

Q1(a) $u = 0 \text{ m/s}$; $v = 70 \text{ m/s}$; $a = 4.0 \text{ m/s}^2$

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

$$\therefore s = \frac{v^2 - u^2}{2a} = \frac{70^2 - 0^2}{2 \times 4}$$

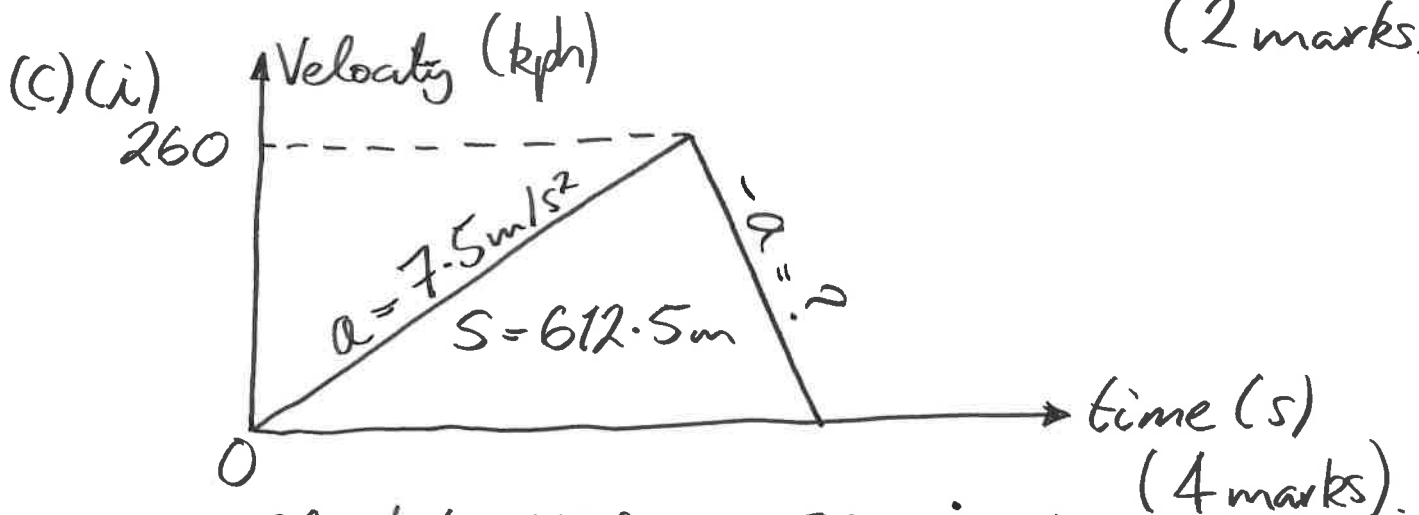
So, $s = 612.5 \text{ m}$

Assumptions: - constant acceleration
 - no skidding
 - length of aircraft ignored.
 (5 marks)

(b) Now, $a = 4 \times 0.9 = 3.6 \text{ m/s}^2$

$$\therefore s = \frac{70^2 - 0^2}{2 \times 3.6} = 680.56 \text{ m}$$

So, extension required is $= 680.56 - 612.5$
 $= 68.06 \text{ m}$.
 (2 marks)



(ii) $\frac{260 \text{ kph} \times 1000 \text{ m}}{3600 \text{ s}} = 72.22 \text{ m/s}$

For acceleration; $s = \frac{v^2 - u^2}{2a} = \frac{72.22^2 - 0}{15}$

$$\therefore s = 347.74 \text{ m}$$

So, distance travelled during deceleration
 $= 612.5 - 347.74 = 264.76 \text{ m}$

Q1(c)(ii) Cont.

$$\text{From, } v^2 = u^2 + 2as \Rightarrow a = \frac{v^2 - u^2}{2s}$$

$$\therefore a = \frac{0 - 72.22^2}{2 \times 264.76}$$

$$\text{So, deceleration, } a = -9.851 \text{ m/s}^2 \quad (5 \text{ marks}).$$

$$(iii) \text{ Time for acceleration, } t_{\text{acc.}} = \frac{v - u}{a}$$

$$\therefore t_{\text{acc.}} = \frac{72.22 - 0}{7.5}$$

$$\text{So, } t_{\text{acc.}} = 9.63 \text{ s}$$

$$\text{Time for deceleration, } t_{\text{decel.}} = \frac{v - u}{a}$$

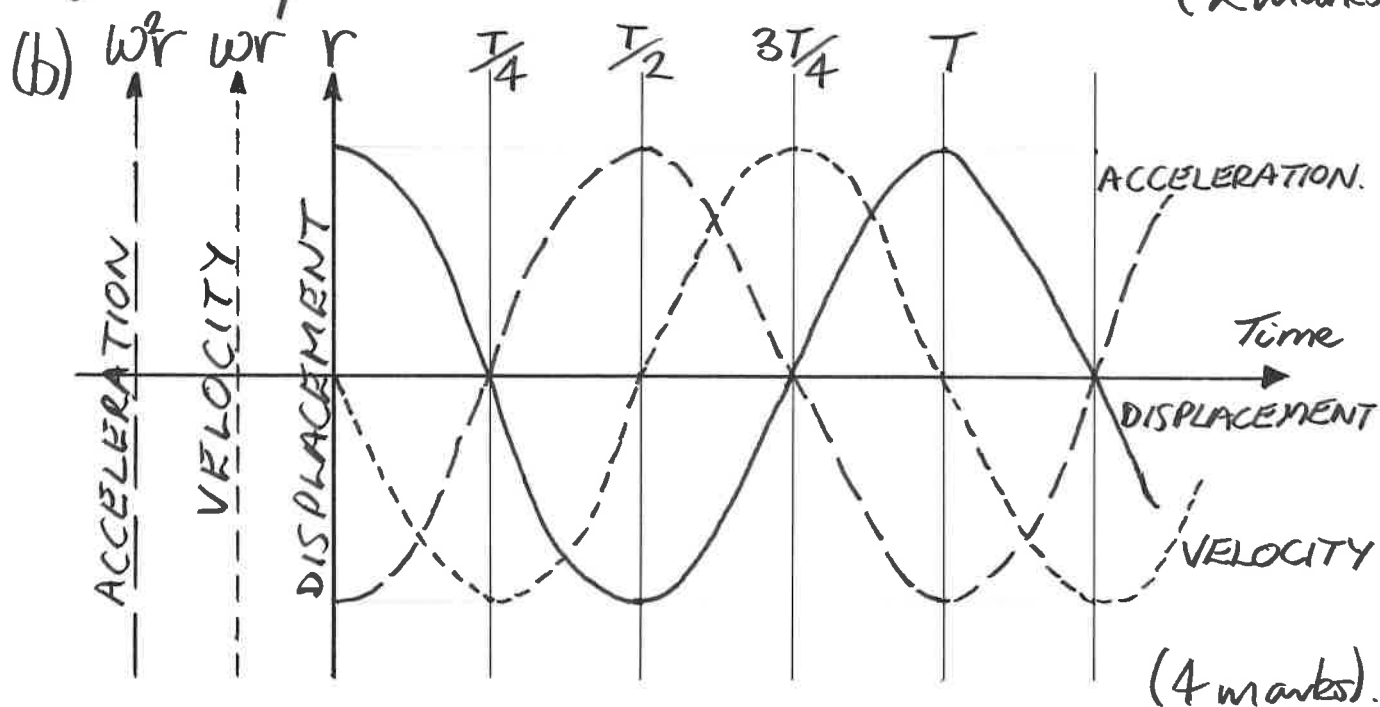
$$\therefore t_{\text{decel.}} = \frac{0 - 72.22}{-9.851}$$

$$\text{So, } t_{\text{decel.}} = 7.33 \text{ s}$$

$$\begin{aligned} \text{Duration of journey} &= 9.63 + 7.33 \\ &= 16.96 \text{ s.} \end{aligned}$$

Q2(a)

- acceleration of the body is always directed towards a fixed point in its path, and
 - magnitude of the acceleration of the body is proportional to its distance from the fixed point.
- (2 marks).



(c)(i) Find amplitude, 'r'; using $v = \omega \sqrt{r^2 - x^2}$

So, $12 = \omega \sqrt{(r^2 - 0.005625)}$ ————— ①

$4 = \omega \sqrt{(r^2 - 0.04)}$ ————— ②

Divide ① by ② to eliminate ω , and square both sides;

$$9 = \frac{r^2 - 0.005625}{r^2 - 0.04}$$

∴ $9r^2 - 0.36 = r^2 - 0.005625$

$8r^2 = 0.354375$

Hence, $r = 0.2105\text{m}$ (210.5mm) (6 marks).

Q2(c)(ii)

Maximum velocity occurs at $x = 0\text{m}$;

$$\therefore v_{\text{MAX.}} = \omega \sqrt{r^2}$$

Need to find ω from (1).

$$12 = \omega \sqrt{0.2105^2 - 0.005625}$$

$$\therefore \omega = 61.01 \text{ rad/s}$$

$$\text{Hence, } v_{\text{MAX.}} = 61.01 \sqrt{0.2105^2}$$

$$\text{So, } v_{\text{MAX.}} = 12.84 \text{ m/s}$$

(4 marks).

(iii) Maximum acceleration occurs at r ;

$$\text{Using, } a = \omega^2 x \quad \text{where, } x = 0.2105$$

$$\begin{aligned} \therefore a_{\text{MAX.}} &= (61.01)^2 \times 0.2105 \\ &= 783.53 \text{ m/s}^2 \end{aligned}$$

Hence, maximum force;

$$F_{\text{MAX.}} = 2.27 \text{ kg} \times a_{\text{MAX.}}$$

$$\therefore F_{\text{MAX.}} = 1778.61 \text{ N}$$

(4 marks).

Q3(a). Accelerating torque, $T = I\alpha$

where, $I = \frac{1}{2}mr^2 = \frac{1}{2} \cdot (85) \cdot (0.225)^2$

$\therefore I = 2.152 \text{ kg m}^2$

Knowing, $\omega_2 = \omega_1 + \alpha \cdot t \Rightarrow \alpha = \frac{\omega_2 - \omega_1}{t}$

where, $\omega_2 = 120 \times \frac{2\pi}{60} = 4\pi \text{ rad/s}$

so, $\alpha = \frac{4\pi - 0}{25} = 0.503 \text{ rad/s}^2$

$\therefore$ accelerating torque, $T = 2.152 \times 0.503$

$T = 1.082 \text{ Nm}$

Fundamental assumption is no resisting torque, i.e. frictionless system. (6 marks)

(b). For original flywheel, $K.E. = \frac{1}{2}I\omega^2$

$K.E. = \frac{1}{2}(2.152)(4\pi)^2$

$= 169.92 \text{ J}$

For compound flywheel, $I = m \cdot k^2$

$I = 70 \times (0.375)^2 = 9.844 \text{ kg m}^2$

$\therefore K.E. = \frac{1}{2}(9.844)(4\pi)^2$

$= 777.25 \text{ J}$

Hence, difference in K.E. is 607.33 J .

(4 marks)

Q3(c).

$$\begin{aligned}\text{Resisting torque} &= 0.05 \times 1.082 \text{ Nm} \\ &= 0.0541 \text{ Nm}\end{aligned}$$

$\therefore$ available accelerating torque is;

$$T = 1.0279 \text{ Nm}$$

$$\text{Knowing, } T = I\alpha \Rightarrow \alpha = \frac{T}{I} = \frac{1.0279}{2.152}$$

$$\therefore \alpha = 0.478 \text{ rad/s}^2$$

$$\text{Now, } \omega_2 = \omega_1 + \alpha \cdot t ;$$

$$\text{So, } \omega_2 = 0 + (0.478 \times 25)$$

$$\therefore \omega_2 = 11.94 \text{ rad/s}$$

(4 marks)

(d). Assuming that, K.E. = P.E.

$$\therefore h = \frac{\text{K.E.}}{mg} = \frac{7777.25}{25 \times 9.81}$$

so, vertical height of travel, $h = 3.17 \text{ m}$
(3 marks).

$$(e) \text{ Now, } \omega = \frac{100 \times 2\pi}{60} = \frac{20}{6} \pi \text{ rad/s}$$

$$\therefore \text{K.E.} = \frac{1}{2} \cdot (9.844) \cdot \left(\frac{20}{6} \pi\right)^2 = 539.76 \text{ J}$$

$$\text{So, new height, } h = \frac{539.76}{25 \times 9.81}$$

$$\therefore h = 2.2 \text{ m}$$

(3 marks).

Q4(a).

- If a force applied to move a body over another, the opposing friction that arises is tangential to the surfaces in contact and just sufficient to balance the applied force.
- limiting force is proportional to the normal force between the surfaces, and is independent of area of contact.
- Ratio of limiting frictional force (F) and normal reaction (R_N) is a constant and depends on nature of surfaces in contact, thus $F = \mu \cdot R_N$.

(3 marks)

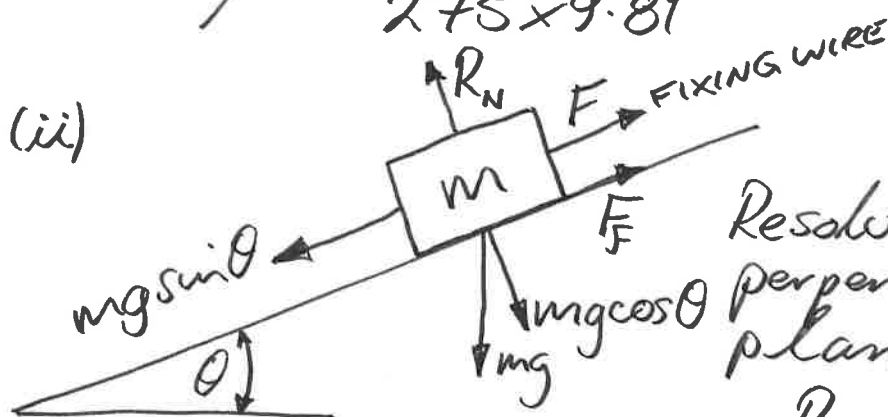
(b)(i) Knowing, $F = \mu \cdot R_N$

then, $\mu = \frac{F}{R_N}$ where F is applied force.

$$\therefore \mu = \frac{1200}{275 \times 9.81} = 0.445.$$

(4 marks)

(ii)



Resolving forces perpendicular to plane;

$$R_N = mg \cos \theta$$

Resolving forces parallel to plane;

$$F + F_f = mg \sin \theta \quad \text{where, } F_f = \mu \cdot R_N$$

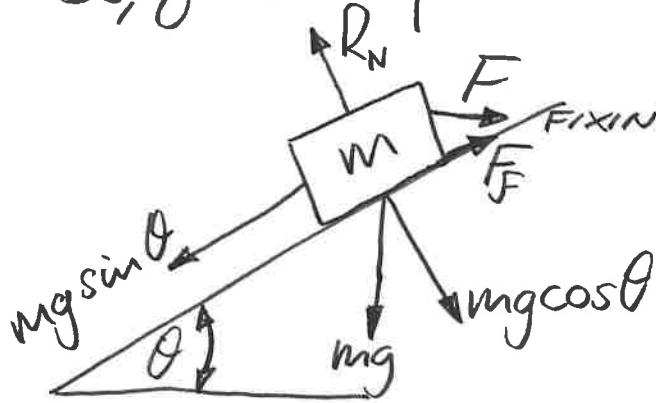
$$\therefore F + \mu \cdot mg \cos \theta = mg \sin \theta$$

$$\text{So, } F = mg \sin \theta - \mu \cdot mg \cos \theta$$

$$\therefore F = (275 \times 9.81) \sin 35^\circ - (0.445 \times 275 \times 9.81) \cos 35^\circ$$

Q4(b)(ii) Cont.

So, force in parallel fixing wire, $F = 563.98 \text{ N}$



Resolve F into perpendicular ($F \sin \theta$) and parallel ($F \cos \theta$) components.

Resolving forces perpendicular to plane;

$$R_N = mg \cos \theta + F \sin \theta \quad \text{--- (1)}$$

Resolving forces parallel to the plane;

$$F \cos \theta + F_f = mg \sin \theta$$

$$\therefore F \cos \theta + \mu R_N = mg \sin \theta \quad \text{--- (2)}$$

Substituting (1) into (2) for R_N ;

$$F \cos \theta + \mu (mg \cos \theta + F \sin \theta) = mg \sin \theta$$

$$\text{So, } F \cos \theta + \mu F \sin \theta = mg \sin \theta - \mu mg \cos \theta$$

$$\therefore F = \frac{mg (\sin \theta - \mu \cos \theta)}{(\cos \theta + \mu \sin \theta)}$$

$$F = \frac{(275 \times 9.81) (\sin 35^\circ - 0.445 \cos 35^\circ)}{(\cos 35^\circ + 0.445 \sin 35^\circ)}$$

So, force in horizontal fixing wire,

$$F = 524.92 \text{ N}$$

(10 marks)

$$\text{(iii) } \sigma = \frac{F}{A} = \frac{563.98}{\pi \times \frac{0.008^2}{4}}$$

$$\therefore \sigma = 11,220,025.6 \text{ N/m}^2 (11.22 \text{ MN/m}^2) \quad (3 \text{ marks})$$