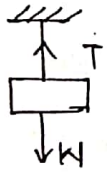
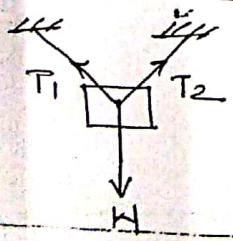
TO - NB

GOVERNMENT POLYTECHNIC PUNE

Model Answers & Marking scheme (ODD-2019)

Course Name: Engineering Mechanics Course Code: AM2101.

Q.No.	Sub-Que.	Model Answers	Marking scheme
Q1	a)	**Statics** – It is that branch of applied mechanics which deals with action of forces on bodies at rest. **Dynamics** – It is that branch of applied mechanics which deals with action of forces on bodies in motion.	
	b)	See table below	
	c)	Two types of system of forces with sketch. i) **collinear force system**  The forces acting along the same line of action are known as collinear force system ii) **Concurrent force system** –  The forces which meet at a point are called as concurrent force system	

Mass	Weight
i) Mass is the quantity of matter contained in a body	i) Weight of body is the force with which body is attracted by the earth towards it's centre.
ii) It's a scalar quantity	ii) it is a vector quantity
iii) SI unit - kg	iii) SI unit Newton

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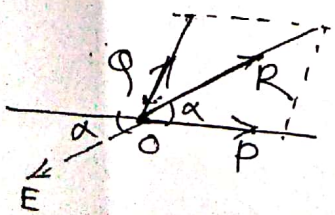
	d)	**Law of polygon forces –** It state's that, if number of coplaner concurrent forces acting simultaneously on a body, be represented in maginitude and direction by the sides of a polygon taken in order, then their resultant may be represented in magnitude and direction by the closing side of a polygon taken in opposite order.	
	e)	**Equilibrant –** Definition – An equilibrant of no. of forces acting on a body is a single force which when acting with other forces brings the set of forces and the body in equilibrium. **Relation between equilibrant and Resultant** An equilibrant force must be equal in magnitude, opposite in direction and collinear to the resultant.  R is resultant of forces P and Q. E equilibrant forces which is equal and opposite to the Resultant	

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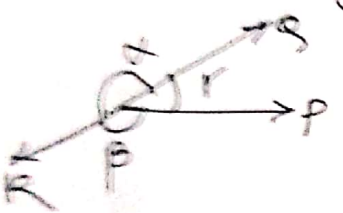
f) **Lami's theorem with it's mathematical expression**

If three forces acting at a point on a body keep it at rest then each force is proportional to the sine of the angle between the other two forces.

Mathematically -



$$\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$$

g) **Analytical condition's of equilibrium for coplanar concurrent forces.**

i) $\Sigma F_x = 0$ (ie) Algebric sum of components of all forces along x-axis must be equal to zero

ii) $\Sigma F_y = 0$ (ie) Algebric sum of components of all forces along Y axis must be equal to zero.

h) **Effort** → The forces applied to overcome the resistance or to lift the load is known as effort.

Ideal effort = Effort when the forces applied to overcome resistance or to lift

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a load when there is no friction or machine is ideal machine. And it is ratio of Load to velocity Ratio — $P_i = \frac{W}{V_R}$

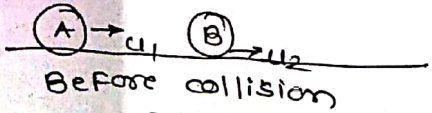
i) Laws of static friction

i) The frictional force always acts tangential to the plane of contact and in the direction opposite to impending motion.

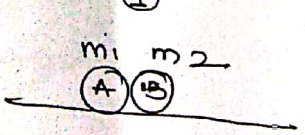
ii) When body is in limiting equilibrium the limiting friction bears a constant ratio to the normal reaction, This ratio is called as 'coefficient of friction'.

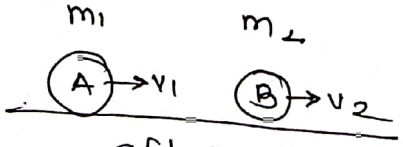
j) Law of conservation of momentum

It state's, "The total momentum of a system consisting of two or more colliding bodies before impact remains unchanged even after the impact, provided no external forces act."



(I)





(II)

Suppose we have two bodies of masses m_1 and m_2 moving in same direction, with initial velocities

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u_1 and u_2 on a straight line ($u_1 > u_2$)
The body A at a particular instance collide with the body B. After collision both bodies will move in same direction with velocities v_1 and v_2 ($v_2 > v_1$) as shown in fig

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

k) Newton's second law of motion :-

The rate of change of momentum of a body is directly proportional to the net force acting on the body and takes place in the direction of force.

l) Energy :-

Energy possessed by a body is defined as capacity or ability of the body to do work.

forms of energy —

1) mechanical 2) electrical 3) chemical
4) Heat 5) Light 6) sound.

Mechanical energy — potential energy
kinetic energy

m) Given

$m = 10\ kg$
$S = 2m$
$F = 100\ N$
Work Done = ?

Solution —

Work Done = Force × Displacement
= 100 × 2
= 200 N-m or joule.

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	n)	$VR = \frac{D}{d} \times T$ $= \frac{50}{40} \times 60$ $VR = 75$	

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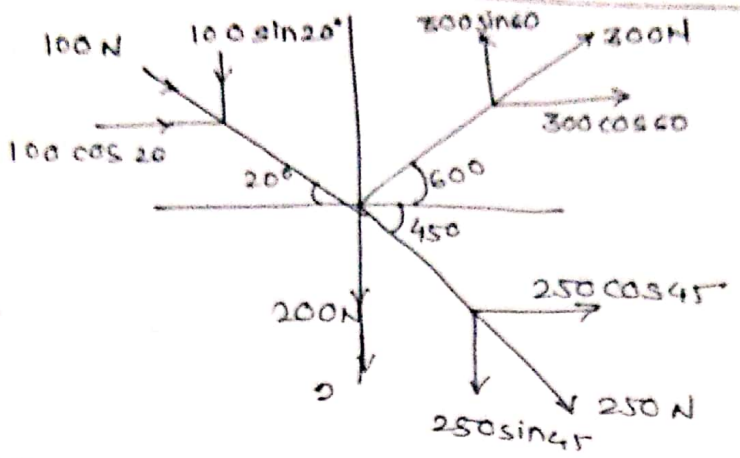
Q.2 a)



$\Sigma fx = 300\cos 60 + 100\cos 20 + 250\cos 45° + 0$

$\Sigma fx = 420.74\ N$

$\Sigma fy = +300\sin 60 - 100\sin 20 - 250\sin 45 - 200$

$\Sigma fy = -151.17\ N$

$R = \sqrt{(\Sigma fx)^2 + (\Sigma fy)^2}$

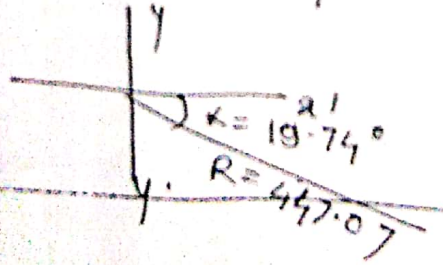
$= \sqrt{(420.74)^2 + (-151.17)^2}$

$= 447.07\ N$

To find direction of R

$\tan\alpha = \frac{\Sigma fy}{\Sigma fx} = \frac{-151.17}{420.74} = 0.359$

$\alpha = \tan^{-1}(0.359) = 19.74°$



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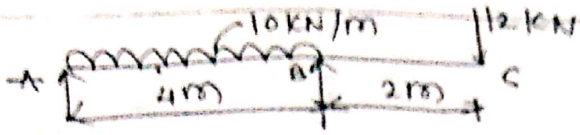
Q2 b)



$\Sigma F_y = 0$

$R_A + R_B - 10 \times 4 - 12 = 0$

$R_A + R_B - 40 - 12 = 0$

$\boxed{R_A + R_B = 52\ KN}$

$\Sigma M_A = 0$

$(10 \times 4 \times 2) + (12 \times 6) - 4R_B = 0$

$152 = 4R_B$

$R_B = \frac{152}{4} = 38\ KN$

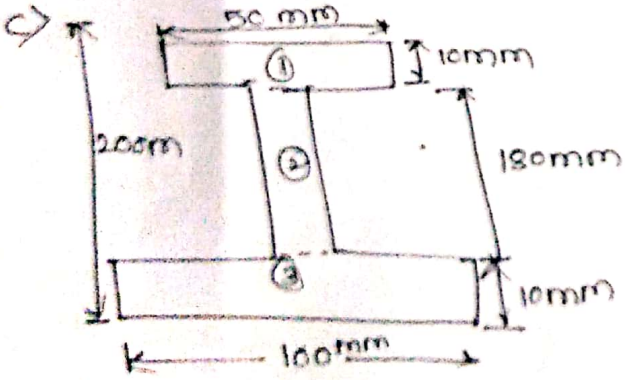
$\boxed{R_B = 38\ KN}$

$R_A + 38 = 52$

$R_A = 52 - 38$

$\boxed{R_A = 14\ KN}$

c)



$a_1 = 50 \times 10 = 500\ mm^2$

$y_1 = 10 + 180 + \frac{10}{2} = 195$

$a_2 = 180 \times 15 = 2700\ mm^2$

$y_2 = 10 + \frac{180}{2} = 100$

$a_3 = 100 \times 10 = 1000\ mm^2$

$y_3 = \frac{10}{2} = 5\ mm$

$$\bar{y} = \frac{a_1y_1 + a_2y_2 + a_3y_3}{a_1 + a_2 + a_3} = \frac{500 \times 195 + 2700 \times 100 + 1000 \times 5}{500 + 2700 + 1000}$$

$\bar{y} = 88.69\ mm$

$\bar{x} = \frac{100}{2} = 50\ mm$

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Model Answers & Marking scheme (ODD-2019)

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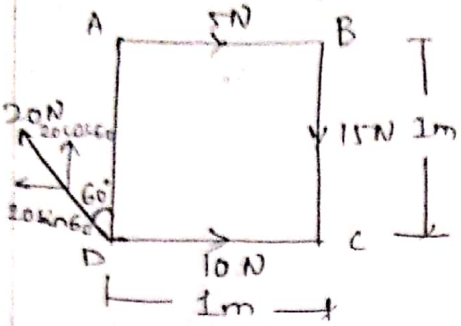
Q°3.		Attempt any two of following	(2×6 = 12 m)
	a)	 To find - ① R = ? ② θ = ? ③ x from A = ? Soln → Resolving all forces Horizontally & vertically.	
		$\Sigma Fx = 0$	
		$10 + 5 - 20 \sin 60 = -2.320\ N$	
		$\Sigma Fy = 0$	
		$20 \cos 60 - 15 = -5\ N$	
		1) magnitude (R) -	
		$R = \sqrt{(\Sigma Fx)^2 + (\Sigma Fy)^2} = \sqrt{(-2.320)^2 + (-5)^2}$	
		$\boxed{R = 5.511\ N}$	2m
		2) Direction (θ) -	
		$\theta = \tan^{-1}\left(\frac{\Sigma Fy}{\Sigma Fx}\right) \therefore \tan^{-1}\left(\frac{5}{2.320}\right)$	
		$\boxed{\theta = 65.28^\circ}$	2m
		3) Position (x) -	
		Σm_A = Algebraic sum of moment of all forces about 'A'.	
		$= 15 \times 1 + 20 \sin 60 \times 1 + 5 \times 0 - 10 \times 1 + 20 \cos 60 \times 0$	

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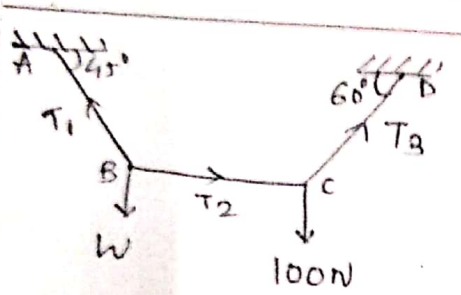
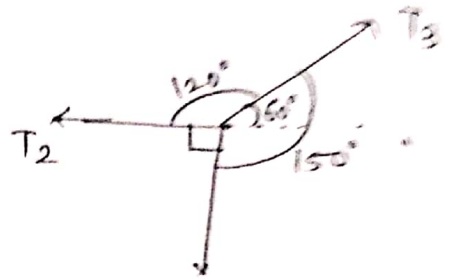
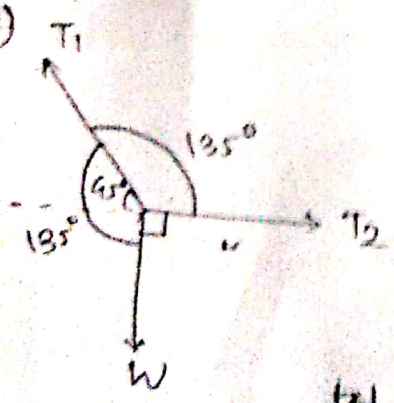
		$\boxed{EMF_A = 22.320\ N\cdot m}$ (Give)	
		$EMF_A = EMR_A$	
		$22.320 = 5.511\ x_c$	
		$\therefore x_c = \frac{22.320}{5.511}$	
		$\boxed{x_c = 4.05\ m}$	2m
b)			
	1)		
		Applying Lami's theorem -	
		$\frac{T_2}{\sin 150} = \frac{T_3}{\sin 90} = \frac{100}{\sin 120}$	1m
		$T_2 = \sin 150 \times \frac{100}{\sin 120} = \underline{57.73\ N}$	1m
		$T_3 = \sin 90 \times \frac{100}{\sin 120} = \underline{115.47\ N}$	1m
	2)		
		$\frac{T_1}{\sin 90} = \frac{57.73}{\sin 135} = \frac{W}{\sin 135}$	1m
		$T_1 = \sin 90 \times \frac{57.73}{\sin 135}$	
		$= \underline{81.67\ N}$	1m
		$W = \sin 135 \times \frac{57.73}{\sin 135} = \underline{\quad\quad}$	1m

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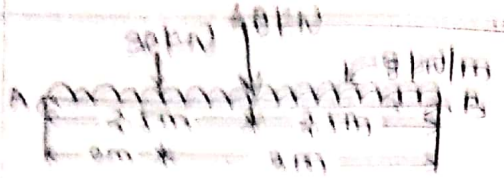
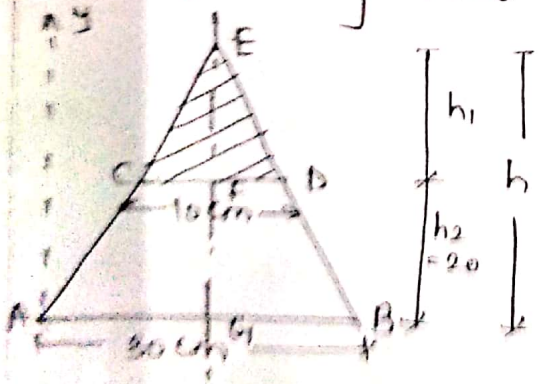
	c)	 equivalent point load = 8 × 5 (kN·m) = 40 kN, 8 kN/m downward at centre span is 2.5 m from A & B.	
		1) $\Sigma M_A = 0$ (⟳ +ve, ⟲ -ve) $30 \times 2 + 40 \times 2.5 = R_B \times 1$ $\therefore 160 = 5R_B$ $\therefore \boxed{R_B = 32 \text{ kN}}$	3m
		2) $\Sigma F_y = 0$ (↑ +ve, ↓ -ve) $R_A - 30 - 40 + 32$ $\boxed{R_A = 38 \text{ kN } (\uparrow)}$	3m
Q.4		Attempt any two of following	(2×6 = 12m)
	a)	 As composite solid is symmetrical about the vertical axis, C.G lies on the axis. $\bar{x} = \frac{30}{2} = 15 \text{ cm}$	1m
		h = height of full cone h1 = height of frustum of cone h2 = height of cut cone	
		Similar triangle ABC & CDE $h = \frac{30}{10} \times h_2 = 3h_2$	

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$h_1 + h_2 = 3h_2$

$20 + h_2 = 3h_2$

$20 = 3h_2 - h_2 = 2h_2$

$h_2 = \frac{20}{3}$ $\therefore$ $\boxed{h_2 = 10\ cm}$

$\therefore h = h_1 + h_2 = 10 + 20 = 30$ $\therefore$ $\boxed{h = 30\ cm}$ 1m

Volume -

V_1 = Volm of full cone -

$\frac{1}{3}\pi r_1^2 h = \frac{1}{3}\pi (1+)^2 \times 30$

$\boxed{V_1 = 7068.586\ cm^3}$ 1m

V_2 = Volm of cut cone.

$\frac{1}{3}\pi (r_2)^2 h_2 = \frac{1}{3}\pi (+)^2 \times 10$

$\boxed{V_2 = 261.799\ cm^3}$ 1m

$V = V_1 - V_2$

$= 7068.586 - 261.799$

$\boxed{V = 6808.79\ cm^3}$ 1m

→ Distance of C.G from base -

$y_1 = \frac{30}{4} = 5\ cm$

$y_2 = 20 + \frac{10}{4} = 22.5\ cm$

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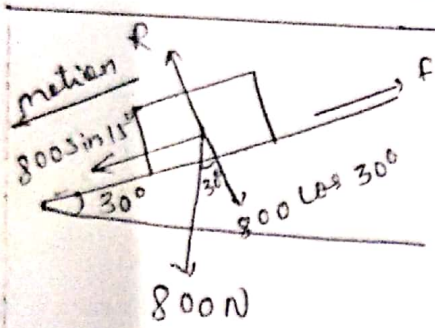
Let $\bar{y}$ be the C.G of frustum from the base AB.

$$\bar{y} = \frac{V_1 y_1 - V_2 y_2}{V} = \frac{(7068.586 \times 5) - (261.80 \times 22.5)}{6806.79}$$

$$\boxed{\bar{y} = 6.92 \text{ cm}}$$ 2m

b)



Given - $W = 800$ N
$\alpha = 30°$
$\mu = 0.2$

To find - $P = ?$

Soln - $\Sigma F_y = 0$

$R - 800 \cos 30 = 0$

$$\boxed{R = 692.82 \text{ N}}$$ 2m

$f = \mu R$
$= 0.2 \times 692.82$

$$\boxed{f = 138.56 \text{ N}}$$ 1m

$\Sigma F_x = 0$

$P + f - 800 \sin 30°$

$P + \mu P - 800 \sin 30°$

$P + 138.56 - 800 \sin 30°$

$$\boxed{P = 261.44 \text{ N}}$$ 1m

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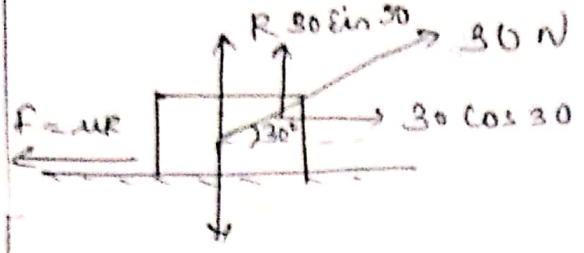
c)



$\Sigma F_y = 0$

$R - 100$

$30 \sin 30 + R - 100$

~~$R = 100$ N~~

$\boxed{R = 85\ N}$ 2m

$\Sigma F_x = 0$

$-F + 30 \cos 30$

$-\mu R + 25.98$

$-\mu R = 25.98$

$\therefore \mu = \frac{25.98}{85}$ $\therefore \boxed{\mu = 0.305}$ 2m

$\tan \phi = \mu$

$\tan^{-1}(0.305)$

$\boxed{\phi = 16.96°}$ 2m

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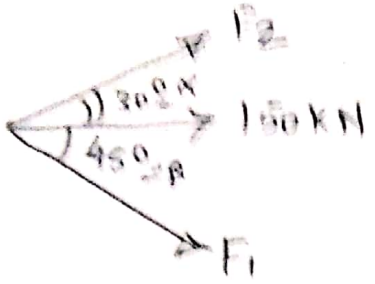
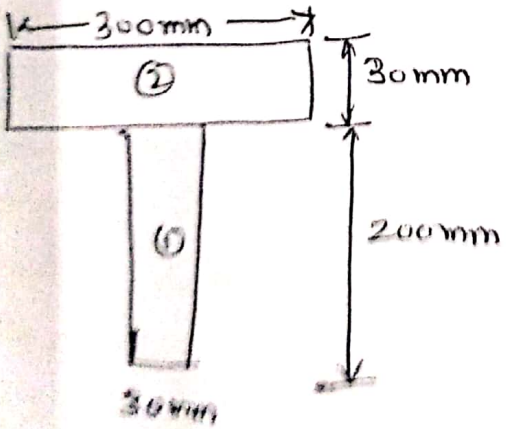
Q5 a)



$$F_1 = \frac{F \sin\beta}{\sin(\alpha+\beta)} = \frac{150 \sin 45}{\sin(45+30)} = 109.80\ N$$

$$F_2 = \frac{F \sin\alpha}{\sin(\alpha+\beta)} = \frac{150 \sin 30}{\sin(45+30)} = 77.64\ N$$

b)



$$\bar{x} = \frac{300}{2} = 150\ mm$$

$$a_1 = 200 \times 30 = 6000\ mm^2$$

$$a_2 = 300 \times 30 = 9000\ mm^2$$

$$y_2 = 200 + \frac{30}{2} = 215\ mm, \quad y_1 = \frac{200}{2} = 100\ mm$$

$$\bar{y} = \frac{(6000 \times 100) + (9000 \times 215)}{6000 + 9000} = 169\ mm$$

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c7 Force = 200 × 0·6 = 120 KN

Workdone = F × d = 120 × 0·6 = 72 KN m

d7 capacity = 15000 lit

Time = 30 min, h = 12 m, η = 70 %, Power = ?

$$\text{Power} = \frac{15000 \times 12}{30 \times 60 \times 0.7} = 142.85 \text{ sec}$$

Q6 a) i) Momentum – It is a quantity of motion that an object has

Momentum = mass × Velocity

ii) $m_1 = 300 \text{ gms} = 0.3 \text{ kg}$

$V_1 = 520 \text{ m/s}$

$m_2 = 15 \text{ kg}$

$V_2 = ?$

$m_1 V_1 = m_2 V_2$

$0.3 \times 500 = 15 \times V_2$

$$V_2 = \frac{0.3 \times 500}{15} = 10 \text{ m/sec}$$

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b) $m_1 = 1200$ kg $\quad V_1 = 30$ kmph $= \quad V_1 = 10$ kmph

$m_2 = 600$ kg $\quad V_2 = 40$ kmph $\quad V_2 = ?$

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$1200 \times 8.33 - 600 \times 11.11 = 1200 \times 2.77 + 600 \times V_2$

$3330 - 3324 = 600\ V_2$

$V_2 = 0.01$ m/sec.

c) Load = 1 kN ; Load = 5 kN
effort = 100 N ; effort = 400 N

$100 = 1000m + c$

$400 = 5000m + c$

$-300 = -4000m$

$\boxed{m = 0.075}$

$\boxed{c = 25}$

$P = 0.075\,W + c$

$= 0.075 \times 10{,}000 + 25$

$\boxed{P = 775\ N} = 775$ N.

d) D = 500 mm, d_1 = 150 mm, d_2 = 100 mm

η% = 70%, W = ?, P = 250 N.

$$V.R = \frac{d \times 500}{150 - 100} = 20$$

$$\eta_1 = \frac{W}{250 \times 20}$$

$$0.70 = \frac{W}{5000}$$

$$W = 3500\ N$$

e) W = 2500 N, P = 50 N, V.R = 80

$$\eta_1 = \frac{2500}{50 \times 80} \times 100$$

$$= 62.5\ \%$$

Ideal load = P × V.R = 50 × 80 = 4000 N

Load lost in friction = P × V.R − W

= 50 × 80 − 2500

= 1500 N

Q5 c) $v^2 = u^2 + 2as$

$= 2 \times 9.81 \times 5$

$= 98.1\ m^2$

$v^2 = u^2 + 2as$

$0 = 98.1 + 2 \times a \times 5$

$a = 98.1\ m/s^2$) × 98.1 = 4000 N.