EDUH 1017 Sports Mechanics Exam Solutions  
Semester 1, 2008

SECTION A

Question 1
(a)
(i)
\[ v = \frac{\Delta x}{\Delta t} \]
so taking the difference of adjacent (in time) position measurements and dividing by the time measurement gives the simplest estimate of instantaneous velocity.  
1 mark

1/2 only if the idea of small \( \Delta t \) to get instantaneous velocity isn’t there

(ii)
Simply use \( m \) and \( v \) to calculate \[ KE = \frac{1}{2}mv^2 \]  
1 mark

(iii)
Simply use \( m \) and \( h \) to calculate \[ GPE = mgh \]  
1 mark

(b)
The hip marker is closest to the centre of mass of the jumper and therefore best represents the motion of the body as a whole.  
1 mark

The ankle and wrist have extra motion relative to the centre of mass as the arms and legs move.  
1 mark

Total – 5 marks
Question 2
(a) Forces on arrow before release

½ mark for each of 4 correct forces
½ mark for each of 4 correct labels
sub-total 4 marks

(b) Forces on arrow just after release and left the bow (ignoring air resistance)

½ mark for 1 correct force
½ mark for 1 correct label
penalise ½ mark for each incorrect force
sub-total 1 mark

total 5 marks
Question 3

(a) Using energy considerations (although using the equations of constant acceleration will also work)
\[ v = \sqrt{2gh} \]
\[ = \sqrt{2 \times 9.8 \times 2} \]
\[ = 6.26 \text{ m/s}^{-1} \]

\[ \begin{array}{ll}
\text{a correct approach - 1/2 mark} \\
\text{correct result - 1/2 mark}
\end{array} \]

Yes

1/2 mark

This value is the same for both surfaces (since the ball hasn’t touched either surface yet!)

1/2 mark

sub-total - 2 marks

(b) The height of the rebound from each surface is used to calculate the velocity with which the ball rebounds off the surface.
\[ v = \sqrt{2gh} \]

For grass
\[ = \sqrt{2 \times 9.8 \times 1.2} \]
\[ = 4.85 \text{ m/s}^{-1} \]

\[ \begin{array}{ll}
\text{a correct approach - 1/2 mark} \\
\text{correct result - 1/2 mark}
\end{array} \]

For Plexicushion
\[ = \sqrt{2 \times 9.8 \times 1.5} \]
\[ = 5.42 \text{ m/s}^{-1} \]

\[ \begin{array}{ll}
\text{a correct approach - 1/2 mark} \\
\text{correct result - 1/2 mark}
\end{array} \]

sub-total – 2 marks

(c) The ball rebounds less from the grass surface because more energy is lost in the ‘collision’ between the ball and the grass than between the ball and the Plexicushion.

1/2 mark

Different bounce height and speed off the court requires players to adjust their technique.

1/2 mark

sub-total – 1 mark

Total - 5 marks
Question 4

(a)  
\[ v_i = 150 \text{ km.h}^{-1} = +41.7 \text{ m.s}^{-1} \text{ (towards the batsman)} \]
\[ v_f = 130 \text{ km.h}^{-1} = -36.1 \text{ m.s}^{-1} \text{ (away from batsman)} \]

So the change in momentum is

\[ \Delta p = m v_f - m v_i \]
\[ = m (v_f - v_i) \]
\[ = (0.156)(-36.1 - 41.7) \]
\[ = 12.1 \text{ kg.m.s}^{-1} \]

(or 43.7 kg.km.h\(^{-1}\))

_conversion attempted – 1/2 mark_

_a correct approach (esp. signs correct) - 1 mark_

_correct result – 1/2 mark_

_sub-total – 2 marks_

(b)  
Using the change in momentum

\[ \Delta p = F \times t \]
\[ 12.1 \text{ kg.m.s}^{-1} = F \times 0.001 \]

Hence the average force \( F = 12100 \text{ N} \).

_a correct approach - 1 mark_

_correct result (with correct units) - 1 mark_

_sub-total – 2 marks_

(c)  
A heavier bat will result in greater speed of the ball off the bat for the same bat speed (more ‘power’). However it will be harder to swing a heavier bat fast enough – i.e. the bat speed may be lower.

_Sensible comments – 1/2 mark each_

_sub-total – 1 mark_

_Total 5 marks_
**Question 5**

(a)
She needs to have a torque applied to her body to begin a rotation about her centre of mass.  
This is applied by the diving board (or platform) reaction force.  

(b)
Diver rotates faster (greater $\omega$) when she pulls her body in more tightly (or vice versa) since  
$L = I\omega$  
Why? Conservation of angular momentum ($L$)  
Pulling her body in more tightly minimises her moment of inertia ($I$)

Total - 5 marks
SECTION B

Question 6

(a) Acceleration versus time:

-9.8 m.s\(^{-2}\)

- only partially correct – 1 mark
- OR general shape correct (ignoring sign) – 2 marks
- OR correct in detail – 3 marks

(b) Speed versus time:

only partially correct – 1 mark
- OR general shape correct – 2 marks
- OR correct in detail – 3 marks
(c) Square speed (~velocity) to get $v^2$ and hence the KE:

(f) GPE versus time (note: GPE + KE should be a constant):

Total - 10 marks
Question 7

(a) Considering only the phase when the arrow was accelerated:
\[ v_i = 0 \text{ m.s}^{-1} \]
\[ v_f = 80 \text{ m.s}^{-1} \]
\[ d = 0.40 \text{ m} \]

Then
\[ v_f^2 = v_i^2 + 2ad \]
\[ 6400 = 0 + 2a(0.40) \]
\[ a = \frac{6400}{0.8} = 8000 \text{ m.s}^{-2} \]

\text{use of a suitable formulae – 1 mark}
\text{correct answer – 1 mark}

(b) The average force is given by
\[ F = ma \]
\[ = (0.025)(8000) \]
\[ = 200 \text{ N} \]

\text{use of a suitable formulae – 1 mark}
\text{correct answer – 1 mark}

(c) Time to cover 0.40 m:
\[ v_f = v_i + at \]
\[ 80 = 0 + 8000t \]
\[ t = 0.01 \text{ s} \]

\text{use of a suitable formulae – 1 mark}
\text{correct answer – 1 mark}

(d) Ignoring air resistance, horizontal velocity remains unchanged:
\[ d = v_it + \frac{1}{2}at^2 \]
\[ 15 = 80t + 0 \]
\[ t = 0.1875 \text{ s} \approx 0.19 \text{ s} \]

\text{use of a suitable formulae – 1 mark}
\text{correct answer – 1 mark}

(e) Ignoring air resistance, vertical displacement is given by:
\[ d = v_it + \frac{1}{2}at^2 \]
\[ = 0 + \frac{1}{2}(-9.8)(0.1875)^2 \]
\[ = -0.17 \text{ m} \]

\text{use of a suitable formulae – 1 mark}
\text{correct answer (ignoring sign) – 1 mark}

Total – 10 marks
Question 8

(a)

For each force - 1 mark
Only ½ mark if not named
(few will get $F_{\text{elbow}}$)

\[ \text{sub-total 4 marks} \]

(b)
Weight of arm and weight of book impose clockwise torques
Biceps muscle must apply an \textit{opposite} anti-clockwise torque

Must \textit{equal} the clockwise torque

Force must be much larger because of closeness to elbow joint.

\[ \text{sub-total 3 marks} \]

(c)
Torque due to $F_{\text{elbow}}$ will be zero because distance from pivot is zero (few will get this so ignore it)
Balancing clockwise and anti-clockwise torques:

\[ \tau_{\text{arm}} + \tau_{\text{book}} = \tau_{\text{biceps}} \]

\[ \left( \frac{6}{100} \times 80 \text{ kg}\right)(9.8 \text{ m/s}^2)(0.16 \text{ m}) + (3.0 \text{ kg})(9.8 \text{ m/s}^2)(0.34 \text{ m}) = (F_{\text{biceps}})(0.05 \text{ m}) \]

\[ \Rightarrow F_{\text{biceps}} = 350.55 \text{ N} \approx 350 \text{ N} \]

\[ \text{calculation - 1 mark} \]
\[ \text{result - 1 mark} \]

\[ \text{sub-total 3 marks} \]

Total – 10 marks
Question 9

(a)  
(i)  Horizontal position versus time (ignore values on graph):

Graph shows the basic forward motion (dashed line) plus the periodic acceleration and deceleration associated with each step – accelerating as you push off the back foot and decelerating as the front foot lands.

Graph only partially correct – 1/2 mark
OR Graph general shape correct – 1 mark

Sensible comment of what graph is showing – 1 mark
Sub-total – 2 marks

(ii)  Vertical position versus time (ignore values on graph):

Graph shows the essentially constant height of the centre-of-mass (dashed line) plus the periodic up and down motion associated with each step.

Graph only partially correct – 1/2 mark
OR Graph general shape correct – 1 mark

Sensible comment of what graph is showing – 1 mark
Sub-total – 2 marks
(iii) Horizontal velocity versus time (ignore values on graph):

Graph shows the basic forward motion (dashed line) plus the periodic acceleration and deceleration associated with each step – accelerating as you push off the back foot and decelerating as the front foot lands. [same comment as (a)!]

Graph only partially correct – 1/2 mark
OR Graph general shape correct – 1 mark
Sensible comment of what graph is showing – 1 mark
Sub-total – 2 marks

(iv) Vertical velocity versus time (ignore values on graph):

Graph shows the essentially zero vertical velocity of the centre-of-mass plus the periodic up and down motion associated with each step.

Graph only partially correct – 1/2 mark
OR Graph general shape correct – 1 mark
Sensible comment of what graph is showing – 1 mark
Sub-total – 2 marks
(b)

(i)

Horizontal force – running
Positive and negative peak structure as foot is decelerated in landing and then accelerated in pushing off.
(time is too long since this is actually a walking example)

Graph only partially correct – 1/2 mark
OR Graph general shape correct – 1 mark

Sensible comment of what graph is showing – 1 mark
Sub-total – 2 marks

(ii)

Vertical force – running
Single peak only – larger force and shorter duration than the walking peak below
(even if values don’t really show that)

Graph only partially correct – 1/2 mark
OR Graph general shape correct – 1 mark

Sensible comment of what graph is showing – 1 mark
Sub-total – 2 marks
(c) For walking:
Graphs in (a) would be similar shapes
but show
- less vertical motion
- slower horizontal velocity (obviously)
- longer time per step

This the key point - 1/2 mark
any two other valid points - 1/2 mark each

Graphs in (b) are somewhat different:

The major difference is that the Vertical force shows a double peak with a minimum
This the key point - 1/2 mark
as the heel landing and ball pushing off are seen as separate actions

The horizontal force is basically similar,
This the key point - 1/2 mark
although the time duration is less.

any other valid point - 1/2 mark

Sub-total – 3 marks
Total – 15 marks