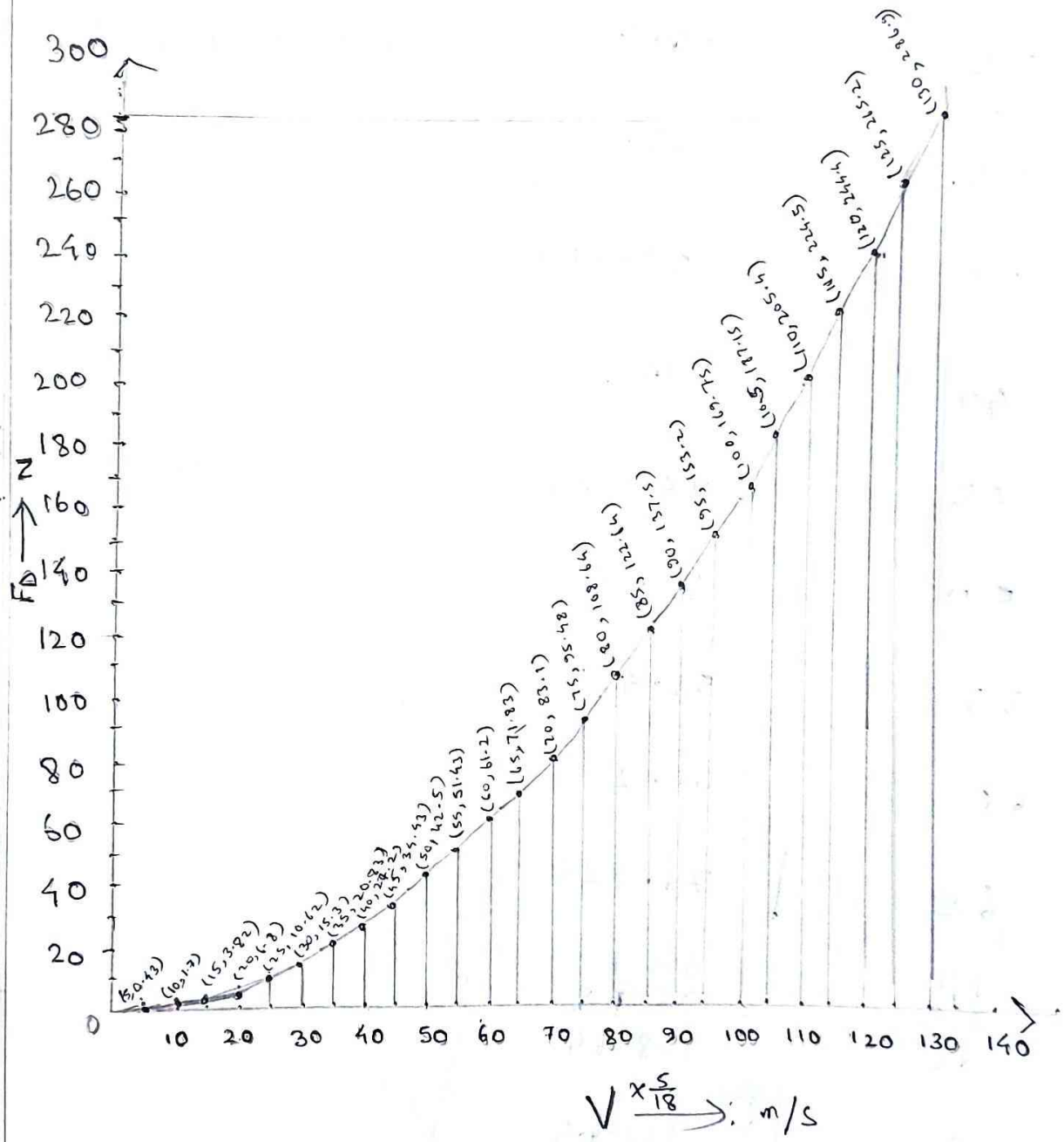
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Fd → N
10 20 30 40 50 60 70 80 90 100 110 120 130 140
V x 5/18 → m/s
(5, 0.43)
(10, 1.7)
(15, 3.82)
(20, 6.8)
(25, 10.62)
(30, 15.3)
(35, 20.83)
(40, 27.22)
(45, 34.43)
(50, 42.5)
(55, 51.43)
(60, 61.2)
(65, 71.83)
(70, 83.1)
(75, 95.48)
(80, 108.96)
(85, 123.4)
(90, 137.5)
(95, 153.2)
(100, 169.75)
(105, 187.15)
(110, 205.4)
(115, 224.5)
(120, 244.4)
(125, 265.2)
(130, 286.8)

Q2 For the following vehicles determine the drag resistance at the speed of 40 Kmph.

1) Nissan Leaf
2) Tesla Model S Plaid
3) Tata Nexon
4) Toyota Prius
5) Ather 450 X
6) Royal Enfield.

→ 1) Nissan Leaf (2013 model)

$C_D = 0.28$, $A = 24.5$ sq ft $= \frac{24.5}{10.764}\ m^2$

$v = 40$ Kmph. $= 2.276\ m^2$

$$f_D = \frac{1}{2} \times 1.2 \frac{Kg}{m^3} \times \left(\frac{40 \frac{km}{hr} \times 1000 \frac{m}{km}}{3600\ s/hr} \right)^2 \times 0.28 \times 2.276$$

$$= \frac{1}{2} \times 1.2 \frac{Kg}{m^3} \times \left(\frac{40 \times 1000}{3600} \right)^2 \frac{m^2}{s^2} \times 0.28 \times 2.276$$

$$= 47.205\ N$$

2) Tesla Model S Plaid ($P8_S$) [2012]

$C_D = 0.24$ $A = 25.2$ sq ft $= \frac{25.2}{10.764}\ m^2 = 2.341\ m^2$

$v = 40$ Kmph

$$f_D = \frac{1}{2} \times 1.2 \times \left(40 \times \frac{5}{18} \right)^2 \times 0.24 \times 2.341\ N$$

$$= 41.617\ N$$

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3) Tata Nexon

$C_D = 0.18$, $A = 2.472\ m^2$, $V = 40$ Kmph

$$F_D = \frac{1}{2} \times 1.2 \times \left(40 \times \frac{5}{18}\right)^2 \times 0.18 \times 2.472\ N$$

$$= 32.96\ N$$

Frontal area

$= 0.85 \times$ weight $\times$ height of car

$= 0.85 \times 1.811 \times 1.606\ m^2$

$= 2.472\ m^2$

Since,

width = 1811 mm → 1.811 m

height = 1606 mm → 1.606 m

4) Toyota Prius

$C_D = 0.26$ $A = 23.9$ sqft $= \frac{23.9}{10.764}\ m^2 = 2.22\ m^2$

$V = 40$ Kmph.

$$F_D = \frac{1}{2} \times 1.2 \times \left(40 \times \frac{5}{18}\right)^2 \times 0.26 \times 2.22\ N$$

$$= 42.76\ N$$

5) Ather 450 X

$C_d = 0.9$, $A = 0.743\ m^2$

$V = 40$ Kmph

$$F_D = \frac{1}{2} \times 1.2 \times \left(40 \times \frac{5}{18}\right)^2 \times 0.9 \times 0.743\ N$$

$$= 49.53\ N$$

W = 700 mm

$= 0.7$ m

H = 1250 mm

$= 1.250$ m

∴ Frontal area

$= 0.85 \times W \times H$

$= 0.743\ m^2$

6) Royal Enfield

$C_d = 0.5$ $A = 0.9\ m^2$

$$F_d = \frac{1}{2} \times 1.2 \times \left(40 \times \frac{5}{18}\right)^2 \times 0.5 \times 0.9\ N$$

$$= 33.33\ N$$

Q: For the following vehicle calculate the peak power and torque of the motor Required.

Vehicle	Initial Acceleration Speed (kmph)	Time (s)
Nissan Leaf	0-100	7.9
Tesla model S plaid	0-100	1.99
Tata Nexon EV	0-100	9.3
MG ZS EV	0-100	8.2
Hyundai Kona	0-100	6.6
Ather 450X	0-40	3.9
Royal Enfield	0-60	4.2
Bajaj Dominar	0-100	8.4
Hero splendor	0-60	8

1) Nissan Leaf

$V_f = 100$ Km/hr

$= \frac{100}{3.6}$ m/s $= 27.77$ m/s

$\simeq 28$ m/s

8 inches $\rightarrow$ m

$\frac{8}{39.37}$ m

$= 0.2032$ m

$t = 7.9$ s

$r_{wheel} = 8$ inches $= 0.2032$ m

$m = 1595$ Kg

$P_{Peak} = \frac{mV_f^2}{t} = \frac{1595 \times (28)^2}{7.9}$ $\frac{Kg\,m^2}{s.s^2}$

$= 158288.6076$ W $\simeq 158.2$ Kw

$$\tau = \frac{mv_f}{t} \times r_{wheel}$$

$$= \frac{1595 \times 28}{7.9} \times 0.2032 \quad \frac{kg\ m}{s\ s}\ m$$

$$= 1148.72\ Nm$$

2) Tesla Model S Plaid

$v_f = 100\ km/hr \approx 28\ m/s \quad t = 1.99\ s$

$r_{wheel} = 9.5\ inches = 0.2413\ m$

$m = 2162\ kg$

$$\therefore P_{peak} = \frac{2162 \times (28)^2}{1.99}$$

$$= 851.76\ KW$$

$$\tau = \frac{mv_f}{t} \times r_{wheel}$$

$$= \frac{2162 \times 28}{1.99} \times 0.2413$$

$$= 7340.3\ Nm$$

3) Tata Nexon EV

$v_f = 100\ Km/hr \approx 28\ m/s, \quad t = 9.3\ s, \quad m = 1400\ kg$

$r_{wheel} = 8\ inches \approx 0.2032$

$$\therefore P_{peak} = \frac{mv_f^2}{t} = \frac{1400 \times (28)^2}{9.3} \approx 118\ KW$$

$$\tau = \frac{mv_f}{t} \times r_{wheel}$$

$$= \frac{1400 \times 28}{9.3} \times 0.2032$$

$$= 856.5\ Nm$$

4) MG ZS EV

$V_f = 100\ km/h \simeq 28\ m/s \quad t = 8.2\ s$

$r_{wheel} = 8.5\ inches = 0.2159\ m$

$m = 1539\ kg$

$P_{peak} = \frac{1539 \times (28)^2}{8.2}$

$= 147\ kW$

$\tau = \frac{1539 \times 25}{8.2} \times 0.2159$

$= 1134.5\ N\,m$

5) Hyundai Kona

$V_f = 100\ km/hr \simeq 28\ ms^{-1} \quad t = 6.65$

$r_{wheel} = 8.5\ inches = 0.2159\ m$

$m = 1685\ kg$

$\therefore P_{peak} = \frac{mv_f^2}{t} = \frac{1685 \times (28)^2}{6.6} \simeq 200\ kW$

$\tau = \frac{mv_f}{t} \times r_{wheel}$

$= \frac{1685 \times 28}{6.6} \times 0.2159$

$\simeq 1543\ N\,m$

6) Ather 450X

$V_f = 40\ km/hr \simeq 11.11\ m/s, \quad t = 3.9\ s$

$r_{wheel} = 0.1524\ m$

$m = 108\ kg$

$\therefore P_{peak} = \frac{108 \times (11.11)^2}{3.9} = 3.41\ kW$

$$\tau = \frac{109 \times 11.11 \times 0.624}{3.9}$$

$$\approx 47 \text{ Nm}$$

Royal Enfield (Classic 350)

$v_f = 60 \text{ km/hr} \approx 16.7 \text{ m s}^{-1}$, $t = 4.2 \text{ s}$

$r_{wheel} = 9.25 \text{ inch} = 0.235 \text{ m}$, $m = 375 \text{ kg}$

$$P_{peak} = \frac{375 \times (16.7)^2}{4.2} \approx 25 \text{ kW}$$

$$\tau \approx \frac{375 \times 16.7 \times 0.235}{4.2} = 350 \text{ Nm}$$

2) ## Bajaj dominar (400)

$v_f = 100 \text{ km/hr} \approx 28 \text{ m/s}$, $r_{wheel} = 8.5 \text{ inches} = 0.2159 \text{ m}$

$m = 193 \text{ kg}$, $t = 8.4 \text{ sec}$

$$P_{peak} = \frac{193 \times (28)^2}{8.4} = 18 \text{ kW}$$

$$\tau = \frac{193 \times 28 \times 0.2159}{8.4} = 139 \text{ Nm}$$

Hero splendor

$v_f = 60 \text{ km/h} \approx 17 \text{ m/s}$, $t = 8 \text{ s}$

$m = 112 \text{ kg}$, $r_{wheel} = 8 \text{ inches} = 0.2032 \text{ m}$

$$P_{peak} = \frac{112 \times (17)^2}{8} \approx 4 \text{ kW}$$

$$\tau = \frac{112 \times 17 \times 0.2032}{8} \approx 48 \text{ Nm}$$

Q4 For the vehicle above plot the graph of — Traction force, aerodynamic force and rolling resistance against the vehicle speed. (Take top speed of the vehicle for speed range and take speed interval as 5Kmph)

→ 1) Nissan Leaf

$$F_{trac} = \frac{mv}{t} + mg\mu\cos\theta + mg\sin\theta + F_d$$

$$= \frac{mv}{t} + mg\mu\cos\theta + mg\sin\theta + \frac{1}{2}\rho v_f^2 C_d A$$

$$F_a = \frac{mv_f}{t} = \frac{1595 \times 28}{7.9} = 5.6 \text{ KN}$$

$mg\mu\cos\theta = mg\mu = 1595 \times 9.8 \times 0.013$ [Considering Concrete road)

$\because \theta = 0 \therefore \cos\theta = 1$

Rolling resistance $= mg\mu\cos\theta = 0.2$ KN

∵ Since there is no inclination, $mg\sin\alpha$ for every case will be 0

$$F_d = \frac{1}{2} \times 1.2 \times (28)^2 \times 0.28 \times 2.27 \text{ N}$$

$$= 0.3 \text{ KN}$$

2) Tesla Model $F_{trac} = 5.6 + 0.2 + 0.3$ kN

$= 6.1$ KN

2) Tesla Model S Plaid

$$F_a = \frac{mv_f}{t} = \frac{2162 \times 28}{1.99} = 30.42 \text{ kN}$$

Rolling resistance $= mg\mu\cos\theta$

$= 2162 \times 9.8 \times 0.013$

$= 0.3 \text{ kN}$

$$F_d = \frac{1}{2} \times 1.2 \times C_d \times v_f^2 \times A$$

$$= \frac{1}{2} \times 1.2 \times (28)^2 \times 0.24 \times 2.341 \text{ N}$$

$= 0.26 \text{ kN}$

$F_{trac} = 30.42 + 0.3 + 0.26 \text{ kN}$

$= 31 \text{ kN}$

3) Tata Nexon EV

$$F_a = \frac{mv_f}{t} = \frac{1400 \times 28}{9.3} = 4.2 \text{ kN}$$

Rolling resistance $= mg\mu\cos\theta = 1400 \times 9.8 \times 0.013$

$= 0.17 \text{ kN}$

$F_d = 0.6 \times C_D \times A \times (28)^2 = 0.20 \text{ kN}$

$F_{trac} = 4.2 + 0.17 + 0.20 \text{ kN}$

$= 4.57 \text{ kN}$

4) MG ZS EV

$$F_a = \frac{mv_f}{t} = \frac{1539 \times 28}{8.2} = 5.25 \text{ kN}$$

Rolling Resist $= mg\mu\cos\theta = 1539 \times 9.8 \times 0.013$

$= 0.2 \text{ kN}$

$F_d = 0.6 \times C_d \times A \times V_b^2 = 0.6 \times 0.28 \times 2.472 \times (28)^2$

$= 0.32\ kN$

$F_{trac} = 5.25 + 0.2 + 0.32 = 5.8\ kN$

5) Hyundai Kona

$F_a = \frac{mV_b}{t} = \frac{1685 \times 28}{6.6} = 7.14\ kN$

Rolling Resistance $= mg\mu\cos\theta$

$= 1685 \times 9.8 \times 0.013 = 0.21\ kN$

$F_d = 0.6 \times C_d \times A \times V_b^2$

$= 0.6 \times 0.28 \times 2.472 \times (28)^2$

$= 0.3\ kN$

$F_{trac} = 7.65\ kN$

6) Ather 450x

$F_a = \frac{mV_b}{t} = \frac{168 \times 11.11}{3.9} = 0.3\ kN$

Rolling resist $= mg\mu\cos\theta$

$= 108 \times 9.8 \times 0.013$

$= 0.01\ kN$

$F_d = 0.6 \times C_d \times A \times V_b^2 = 0.6 \times 0.9 \times 0.7 \times (11.11)^2$

$= 0.04\ kN$

$F_{trac} = 0.35\ kN$

7) Royal Enfield

$F_a = \frac{mV_b}{t} = \frac{375 \times 16.66}{4.2} = 1.5\ kN$

Rolling Resistance = $375 \times 9.8 \times 0.013$

$= 0.05$ kN

$f_d = 0.6 \times C_d \times A \times v^2$

$= 0.6 \times 0.5 \times 0.2 \times (16.66)^2$

$= 0.07$ kN

$f_{frac} = 1.62$ kN

Bajaj Dominar

$f_a = \frac{mv_b}{t} = \frac{193 \times 28}{8.4} = 0.64$ kN

Rolling Resistance $= 193 \times 9.8 \times 0.013 = 0.03$ kN

$f_d = 0.6 \times C_d \times A \times v^2 = 0.6 \times 0.5 \times 0.8 \times (28)^2$

$= 0.2$ kN

$f_{frac} = 0.87$ kN

9) Hero Splendor

$f_a = \frac{mv_b}{t} = \frac{112 \times 16.66}{8} = 0.23$ kN

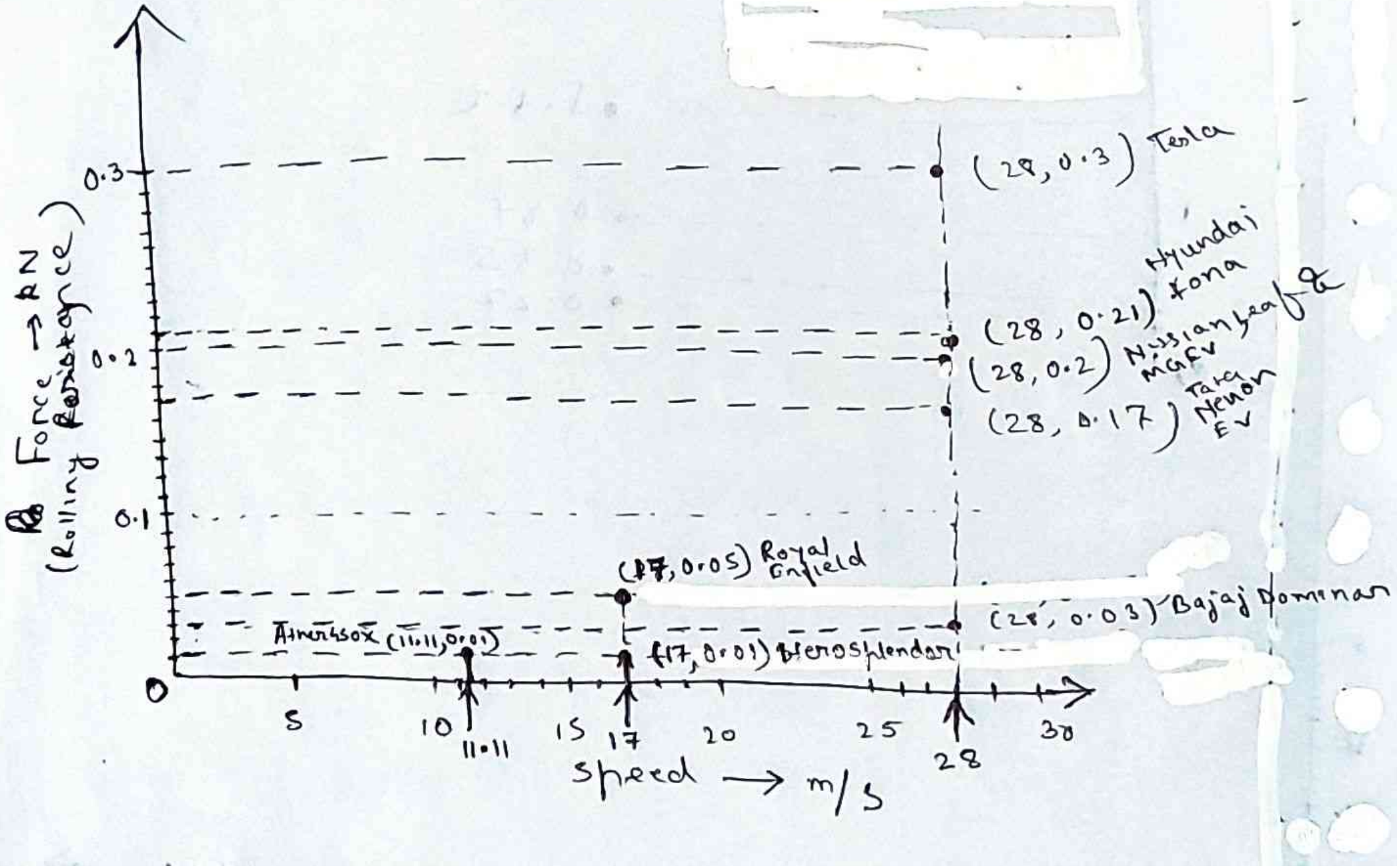
Rolling resistance $= 112 \times 9.8 \times 0.013 = 0.01$ kN

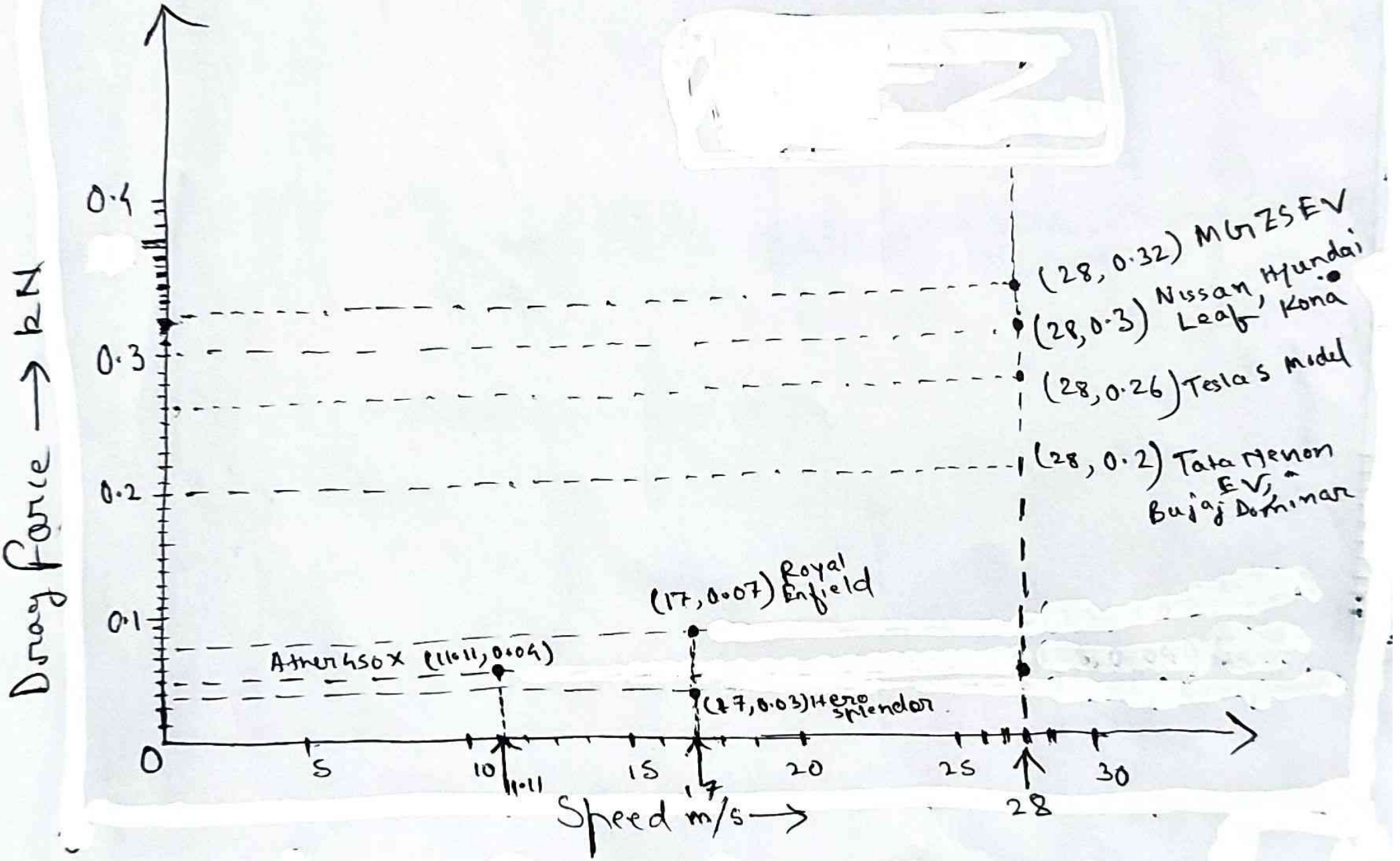
$f_d = 0.6 \times A \times C_d \times v_b^2$

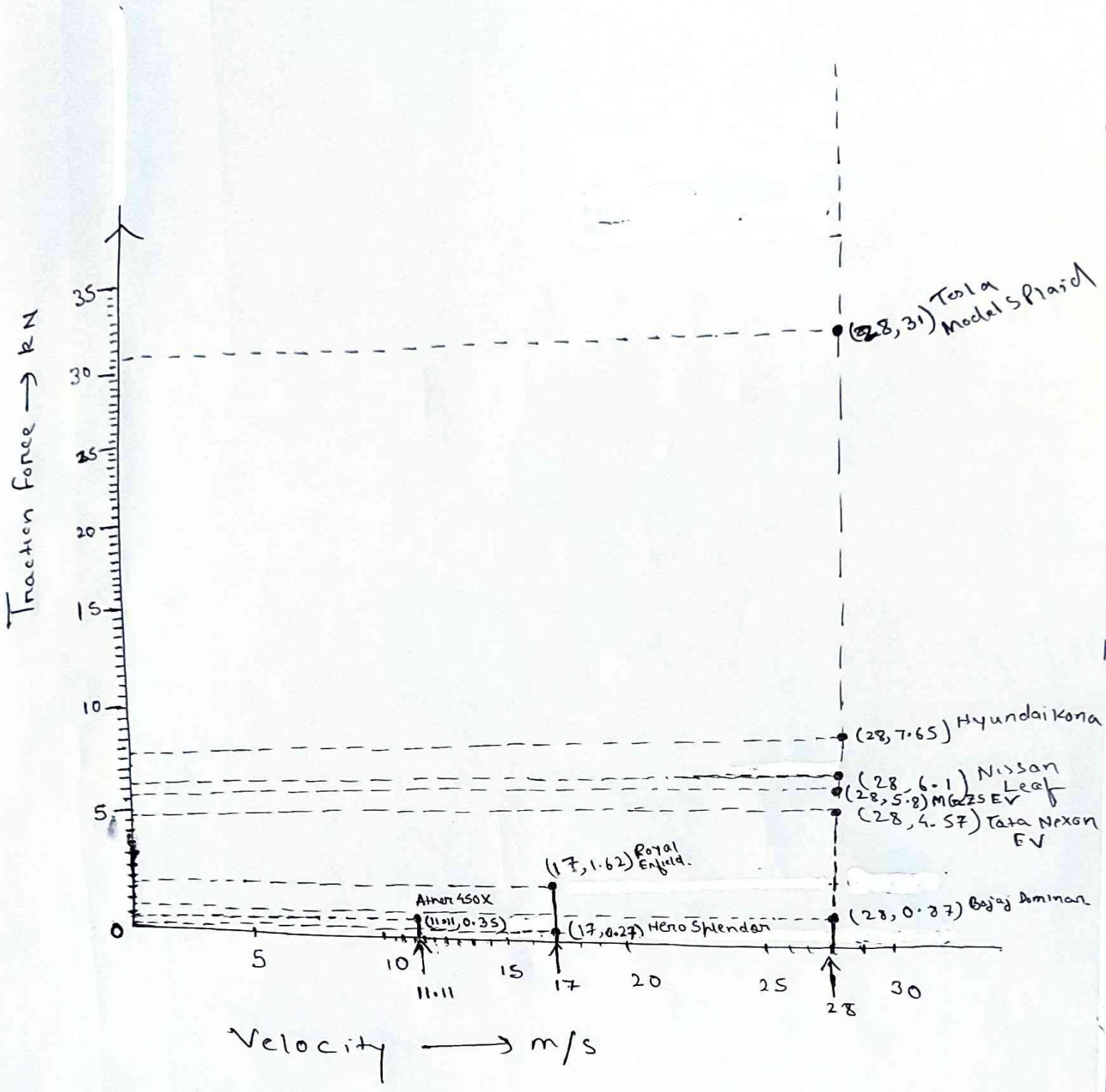
$= 0.6 \times 0.3 \times 0.7 \times (16.66)^2$

$= 0.03$ kN

$f_{frac} = 0.27$ kN


Force → RN
(Rolling Resistance)
0.3
0.2
0.1
0
(28, 0.3) Tesla
(28, 0.21) Hyundai Kona
(28, 0.2) Nissan Leaf & MG EV
(28, 0.17) Tata Nexon EV
(17, 0.05) Royal Enfield
(28, 0.03) Bajaj Pulsar
Ather 450X (11.11, 0.01)
(17, 0.01) Hero Splendor
5
10
11.11
15
17
20
25
28
30
Speed → m/s


Drag force → kN
0.4
0.3
0.2
0.1
0
5
10
11.11
15
17
20
25
28
30
Speed m/s →
(28, 0.32) MG ZS EV
(28, 0.3) Nissan, Hyundai Leaf, Kona
(28, 0.26) Tesla S model
(28, 0.2) Tata Nexon EV, Bajaj Dominar
(17, 0.007) Royal Enfield
Ather 450X (11.11, 0.04)
(17, 0.03) Hero Splendor


Traction force → kN
35
30
25
20
15
10
5
0
(28, 31) Tesla Model S Plaid
(28, 7.65) Hyundai Kona
(28, 6.1) Nissan Leaf
(28, 5.8) MG ZS EV
(28, 4.57) Tata Nexon EV
(17, 1.62) Royal Enfield.
Ather 450X
(11.11, 0.35)
(17, 0.27) Hero Splendor
(28, 0.87) Bajaj Aminan
5
10
15
17
20
25
28
30
11.11
Velocity → m/s