(A) Introduction

This report aims to find out the flying motion of a common myna, the different forces and its magnitude the myna experiences at the different stages of flight. i.e: how does the different position of the wings affect velocity, acceleration and the forces experienced by myna.

The video consists of three main stages: resting, up-stroke wing motion and down-stroke wing motion, which are then split into seven frames.

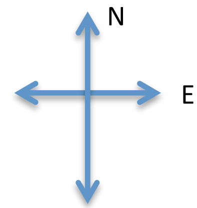
Hypothesis: myna has a greater velocity during down-stroke wing motion, due to the force exerted by the Myna on the air beneath its body, to push itself in the up and forward direction.

(B) Procedure [Labelled diagram refer to appendix.]

As the flying motion of a myna is unpredictable, its course of flight and timing of take off are extremely hard to predicate, therefore, the use of a tripod is not applicable. Student film the motion with high speed camera, with arms propped against stable structure to minimize human error while filming. Filmed multiple times before choosing the video that best capture the object in motion, when myna is large and clearly captured to facilitate plotting of mass points. The depth of the myna's flight should be at minimum, which means myna is neither flying towards or away from the camera. Flight should be as 2D as possible to ensure more accurate discussion of dynamic and kinematic of the myna. Trim the video into multiple frames and phases before recording data and carry out discussions. By plotting as many mass points as possible to obtain a more detailed and accurate data. The myna's flying angle is calculated by tracing the mass points (trails left by the myna) against the x-axis on the tracker, to determine the angle of flight as 45°.

Wind condition when filming is taken to be negligible, weather condition was sunny and around 11 at noon, which usually has little or no wind.

All values in the report have been rounded off to 2s.f.



(C) Assumption and Limitation

1. Average acceleration of myna should remain constant throughout the journey.
2. $F_{lift} = W_{gravity\ on\ myna}$
3. Mass of myna is taken to be 0.11kg which is the average body mass of myna from online resources. As it is impossible to catch the myna in the video and weigh it.
4. Body length of myna is taken to be 0.25m, which is the average body length of myna from online resources.

4. The angle of myna's flight with regards to the x-axis is measured to be at a 45° to the north east direction.

5. Calculation done with the assumption that myna is flying in a 2D plane, which is not the case in real life, there is a depth to their flight (away from camera/towards camera).

6. The aerodynamics of myna's flight is very complex. The motion of myna's wings is not straight up and down, as can be observed in the video. The direction of beat is slightly backwards for the up-stroke and slightly forwards for the down stroke. This report did not manage to trace the tips of the wings, but only the CG of myna.

(D) Discussions (kinematics and dynamics) *[Refer to appendix for screenshots of phases, simplified drawing and free body diagrams]*

The mass of a common myna is 0.11 kg, it has an average body length of 0.25 m . scaling of the diagram is based on the body length of myna. The gravitational acceleration is taken to be 9.81 ms^{-2} for gravitational forces exerted on the myna.

Phases, duration	x-direction (horizontal) Discussion of kinematics and dynamics	y-direction (vertical) Discussion of kinematics and dynamics
A t=0.00 ~ t=0.93s Myna resting on the railing	x=0.0 ~ 0.0 m vx=0.0 ~ -0.10 ms^{-1} ax=0.00 ~-0.86 ms^{-2} No horizontal displacement. Magnitude of W = y component of $F_N + F_f$, As F_f and F_N 's y component lies on the same line as W F_N =W=ma=1.1N	Myna is not moving at all so there is no vertical displacement, velocity or acceleration. As the myna is at rest, it is experiencing a balanced force. Based on N2L $F_y=ma_y$

A to B t=0.93 ~ t=1.67s Myna lowering its body (CG)	x=- 0.0 ~ 0.0 m vx= 0.0 ~ -0.20ms^{-1} ax= 0.0 ~ -1.5 ms^{-2} average acceleration = 0 ms^{-2} The displacement in the horizontal axis is negligible, but as seen in the velocity and acceleration data value, there is minimal displacement. This is caused by the frictional force of the railing acting on the myna. Magnitude of W = y component of $F_N + F_f$, F_N =W=ma=1.1N Based on N1L: $F_{net} = 0$	y= - 0.0 ~ - 0.02m vy= 0.1 ~ 0.10ms^{-1} ay= -0.30 ~ -0.30ms^{-2} Myna lowers its body, a displacement in the negative y direction to prepare Myna lowers only the abdomen parts of its body while still resting on the beam. No vertical acceleration experienced, therefore net force=0N. F_f and F_N 's y component lies on the same line as W, magnitude of W= y component of F_N and F_f.
B to C t=1.67 ~ t=3.27 s Myna stretches its body while its claws are still resting on the beam	x = -0.0 ~ 0.0m vx = -0.2 ~ 0.1ms^{-1} ax = 1.5~ 0.9 ms^{-2} average acceleration = 0ms^{-2} Negligible change in displacement$_x$, CG remain the same value on the x-axis. $F_{thrust} = R_{air\ resistance}$ F_{lift} + y component of F_N = W F_{net} of x = 0	y=-0.0 ~ -0.0m vy=0.1 ~ 0.0ms^{-1} ay=-0.3 ~ -0.3ms^{-2} change in acceleration = 0 Acceleration experienced is insignificant. As the time not enough for the acceleration to act on the bird to be captured and seen. F_{lift} + y component of F_N = W N1L: Net force = F_{lift} – W=ma=0 (for 3.27s) Myna is giving an upward thrust, so the CG of myna goes up as it extends its body and stretch its wings. myna experiences a slight air drag as it moves in the right upward direction, however, that may be counted as negligible.
C to D t=3.27 ~ t=3.54 s Myna leaps off the beam, middle of down-stroke	x=0.0 ~ 0.1 m vx=0.1 ~ 0.2 ms^{-1} ax = -2.0 ~ -1.6ms^{-2} average acceleration = $\frac{\Delta v}{\Delta t}$ =0.37 ms^{-2} $F_{net} = F_{thrust} - R_{air\ resistance}$ =ma =0.110 x 3.7 = 0.41N Since F_{lift} = W= 0.11x9.81=1.1N Angel of direction of flight =45° F_{thrust}=F_{lift} sin(45°) = 0.11x9.81xsin(45°)=0.76N $R_{air\ resistance}$ = 0.76 – 0.41 =0.35N	y=-0.0 ~ 0.06 m vy=0.0 ~ 0.03ms^{-1} ay=-0.3 ~ -0.2ms^{-2} vertical F_{net} =0, as myna is gliding horizontally, force not applied to air to push its self upwards, therefore, F_{lift}= W, F_{net} = 0, so there is little vertical displacement, and negligible vertical acceleration.
D to E t=3.54 ~ t=3.87 s Down-stroke motion	x=0.080 ~ 0.14 m vx=0.10 ~ 0.24 ms^{-1} ave. acc. = 0.42 ms^{-2} F_{thrust}=F_{lift} sin(45°) =0.78N F_{net}=ma = 0.11 x 0.42 = 0.046N $R_{air\ resistance}$ = 0.78 – 0.046 =0.73N The horizontal air resistance may be counted as negligible, as the forward thrust	y=0.06 ~ 0.09 m vy=0.03 ~ 0.13ms^{-1} average acceleration = 0.30ms^{-2} myna experiences a greater F_{thrust}, exerted on myna by the friction of the wind acting against the myna. F_{thrust}=F_{lift} sin(45°) =0.78N F_{net}=ma = 0.11 x 0.30 = 0.33N $R_{air\ resistance}$ = 0.78 – 0.41 =0.37N Wings pushes air down to give itself the lift force, so increase gain in X_y, the top part of the wings are curved, the air that flows over the top of the wing travels a longer distance than air that flows under the wing in the same amount of time, so the air above wings has to travel faster to meet the bottom air at the trailing edge of the wing. The higher velocity of wind on top of the wing creates a lower air pressure

	for it to continue its course of flight.	Based on N2L, the opposing force is always equal to one another. Pressure above wings lower than pressure below wing when the myna is moving in the horizontal upward direction.
E to F: t=3.87 ~ t=4.17 s	Myna in the middle of up-stroke x=0.14 ~ 0.20 m vx=0.24 ~ 0.44 ms^{-1} ax=1.5 ~ 2.0 ms^{-2} average acceleration =0.6ms^{-2} F_{net}=ma=0.11 x 0.6 = 0.066N $R_{\text{air resistance}}$ = 0.78 – 0.066 =0.71N Compared to air resistance experience from D to E, there is less air resistance experienced by the myna.	y=0.09 ~ 0.12 m vy=0.13 ~ 0.13ms^{-1} ay=1.2 ~ 1.2ms^{-2} negligible when rounded off to 2s.f. average acceleration = 0.03 ms^{-2} F_{net}=ma=0.11 x 0.03 = 0.003 N $R_{\text{air resistance}}$ = 0.78 – 0.03 =0.45N Compared to phase (D to E), myna experiences significantly lesser acceleration, but greater air resistance.
F to G: t=4.17 ~ t=4.37 Completion of up-stroke	x=0.20 ~ 0.23 m vx=0.24 ~ 0.40 ms^{-1} ax=2.0 ~ 1.2ms^{-2} Average deceleration =0.75ms^{-2},increase in acceleration in the negative direction	y=0.12 ~0.14 m vy=0.13 ~0.20 ms^{-1} ay=1.1~0.86 ms^{-2} myna experience a decrease in acceleration, average deceleration = -0.50ms^{-2}. Fnet= ma = 0.11 x -0.50 = -0.055N $R_{\text{air resistance}}$ = 0.78 – (-0.055) = 1.3N Greater air resistance is experienced by myna in the up-stroke, therefore greater energy is used to allow the myna to have the same increase in velocity and displacement in the vertical direction. Lesser time is used to complete the up-stroke, so F needed to complete up-stroke may be minimized to conserve energy to increase $\text{displacement}_{y.}$

For the rest of the flight, myna repeats its flying cycle of down-stroke wing motion with up-stroke wing motion.

(E) Conclusion

A myna has a stream line body which makes it well adapted to flying through the air. Its small head, sharp wing tip, curved wing shape, and sharp tail allows it to waste minimum energy in flight. As observed in the video, the legs of the myna are tucked up to minimum air-resistance as well. During down-stroke (frame C~E) displacement_x is much larger than up-stroke(frame E~G), 0.14m and 0.09 respectively; vertical displacement gained are 0.09 and 0.05m respectively. Therefore, conclusion may be drawn that the power stroke is downward stroke, which acts against the resistance of the air beneath myna, and during it the air resistance closes the feathers and the wings extend to the fullest to have the largest surface area in contact with the air, to maximize the thrust exerted by myna. The up-stroke however, is much less powerful, but takes less time than down-stroke. As can be observed in the tracker data, though the difference is quite insignificant. Therefore, I conclude that more force is required to exert on the up-stroke than down-stroke. During up-stroke, the wings folds partially to have a smaller surface area, so less resistance against myna's body. Myna's body is tilted upwards, and the head is always lifted during the down-stroke and falls a bit during the up-stroke, to reduce the air resistance coming against the myna. Based on the data obtained from the tracker, the up-stroke motion takes slightly longer than up-stroke, (though very insignificant difference). The length of the repeat depends on the speed of myna as well as the current height of the myna. The repetition of the wing is more frequent when object first take off at a relative lower height, when myna reaches a certain height, the beating of wing motion will be less frequent as it no longer need the extra force to gain positive vertical displacement.