2009 PART 1A P1

Mechanical Engineering

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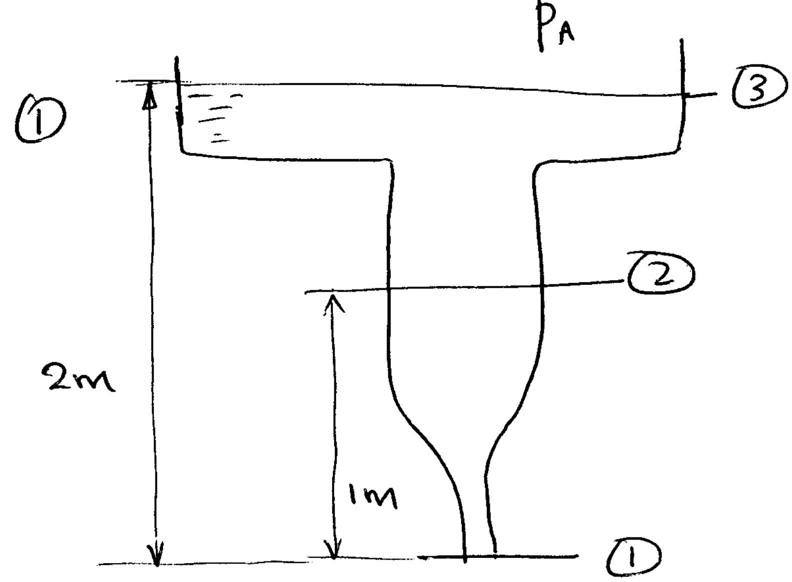
Paper - 1, PART - IA - 2009
CRIBS

Section - A



$\rho = 1000\ kg/m^3$

$A_1 = 0.01\ m^2$

$A_2 = 0.02\ m^2$

$g = 9.81\ m/s^2$

(a) (i) Bernoulli between 3 and 1

$$\cancel{P_1}^{p_A} + \rho g \cancel{h_1}^{0} + \frac{1}{2}\rho V_1^2 = \cancel{P_3}^{p_A} + \rho g h_3 + \frac{1}{2}\rho \cancel{V_3^2}^{0}$$

$$\therefore \quad V_1 = \sqrt{2gh_3} = \sqrt{2 \times 9.81 \times 2}$$

$$\boxed{V_1 = 6.264\ m/sec}$$

(ii) Bernoulli between 3 and 2

$$P_2 + \frac{1}{2}\rho V_2^2 + \rho g h_2 = \cancel{P_3}^{p_A} + \rho g h_3$$

The guage pressure @ 2 is

$$(P_2 - P_A) = \rho g(h_3 - h_2) - \frac{1}{2}\rho V_2^2$$

Continuity between 1 & 2

$$\cancel{\rho_1} V_1 A_1 = \cancel{\rho_2} V_2 A_2 \Rightarrow V_2 = \frac{V_1 A_1}{A_2} = \frac{V_1}{2}$$

$$V_2 = 3.132 \text{ m/sec.}$$

$$\Rightarrow (p_2 - p_A) = 1000 \times 9.81 \times 1 - \frac{1000 \times 3.132^2}{2}$$

$$\boxed{(p_2 - p_A) = 4.905 \text{ kPa}}$$

(b) Bernoulli between 3 & 1

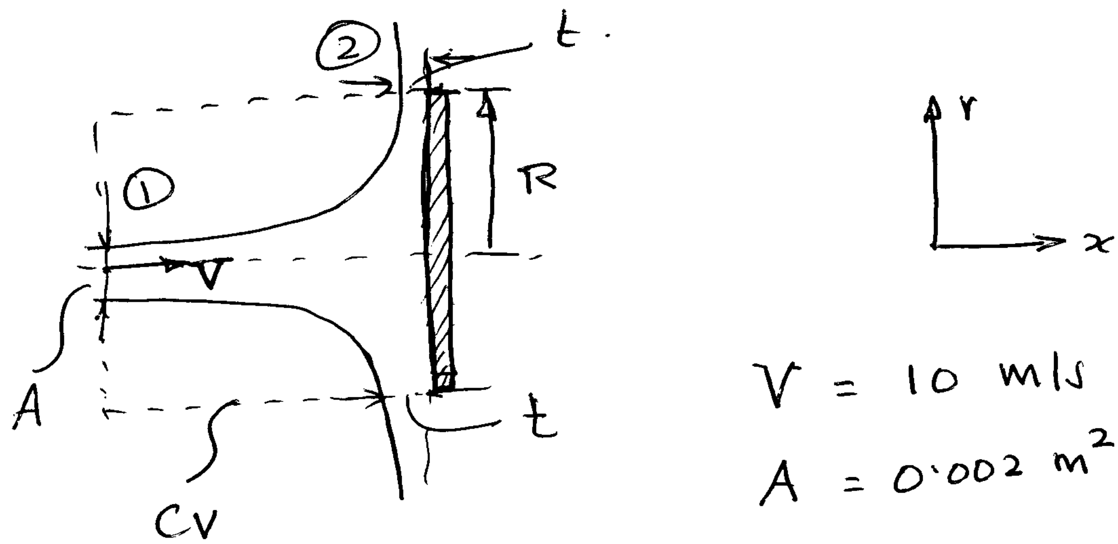
$$\cancel{p_3}^{\,p_A} + \rho g h_3 - \rho_{air} g h_3 = \cancel{p_1}^{\,p_A} + \rho g \cancel{h_1}^{\,0} + \frac{1}{2}\rho V_1^2$$

$$2 g h_3 \rho \left(1 - \frac{\rho_{air}}{\rho}\right) = \rho V_1^2$$

$$\Rightarrow V_1 = \sqrt{2 g h_3 \left(1 \quad \frac{\rho_{air}}{\rho}\right)} = 6.26$$

$$\Rightarrow \boxed{\%\ \text{change is } -0.06\,\%}$$

2)



$V = 10$ m/s

$A = 0.002 \ m^2$

$R = 0.05$ m

$\rho = 1000$ kg/m^3

(a) Flow is frictionless.

Pressure at the free surface is p_A.

Flow is purely radial

Apply Bernoulli between 1 & 2

$$\cancel{p_1}^{p_A} + \frac{1}{2}\rho V_1^2 = \cancel{p_2}^{p_A} + \frac{1}{2}\rho V_2^2$$

$$\Rightarrow \boxed{V_1 = V_2 = V}$$

(b) Continuity of mass:

$$\cancel{\rho} A_1 V_1 = \cancel{\rho} A_2 V_2 = \cancel{\rho}\, 2\pi R t \cancel{V_2}^{V_1}$$

$$\therefore \ t = \frac{A_1}{2\pi R} = \frac{0.002}{2\pi \times 0.05} = 6.37 \times 10^{-3} \text{ m}$$

$$\boxed{t = 6.37 \text{ mm}}$$

(c) Force balance on the control volume

$$\sum F = \sum_{out} \dot{m}V - \sum_{in} \dot{m}V \quad \text{along } x.$$

$$= \dot{m}V_{out} - \dot{m}V_{in}.$$

along x-direction $\dot{m}V_{out} = 0$

$$\Rightarrow \quad F = \rho A V^2 = 1000 \times 0.002 \times 100 = 200 \text{ N}.$$

$$\boxed{F = 200 \text{ N}.}$$

(d) use the same control volume, but moving at 5 m/sec. $\Rightarrow$ $V_{out} = 0$ again

$$\Rightarrow \quad V_{in} = 10 - 5 = 5 \text{ m/sec}.$$

$$\therefore \quad F = \rho A V_{in}^2 = 1000 \times 0.002 \times 5^2$$

$$\boxed{F = 50 \text{ N}.}$$

(3) $V = 1 m^3$, $P = 14 \times 10^5 \ N/m^2$ absolute

$T = 200 °c = 473 K$

$R = 287 \ J/kg\text{-}K$

$C_v = 0.74 \ kJ/kg\text{-}K$.

(a) $PV = mRT \Rightarrow m = \frac{PV}{RT}$

$$m = \frac{14 \times 10^5 \times 1}{287 \times 473} = 10.313 \ kg$$

(b) $Q - \cancel{W}^{0} = \Delta u = m C_v \Delta T$

$$\Rightarrow \Delta T = \frac{1800}{10.313 \times 0.74} = 235.86 \ K$$

$$\therefore \boxed{T_2 = 435.86 °c. = 708.86 K}$$

$$\frac{P_2}{P_1} = \frac{T_2}{T_1} \Rightarrow \boxed{P_2 = 20.98 \ bar}$$

(c) Const pressure process.

$\Rightarrow Q = m C_p \Delta T$ & $C_p = R + C_v = 1.027 \frac{kJ}{kg\text{-}K}$

$$\therefore \Delta T = \frac{1800}{10.313 \times 1.027} = 169.95$$

$$\Rightarrow \boxed{T_2 = 369.95 °c = 642.95 K}$$

$$\frac{V_2}{V_1} = \frac{T_2}{T_1} \Rightarrow V_2 = 1 \times \frac{642.95}{473} = 1.36$$

$$\boxed{V_2 = 1.36 \ m^3}$$

(d) No,

$$dS = \frac{dQ_{rev}}{T} + dS_{irrev}$$

$$dS_{irrev} \geq 0$$

Here $dQ_{rev} > 0 \Rightarrow \boxed{dS > 0.}$

Thus entropy can not remain constant.

(4) $\dot{m} = 1$ kg/sec , $C_p = 1.02$ kJ/kg-K

$P_A = 1.5$ bar absolute $\quad P_B = 1.3$ bar abs.

$T_A = 460$ K $\quad V_B = 250$ m/s

$A_A = 0.01\ m^2$

(a) $$\rho_A = \frac{P_A}{RT_A} = \frac{1.5\times10^5}{287\times460} = 1.136 \text{ kg/m}^3$$

$$\dot{m}_A = \rho_A A_A V_A \Rightarrow V_A = \frac{\dot{m}}{\rho_A A_A}$$

$$\boxed{V_A = \frac{1.0}{1.136\times0.01} = 88.03 \text{ m/sec.}}$$

(b) well insulated ⇒ total energy is const.

$$C_p T_A + \frac{1}{2} V_A^2 = C_p T_B + \frac{1}{2} V_B^2$$

$$1.02\times10^3 \times 460 + \frac{1}{2}(88.03)^2 = 1.02\times10^3\, T_B + \frac{1}{2}(250)^2$$

$$\Rightarrow \boxed{T_B = 433.2 \text{ K}}$$

$$\rho_B = \frac{P_B}{RT_B} = \frac{1.3\times10^5}{287\times433.2} = 1.046 \text{ kg/m}^3$$

$\dot{m} = 1 \quad = \rho_B A_B V_B$

$\Rightarrow A_B = \dfrac{1}{1.046 \times 250} = 3.82 \times 10^{-3} \ m^2.$

$$\boxed{A_B = 3.82 \times 10^{-3} \ m^2}$$

(c) Adiabatic flow

$\Rightarrow$ the flow direction is determined by entropy change.

<u>from data book:</u>

$S_A - S_B = C_p \ln\left(\frac{T_A}{T_B}\right) - R \ln\left(\frac{P_A}{P_B}\right)$

$= 1.02 \times 10^3 \ln\left(\frac{460}{433.2}\right) - 287 \ln\left(\frac{1.5}{1.3}\right)$

$= 61.23 - 41.07 = 20.16 \ \underline{>0}$

$\Rightarrow$ <u>flow is from B to A</u>

(5) $\rho = 1000$ kg/m^3

(a) along the free stream line, apply Bernoulli between (1) & (2)

$$\cancel{P_1}^{P_A} + \rho g h_1 + \frac{1}{2}\rho V_1^2 = \cancel{P_2}^{P_A} + \rho g h_2 + \frac{1}{2}\rho V_2^2$$

$$\Rightarrow V_2^2 = V_1^2 + 2g(h_1 - h_2)$$

Continuity gives

$$V_1 h_1 = V_2 (h_2 - H) \Rightarrow V_2 = V_1 \frac{h_1}{(h_2 - H)}$$

$$\Rightarrow V_1^2 \left(\frac{h_1^2}{(h_2-H)^2} - 1 \right) = 2g(h_1 - h_2)$$

Thus
$$\boxed{V_1 = (h_2 - H)\sqrt{\frac{2g(h_1 - h_2)}{h_1^2 - (h_2 - H)^2}}}$$

$h_1 = 1.1$ m

$h_2 = 0.9$ m

$H = 0.4$ m

$g = 9.81$ m/s^2

$$\Rightarrow \boxed{V_1 = 1.01 \text{ m/Sec.}}$$

$$V_2 = 1.01 \frac{1.1}{0.5} = 2.22 \text{ m/Sec}$$

(b) $V_1 h_1 = V_3 h_3 \Rightarrow V_3 = V_1 \frac{h_1}{h_3}$

$$V_3 = 1.01 \frac{1.1}{0.267} = 4.16 \text{ m/s}$$

$$\boxed{V_3 = 4.16 \text{ m/Sec}}$$

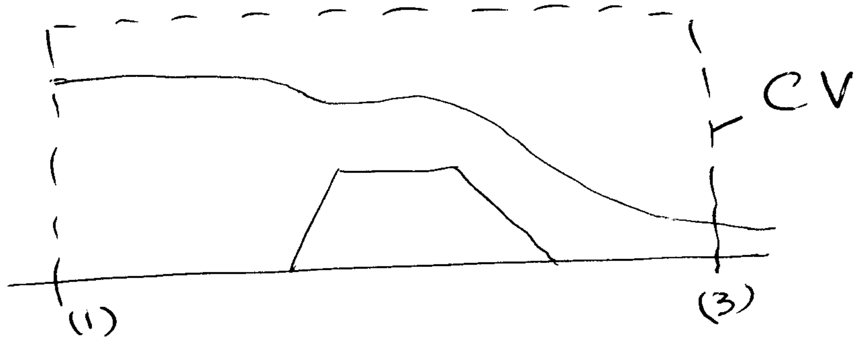
(c) Stream lines are straight & $\parallel^{el}$.

$\Rightarrow$ hydrostatic pressure variation only.

$\therefore p = p_A + \rho g z$

$\Rightarrow$ p varies linearly with depth.

(d)



Control volume as above & force balance gives

$$\Sigma pA + \Sigma F = \sum_{out} \dot{m} V - \sum_{in} \dot{m} V$$

$$= \dot{m} (V_{out} - V_{in}) = \rho h_1 V_1 (V_3 - V_1)$$

$$\therefore F = \rho h_1 V_1 (V_3 - V_1) - \Sigma pA$$

Pressure forces:

@ (1) $\int p\,dA = \int \rho g z\,dz = \rho g \frac{h_1^2}{2}$

$= 5935.05\ N$

@ (3) $\int p\,dA = \rho g \frac{h_3^2}{2} = 349.67\ N.$

$\Rightarrow \quad \Sigma PA = 5935.05 - 349.67 = 5585.38\ N.$

$\therefore F = 1000 \times 1.1 \times 1.01\,(4.16 - 1.01) - 5585.38$

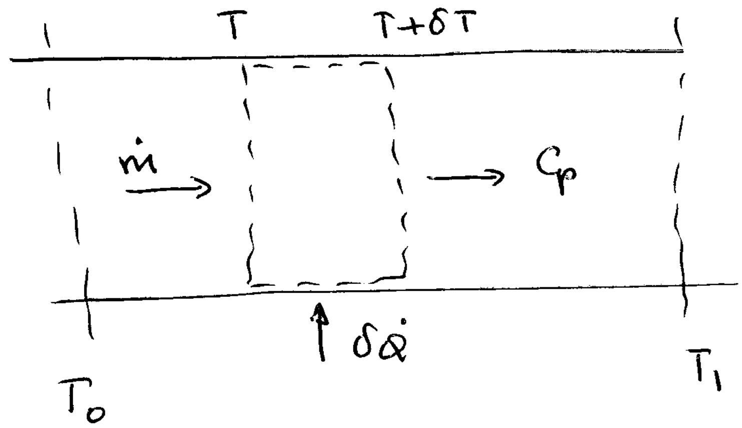
$$\boxed{F = -2085.73\ N.}$$

This is the force on the fluid. (in $-x$ directi

$\Rightarrow$ Force on the weir is in +ve x direction.
(down stream)

(6)

(a)



(i) SFEE from data book.

$$\delta \dot{Q} - \delta \dot{W} = \dot{m}\left[\delta h + \delta\left(\tfrac{1}{2}V^2\right) + \delta(gz)\right]$$

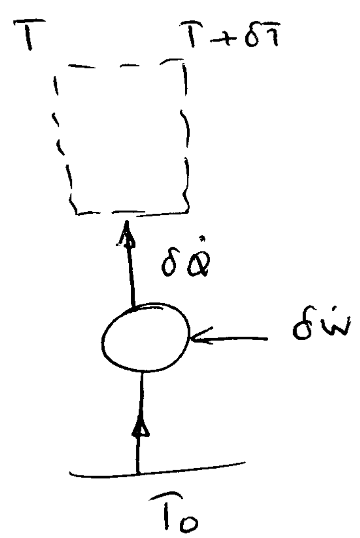
$\dot{m} = \text{const.}$ $A = \text{const.}$ $\Rightarrow$ $\delta\left(\tfrac{1}{2}V^2\right) = 0$

$\delta(gz) = 0$

No work $\Rightarrow$ $\dot{W} = 0$.

$$\therefore \boxed{\delta \dot{Q} = \dot{m}\,\delta h = \dot{m}\,C_p\,\delta T}$$

(ii)



Power will be minimum for reversible heat pump.

$$\Rightarrow \delta \dot{W} = \eta_{rev.}\,\delta \dot{Q}$$

$$= \left(1 - \frac{T_0}{T}\right)\delta \dot{Q}$$

$$\delta \dot{W} = \dot{m}\,C_p\left(1 - \frac{T_0}{T}\right)\delta T$$

$$\therefore \dot{W}_{min} = \dot{m}\,C_p\int_{T_0}^{T_1}\left(1 - \frac{T_0}{T}\right)dT$$

$$= \dot{m} C_p (T_1 - T_0) - \dot{m} C_p T_0 \ln\left(\frac{T_1}{T_0}\right)$$

$$\Rightarrow \boxed{\dot{W}_{min} = \dot{m} C_p \left[(T_1 - T_0) - T_0 \ln\left(\frac{T_1}{T_0}\right) \right]}$$

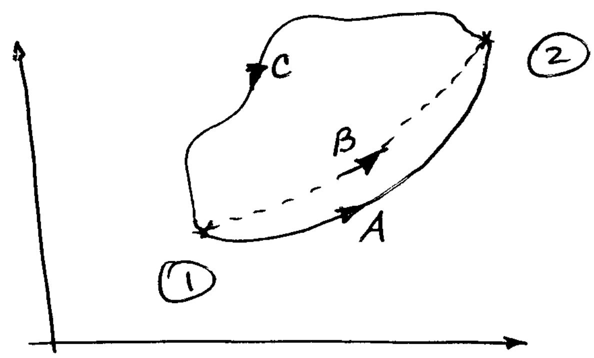
Rate of heat extraction

Total heat supplied must be

$$\dot{m} C_p (T_1 - T_0)$$

$\Rightarrow$ heat extracted is $\dot{m} C_p T_0 \ln\left(\frac{T_1}{T_0}\right)$ //

(b)



The clausius statement for the reversible process 1 – A – 2 – C – 1 is

$$\oint \frac{dQ}{T} = 0 = \int_{A\,1}^{2} \frac{dQ}{T} + \int_{C\,2}^{1} \frac{dQ}{T}$$

$$\Rightarrow \int_{A\,1}^{2} \frac{dQ}{T} = \int_{C\,1}^{2} \frac{dQ}{T} \quad \text{———} \quad \text{(I)}$$

for reversible process 1 – B – 2 – C – 1

For reversible process 1 – B – 2 – C – 1

$$\int_{B\,1}^{2} \frac{dQ}{T} + \int_{C\,2}^{1} \frac{dQ}{T} = 0$$

$$\Rightarrow \int_{B\,1}^{2} \frac{dQ}{T} = \int_{C\,1}^{2} \frac{dQ}{T} \quad \text{— (II)}$$

From (I) & (II)

$$\int_{A\,1}^{2} \frac{dQ}{T} = \int_{B\,1}^{2} \frac{dQ}{T} \Rightarrow$$

Path independent.
⇒ This is a property.

(c)

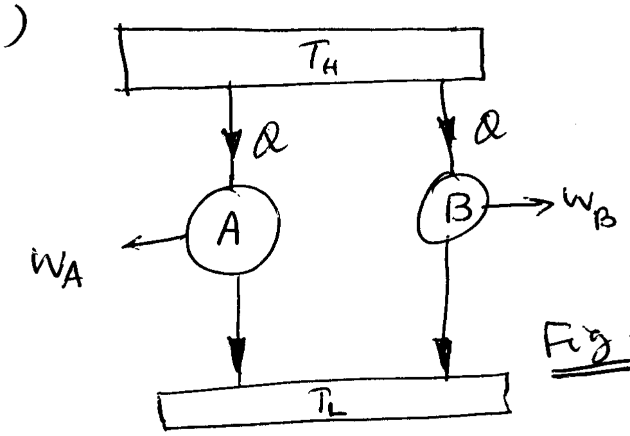
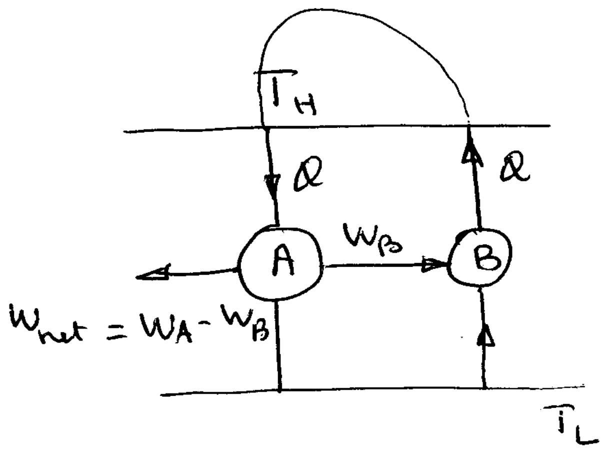


Fig 1

Two heat engines A & B are operating between the same two heat reservoirs, as in Fig 1

If we reverse the engine B, by making it as a heat pump, then the Q - supplied by this ~~*~~ reversed engine can directly go to engine A, as shown in Fig 2.



Now the net work output from engines is

$(W_A - W_B)$

If the efficiency of engine A is greater than that of engine B.

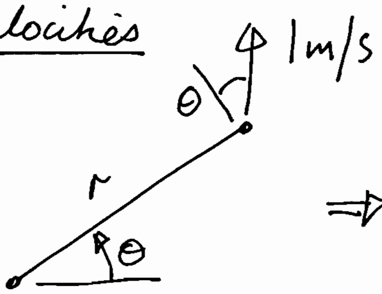
i.e $\eta_A > \eta_B$.

then we have engine A driving engine B as given above, This violates the 2nd law since, there is continuous work from a single heat reservoir.

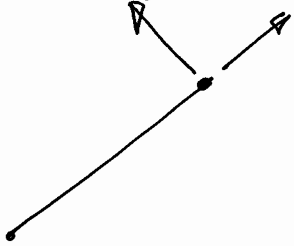
Therefore engine A cannot exist.

and also $\underline{\eta_A = \eta_B}$.

7. <u>velocities</u>



$\Rightarrow$



$1\cos\theta = \frac{3}{5} = r\dot{\theta}$

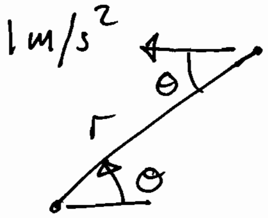
$1\sin\theta = \frac{4}{5} = \dot{r}$

$$\boxed{\begin{aligned} \tan\theta &= \tfrac{4}{3} \\ \cos\theta &= \tfrac{3}{5} \\ \sin\theta &= \tfrac{4}{5} \end{aligned}}$$

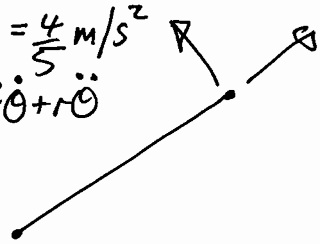
$$\underline{\underline{\dot{r} = \frac{4}{5}\ \text{m/s}}}$$

$$r\dot{\theta} = \frac{3}{5}, \quad \dot{\theta} = \frac{1}{5}\cdot\frac{3}{5} = \underline{\underline{\frac{3}{25}\ \text{rad/s}}}$$

<u>accelerations</u>



$\Rightarrow$



$1\sin\theta = \frac{4}{5}\ \text{m/s}^2$
$= 2\dot{r}\dot{\theta} + r\ddot{\theta}$

$-1\cos\theta = -\frac{3}{5}\ \text{m/s}^2$
$= \ddot{r} - r\dot{\theta}^2$

$$2\dot{r}\dot{\theta} + r\ddot{\theta} = \frac{4}{5}\ \text{m/s}^2$$

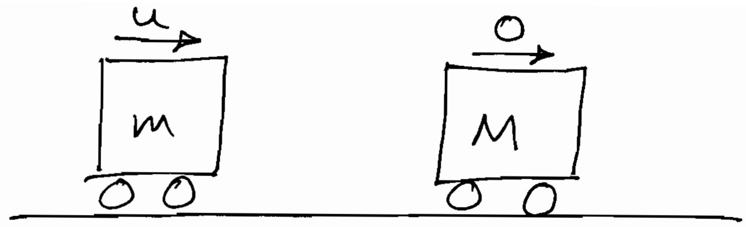
$$\therefore \quad \ddot{\theta} = \frac{\frac{4}{5} - 2\dot{r}\dot{\theta}}{r} = \frac{\frac{4}{5} - 2\cdot\frac{4}{5}\cdot\frac{3}{25}}{5} = \underline{\underline{\frac{76}{625}\ \text{rad/s}^2}}$$

$$\ddot{r} - r\dot{\theta}^2 = -\frac{3}{5}\ \text{m/s}^2$$

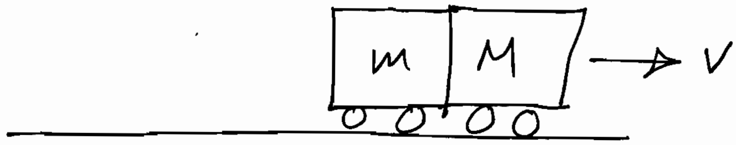
$$\ddot{r} = -\frac{3}{5} + r\dot{\theta}^2 = -\frac{3}{5} + 5\left(\frac{3}{25}\right)^2 = \underline{\underline{\frac{-66}{125}\ \text{m/s}^2}}$$

8.

before



after



a) momentum conserved

$$mu = (m+M)V$$

$$V = \left(\frac{m}{m+M}\right)u$$

b) PE gained in spring = KE lost in $(m+M)$

$$\frac{1}{2}kx_{max}^2 = \frac{1}{2}(m+M)V^2$$

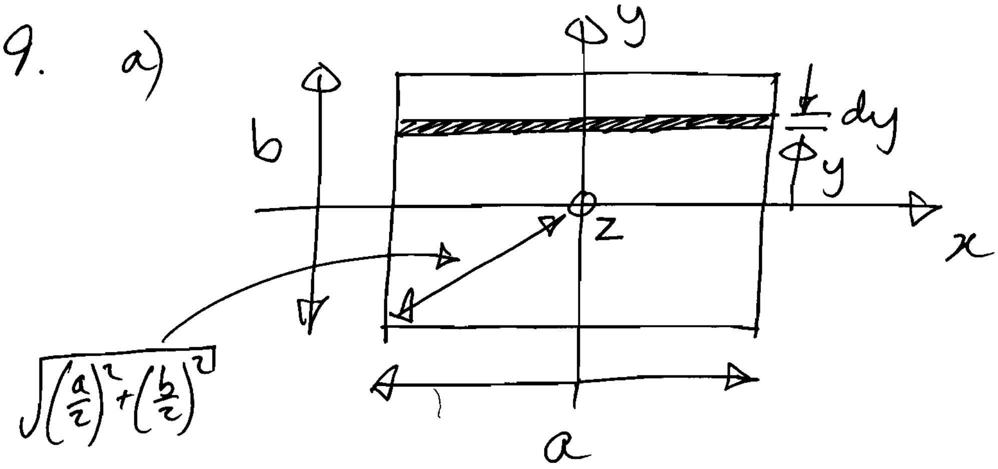
$$x_{max}^2 = \frac{(m+M)}{k}\left(\frac{m}{m+M}\right)^2 u^2$$

$$x_{max} = \frac{mu}{\sqrt{k(m+M)}}$$

c) No change in answer to (a) – no displacement of M immediately after impact so friction has no effect on V.

Deflection of spring is reduced because work is done against the friction.

9. a)



2nd mt. of area $= ab\,k_{xx}^2 = \displaystyle\int_{-\frac{b}{2}}^{\frac{b}{2}} y^2 a\,dy$

$$= \left[\frac{y^3}{3}a\right]_{-\frac{b}{2}}^{\frac{b}{2}}$$

$$= ab.\frac{b^2}{12}$$

hence $k_{xx} = \dfrac{b}{\sqrt{12}}$

b) $I_{xx} = \dfrac{mb^2}{12}$ $\qquad I_{yy} = \dfrac{ma^2}{12}$

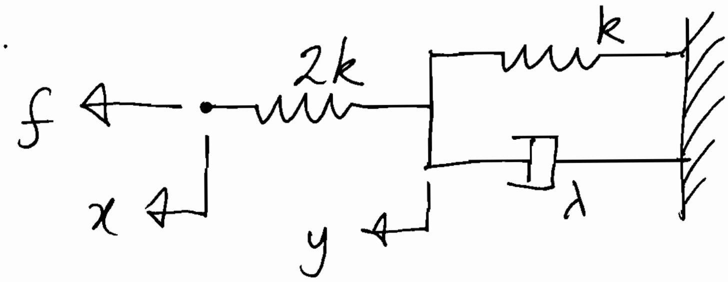
hence $I_{zz} = I_{xx} + I_{yy} = (a^2+b^2)\dfrac{m}{12}$ (perp. axes)

$I_{corner} = I_{zz} + m\left[\left(\frac{a}{2}\right)^2+\left(\frac{b}{2}\right)^2\right]$ (parallel axes)

$$= \left[\frac{(a^2+b^2)}{12} + \frac{(a^2+b^2)}{4}\right]m$$

$$= (a^2+b^2)\frac{m}{3}$$

10.



L.H. spring $\qquad f = (x-y)2k \qquad$ — ①

RH spring/damper $\qquad f = ky + \lambda\dot{y} \qquad$ — ②.

eliminate y: $\qquad$ from ① $\quad y = x - \dfrac{f}{2k}$

put into ②: $\qquad f = k\left(x - \dfrac{f}{2k}\right) + \lambda\left(\dot{x} - \dfrac{\dot{f}}{2k}\right)$

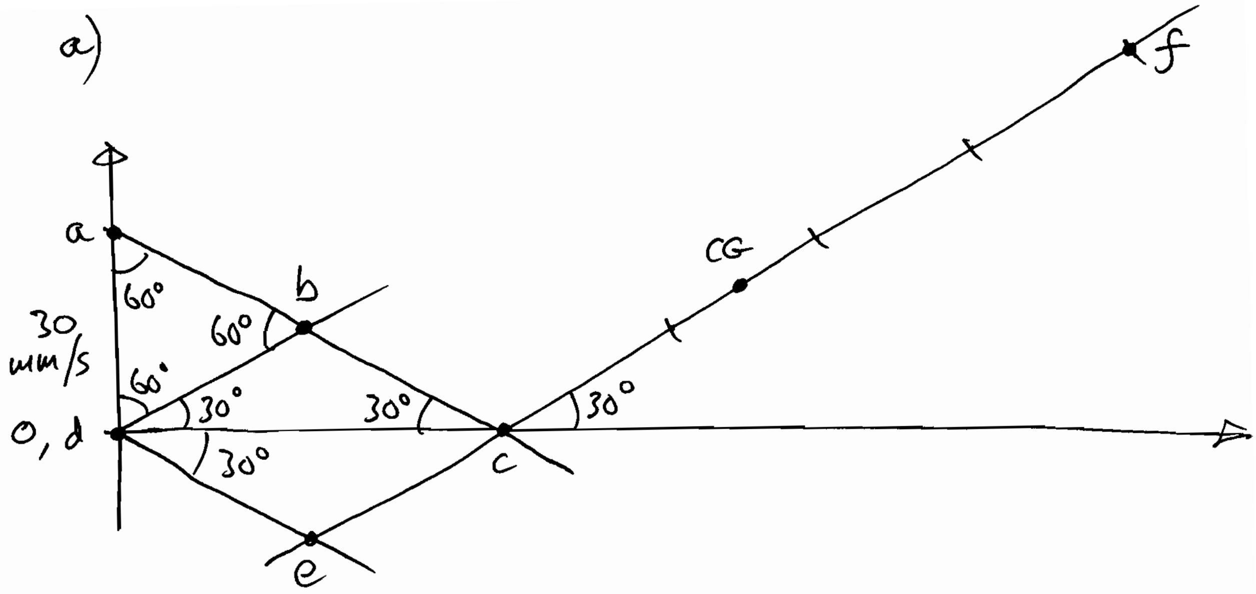
$$f = kx - \frac{f}{2} + \lambda\dot{x} - \frac{\lambda}{2k}\dot{f}$$

$$\frac{3}{2}f + \frac{\lambda}{2k}\dot{f} = kx + \lambda\dot{x}$$

$$f + \frac{\lambda}{3k}\dot{f} = \frac{2}{3}kx + \frac{2}{3}\lambda\dot{x}$$

$\therefore \quad A = \dfrac{\lambda}{3k}, \quad B = \dfrac{2}{3}k, \quad C = \dfrac{2}{3}\lambda$

11. a)



i) $V_f|_{horiz} = 30\,mm/s \times 6 \times \cos 30$

$= 180 \cdot \frac{\sqrt{3}}{2} = \sqrt{3}\,90\ mm/s \longrightarrow$

ii) $\omega_{EF} = \frac{V_{EF}}{EF} = \frac{5 \times 30\,mm/s}{500\,mm}$

$= \frac{3}{10}\ rad/s$ ↻

b) virtual power

vertical velocity at CG is $\left(30 \times \frac{3}{2}\right) \sin 30$

$= \frac{45}{2}\ mm/s \uparrow$

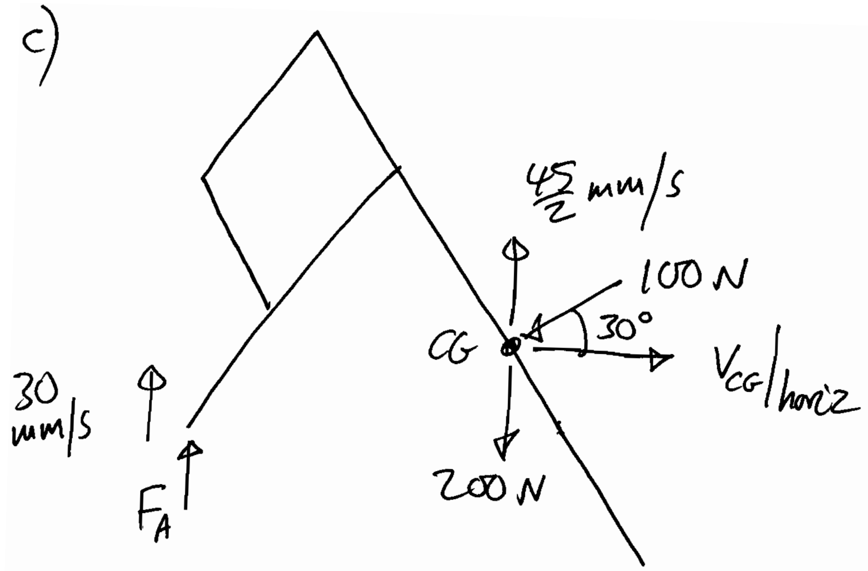
force at CG is $200\,N \downarrow$

$\sum$ power $= 0$: $\frac{45}{2} \times (-200) + F_F|_{horiz} \cdot \sqrt{3}\,90 = 0$

$F_F|_{horiz} = \frac{\frac{45}{2} \cdot 200}{\sqrt{3} \cdot 90}$

$= \frac{50}{\sqrt{3}}\ N \longrightarrow$

c)



$$V_{CG}/\text{horiz} = \frac{7}{2} \cdot 30 \cdot \cos 30 = 105\frac{\sqrt{3}}{2} \text{ mm/s}.$$

$$\sum \text{power} = 0$$

$$30 \cdot F_A + \left[(-200) + (-100)\sin 30\right]\frac{45}{2} + (-100)\cdot\cos 30 \cdot 105 \cdot \frac{\sqrt{3}}{2} = 0.$$

$$30F_A = \left(200 + \frac{100}{2}\right)\frac{45}{2} + 100\frac{\sqrt{3}}{2} \cdot 105\frac{\sqrt{3}}{2}$$

$$= 250 \cdot \frac{45}{2} + \frac{300}{4} \cdot 105$$

$$F_A = \frac{125 \cdot 45 + 75 \cdot 105}{30}$$

$$= \frac{1875 + 2625}{10}$$

$$\underline{\underline{F_A = 450 \text{ N}}}$$

12. a)

$$2m\ddot{x}_1 = f + k(x_2 - x_1)$$
$$m\ddot{x}_2 = k(x_1 - x_2) - kx_2$$

$$\begin{bmatrix} 2m & 0 \\ 0 & m \end{bmatrix}\begin{Bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{Bmatrix} + \underbrace{\begin{bmatrix} k & -k \\ -k & 2k \end{bmatrix}}_{K.}\begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{Bmatrix} f \\ 0 \end{Bmatrix}$$

b) $x = Xe^{i\omega t}$, $\dot{x} = i\omega Xe^{i\omega t}$, $\ddot{x} = -\omega^2 Xe^{i\omega t}$

$$\left\{ -\omega^2 \begin{bmatrix} 2m & 0 \\ 0 & m \end{bmatrix} + \begin{bmatrix} k & -k \\ -k & 2k \end{bmatrix} \right\} \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \quad \text{—} (1)$$

$$\det \begin{bmatrix} k - 2m\omega^2 & -k \\ -k & 2k - m\omega^2 \end{bmatrix} = 0$$

$$(k - 2m\omega^2)(2k - m\omega^2) - k^2 = 0$$
$$2k^2 - mk\omega^2 - 4mk\omega^2 + 2m^2\omega^4 - k^2 = 0$$
$$2m^2\omega^4 - 5mk\omega^2 + k^2 = 0$$
$$\omega^2 = \frac{5mk \pm \sqrt{25m^2k^2 - 4.2.m^2k^2}}{4m^2}$$
$$= \frac{5}{4}\frac{k}{m} \pm \frac{\sqrt{17}}{4}\frac{k}{m}$$
$$\omega^2 = \frac{5 \pm \sqrt{17}}{4}\frac{k}{m}$$

c) $\omega = \frac{5+\sqrt{17}}{4}\frac{k}{m}$

let $X_1 = 1$, put into row ① of eqn ①

$$-2m\omega^2 + k\underbrace{X_1}_{=1} - kX_2 = 0$$

$$kX_2 = -2m\omega^2 + k$$

$$X_2 = -\frac{2m}{k}\cdot\frac{5+\sqrt{17}}{4}\cdot\frac{k}{m} + 1$$

$$= 1 - \frac{5+\sqrt{17}}{2} = \frac{2-5-\sqrt{17}}{2}$$

$$X_2 = -\frac{3+\sqrt{17}}{2} = -3.56$$

so mode shape is $\begin{Bmatrix} 1 \\ -3.56 \end{Bmatrix}$

d) $$\left.\begin{aligned} &-\omega^2 2m X_1 + kX_1 - kX_2 = F \\ &\text{and} \\ &-\omega^2 m X_2 - kX_1 + 2kX_2 = 0. \end{aligned}\right\} \text{from (a)}$$

$$(2k-\omega^2 m)X_2 = kX_1$$

$$X_2 = \frac{kX_1}{2k-\omega^2 m}$$

elim X_2 from first eqn:

$$(k-\omega^2 2m)X_1 - \frac{k^2 X_1}{2k-\omega^2 m} = F(2k-\omega^2 m)$$

$$(k-\omega^2 2m)(2k-\omega^2 m) - k^2 = \frac{F}{X_1}(2k-\omega^2 m)$$

$$\underline{\underline{\frac{X_1}{F} = \frac{2k-\omega^2 m}{(k-\omega^2 2m)(2k-\omega^2 m) - k^2}}}$$

Examiner's comments on 2009 Part 1A Paper 1 Section B

Question 7 (short): velocity and acceleration of a particle in two dimensions
Straightforward question, especially using the databook. The most common mistake was swapping sin and cos.

Question 8 (short): linear momentum, impact, kinetic energy
For those with a clear head, this was an easy question, and many solved it perfectly. The most common mistakes were:
a) use of conservation of energy instead of conservation of momentum - note that energy is not conserved in an inelastic collision.
b) most students identified energy conservation as the key principle in this part, but many used the kinetic energy of just the first mass from part a) rather than the combined masses after the collision. Also strangely, the formula v^2=u^2+2as appeared many times. This is useful for constant acceleration problems, which this is not.
c) Most students correctly identified frictional energy loss as the dissipation mechanism, although many thought that friction would also act on the first mass and thus reduce its impact velocity.

Question 9 (short): moment of inertia of a lamina
In part (a) a few candidates thought that it was sufficient to derive radius of gyration by taking the expression for second moment of area from the data book and then dividing by the area; however most candidates were successful in working from first principles. In part (b) various mistakes were made in applying the perpendicular axes and parallel axes theorems.

Question 10 (short): vibration of first order system
Many candidates were able to write down the force equilibrium equations correctly but then algebraic errors led to incorrect answers. More significant problems were encountered when candidates did not recognise that the forces in the single spring and in the parallel spring/damper are the same.

Question 11 (long): planar mechanism
The majority of solutions used a velocity diagram, the remainder made use of instantaneous centres. Parts (a) and (b) were generally answered well. In part (c) there were two main mistakes. Many solutions omitted the weight of the window from the calculation of the friction force, but otherwise correctly accounted for the wind force. Some solutions quoted F.v=T.ω and then attempted to derive the required friction force (F) at the slider (v) by incorrectly calculating an 'equivalent' torque (T) on the window and multiplying this by the angular velocity (ω) of the window from part (a) of the question. A more straightforward application of virtual power to the wind and weight forces on the window usually resulted in the correct answer being derived.

Question 12 (long): vibration, two degree of freedom, second order
The relatively most common mistake was omission of some terms in part a) resulting in the wrong stiffness matrix. The usual slew of algebraic mistakes tripped up some in parts b) and d). By far the most common cause of marks lost was the omission of part c) or a misunderstanding of what a mode shape meant.