THE UNIVERSITY OF SYDNEY
FACULTY OF EDUCATION AND SOCIAL WORK
EDUH 1017 SPORTS MECHANICS
JUNE 2008

Time allowed: TWO Hours

MARKS FOR QUESTIONS ARE AS INDICATED
TOTAL: 70 MARKS

INSTRUCTIONS
• All questions are to be answered.
• Use a separate answer book for each section.
• All answers should include explanations in terms of physical principles.

DATA

Free fall acceleration at earth's surface \( g = 9.8 \text{ m.s}^{-2} \)
SECTION A
(Please use a separate book for this section.)

Question 1

In several of the Sports Mechanics laboratory sessions you have used VideoPoint software to analyse motion. Consider how you would use this software to analyse the motion of an athlete doing a long jump.

To help track the athlete’s motion you attach markers (exaggerated above) to his wrist, hips and ankle. Using VideoPoint, you track the position of these markers through the jump.

(a) Explain how you think the software calculates

(i) velocity from the position measurements
   (Hint: think of plotting the position measurements on a position versus time graph),

(ii) kinetic energy,

(iii) gravitational potential energy.

(b) To understand the exchange between different types of energy during the jump, you are advised to concentrate on the motion of the hip. Why is this better than considering the motion of the ankle or wrist?

(5 marks)
Question 2

An archer draws an arrow ready to shoot an arrow upwards at a small angle.

(a) Draw a force diagram showing and labelling all the forces on the arrow when the bow is drawn, ready to release the arrow, as shown in the diagram.

(b) Draw a second force diagram showing and labelling all the forces on the arrow just after it has been released and left the bow. Assume that air resistance is negligible.

(5 marks)

Question 3

An experiment is conducted to test the difference between surfaces used on different tennis courts – a grass court used at Wimbledon and a Plexicushion hard court used at the Australian Open in Melbourne.

In each case, a tennis ball of mass 0.057 kg is dropped from a height of 2.0 m and the height to which the ball rebounds is measured. The experiment is repeated many times with different balls to yield an average result. The average rebound height is 1.5 m on the Plexicushion hard court and 1.2 m on the grass court.

(a) Calculate the speed of the ball just before it hits the surface. Will this be the same for the two surfaces? Why?

(b) For each surface, calculate the speed of the ball just after it bounces off the surface.

(c) Use energy to explain why the ball bounces differently on the two surfaces. What are the implications for players?

(5 marks)
Question 4

In a game of cricket, a fast bowler bowls a cricket ball of mass 0.156 kg towards a batsmen at 150 km.h\(^{-1}\). The batsmen hits the ball straight back down the pitch at the bowler at 130 km.h\(^{-1}\).

(a) What is the change in momentum of the ball (in units of kg.m.s\(^{-1}\))?

(b) If the ball is in contact with the bat for 0.001 s, what is the force exerted by the bat on the ball?

(c) Some players use heavier bats than others. What could be some implications for the player of using a heavier bat?

(5 marks)

Question 5

The diagram shows a diver doing a forward dive with somersaults, in the pike position. The diver starts this rotating motion by diving forward off the diving board.

(a) Explain how the forces acting on the diver as she dives off the diving board cause her to start her rotating motion.

(b) For different dives, the diver will alter the position of her limbs relative to her body. The pike position shown is just one standard position. Using the terminology of mechanics, explain how the diver uses body position to control her rate of rotation.

(5 marks)
SECTION B
(Please use a separate book for this section.)

Question 6

Ski jumping is a sport in the Winter Olympics in which skiers build up speed down an ‘inrun’ before launching into the air from a takeoff ramp. The objective is to travel as far as possible down the hill in flight before landing.

Sketch the following graphs to illustrate the motion of the skier from the time she starts moving down the ‘inrun’ until just after the landing. You may ignore the effects of friction and air resistance.

(a) Acceleration of the skier versus time

(b) Speed of the skier versus time

(c) Kinetic Energy of the skier versus time

(d) Gravitational Potential Energy of the skier versus time

Make sure the axes of each graph are correctly labelled.

Include labels on each graph to clearly indicate the different phases – ‘inrun’, ‘takeoff’, ‘flight’ and ‘landing’.

(10 marks)
Question 7

An archer draws an arrow ready to shoot horizontally at a target 15 m away, as shown below. The arrow is accelerated by the bow over a distance of 0.40 m. The arrow goes from rest to a speed of 80 m.s\(^{-1}\) over this distance with a constant acceleration. Assume that air friction is negligible.

(a) Calculate the magnitude of the acceleration of the arrow over the 0.40 m distance.

(b) If the arrow has a mass of 0.025 kg, what average force was required to accelerate the arrow?

(c) Calculate the time for the arrow to travel the 0.40 m distance.

(d) How long will it take the arrow to reach the target?

(e) Remembering that the arrow was shot horizontally, calculate how far below the bullseye the arrow will hit.

(10 marks)
The figure shows a lower arm and hand exerting an upward force to support a book.

The biceps muscle is connected from the shoulder to the radius bone of the lower arm at a point 0.05 m from the elbow, as shown in the diagram. When the biceps contracts it moves the lower arm upward.

(a) Draw a diagram treating the arm as a simple rod. Indicate all the forces acting on the arm.

(b) Using the concepts of forces and torques, briefly explain how your muscles allow the forearm and book to be held in this position.

Take the mass of the hand and lower arm together to be 6% of the total body mass. This mass can be thought of as being located at the centre of mass of the arm. Assume the force applied by the biceps acts vertically.

(c) Calculate the force exerted by the biceps of an 80 kg person holding a 3.0 kg book.

(10 marks)
Please note that Question 9 is worth 15 marks.

Question 9

Running is in some sense the easiest of athletic activities – virtually everyone can do it! Explain the mechanics behind the motion of the running athlete by answering the following questions:

(a) Describe the motion of the athlete’s centre-of-mass using sketched graphs of:

(i) horizontal position versus time,

(ii) vertical position versus time,

(iii) horizontal velocity versus time,

(iv) vertical velocity versus time,

In each case, briefly comment on what the graph is telling you about the motion of the athlete.

(b) Draw a graph of force versus time (not a force diagram) illustrating the variation in time of the

(i) horizontal forces

(ii) vertical forces

on the ground at a point where the athlete’s foot lands.

(c) Briefly comment on how all these graphs would be different if the athlete was walking. Make a few specific comments and don’t go into too much detail.

(15 marks)

THIS IS THE END OF YOUR QUESTIONS