SPH4U, Physics
Grade 12, University Preparation

Course Requirements

| Unit 1: Dynamics | | | | | | | |
|---|---|---|---|---|---|---|---|
| Activity | Suggested Time Frame | Practise Questions | Discussion | Lab | Project | Quiz | Test |
| A1: Review | 1 | | | | | | |
| A2: Vectors, Relative Motion and Projectile Motion | 2 | 2013-02-15 | | | | | |
| A3: Frames of Reference | 1 | 2013-02-19 | | | | | |
| A4: Forces | 2 | | 2013-02-21 | 2013-02-22 | | | |
| A5: FBD and Problem Solving | 2 | 2013-02-21 | | | | | |
| A6: Motion and Forces | 2 | 2013-02-25 | | | | | |
| A7: Around We Go | 2 | | 2013-02-24 | 2013-02-25 | | | |
| A8: Uniform Circular Motion | 2 | 2013-02-27 | | | | 2013-02-28 | |
| A9: Trebuchet Project | ongoing | | 2013-05-03 | | **2013-05-30** | | Friday |
| A10: Test | 1 | | | | | | 2013-03-01 |

| Unit 2: Energy and Momentum | | | | | | | |
|---|---|---|---|---|---|---|---|
| Activity | Suggested Time Frame | Practise Questions | Discussion | Lab | Project | Quiz | Test |
| A1: Work and Energy | 1 | 2013-03-04 | | | | | |
| A2: Energy Exchanges | 2 | 2013-03-06 | | | | | |
| A3: Conservation of Energy Lab | 2 | | 2013-03-06 | 2013-03-08 | | | |
| A4: Momentum | 2 | 2013-03-18 | | | | | |
| A5: Elastic and Inelastic Collisions | 2 | 2013-03-19 | | | | | |
| A6: Conservation of Momentum Lab | 2 | | 2013-03-17 | 2013-03-20 | | | |
| A7: Hooke's Law | 2 | 2013-03-22 | | | | 2013-03-25 | |
| A8: Egg Drop Project | ongoing | | 2013-03-26 | | **2013-05-29** | | Tuesday |
| A9: Test | 1 | | | | | | 2013-03-26 |

| Unit 3: Gravitational, Electric and Magnetic Fields | | | | | | | |
|---|---|---|---|---|---|---|---|
| Activity | Suggested Time Frame | Practise Questions | Discussion | Lab | Project | Quiz | Test |
| A1: Fundamental Forces | 1 | 2013-03-27 | | | | | |
| A2: Gravitational Fields | 2 | 2013-03-29 | | | | | |
| A3: Electric Fields | 2 | 2013-04-02 | | | | | |
| A4: Magnetic Fields | 2 – 3 | 2013-04-04 | | | | | |
| A5: Milikan Lab and Field Comparisons | 3 | | 2013-04-07 | 2013-04-10 | 2013-04-11 | 2013-04-11 | |
| A6: Field Technology | Ongoing | | | | **2013-05-28** | | Monday |
| A7: Test | 1 | | | | | | 2013-04-15 |

| Unit 4: The Wave Nature of Light | | | | | | | |
|---|---|---|---|---|---|---|---|
| Activity | Suggested Time Frame | Practise Questions | Discussion | Lab | Project | Quiz | Test |
| A1: Wave Phenomena | 2 - 3 | 2013-04-17 | | | | | |
| A2: Ripple Tank Lab | 2 | | 2013-04-18 | 2013-04-19 | | | |
| A3: Thin Film Lab | 2 | | 2013-04-21 | 2013-04-02 | | | |
| A4: Slit Experiments | 2 | 2013-04-24 | | | | | |
| A5: Making Electromagnetic Waves | 1 | | | | | 2013-04-25 | |
| A6: Light Technology | Ongoing | | 2013-05-13 | | **2013-05-27** | | Monday |
| A7: Test | 1 | | | | | | 2013-04-29 |

| Unit 5: Revolutions in Modern Physics – Quantum Mechanics and Relativity | | | | | | | |
|---|---|---|---|---|---|---|---|
| Activity | Suggested Time Frame | Practise Questions | Discussion | Lab | Project | Quiz | Test |
| A1: Wave Particle Duality of Light | 1 | 2013-05-0 | 2013-05-02 | 2013-05-03 | | | |
| A2: Wave Particle Duality of Matter | 2 | 2013-05-02 | | | | | |

## Course Requirements

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A3: $E = mc^2$ Lab | 2 | | 2013-05-06 | 2013-05-07 | | | |
| A4: Special Relativity | 2 | | 2013-05-08 | | 2013-05-09 | | |
| A5: Relativistic Effects | 2 | 2013-05-15 | | | | 2013-05-13 | |
| A6: Modern Physics in Technology | 2 | | 2013-05-16 | | **2013-05-22** | | Friday |
| A7: Test | 2 | | | | | | 2013-05-24 |

# Projectiles (Horizontal Launch)

**Projectile** - Any object that is thrown, kicked, etc., while in mid air (after release)
- in free fall
- only influenced by gravity (the only force)

**Examples**

Footballs after being thrown

Frog after a jump (in mid air)

High jumper after leaving ground

**Not Examples**

Airplane

Bird

Rocket

Gliders

Skydiver (parachute op

Hang Glider

For projectiles,

① $\vec{a}_y = 9.8\ m/s^2$ [down] , on Earth (constant

acceleration in y-direction only

∴ ② $\vec{v}_x$ is constant!!

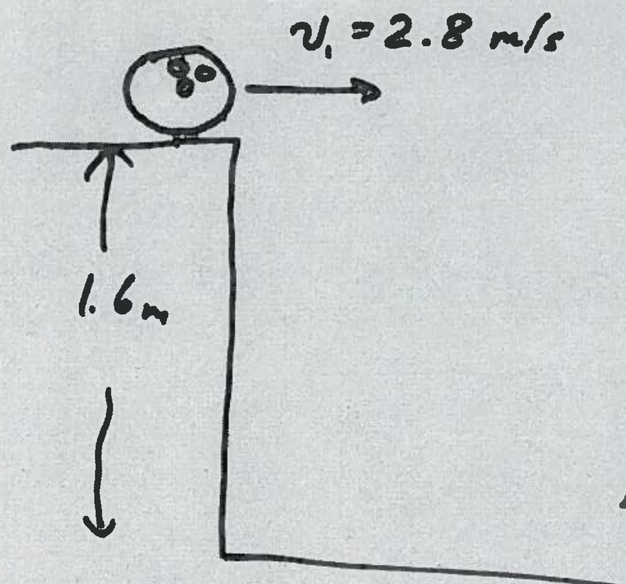
velocity in x-direction only.

③ Analyse the x and y directions separately! (Time is common to both directions)

Example: Selma's bowling ball rolls off her 1.6 m high counter with an initial horizontal speed of 2.8 m/s. Determine

(a) how long it takes for the ball to reach the floor (called "time of flight").

(b) the impact velocity of the ball.




(a) y-direction

$\vec{\Delta d} = -1.6$ m

$\vec{a} = -9.8$ m/s$^2$

$\vec{v}_1 = 0$

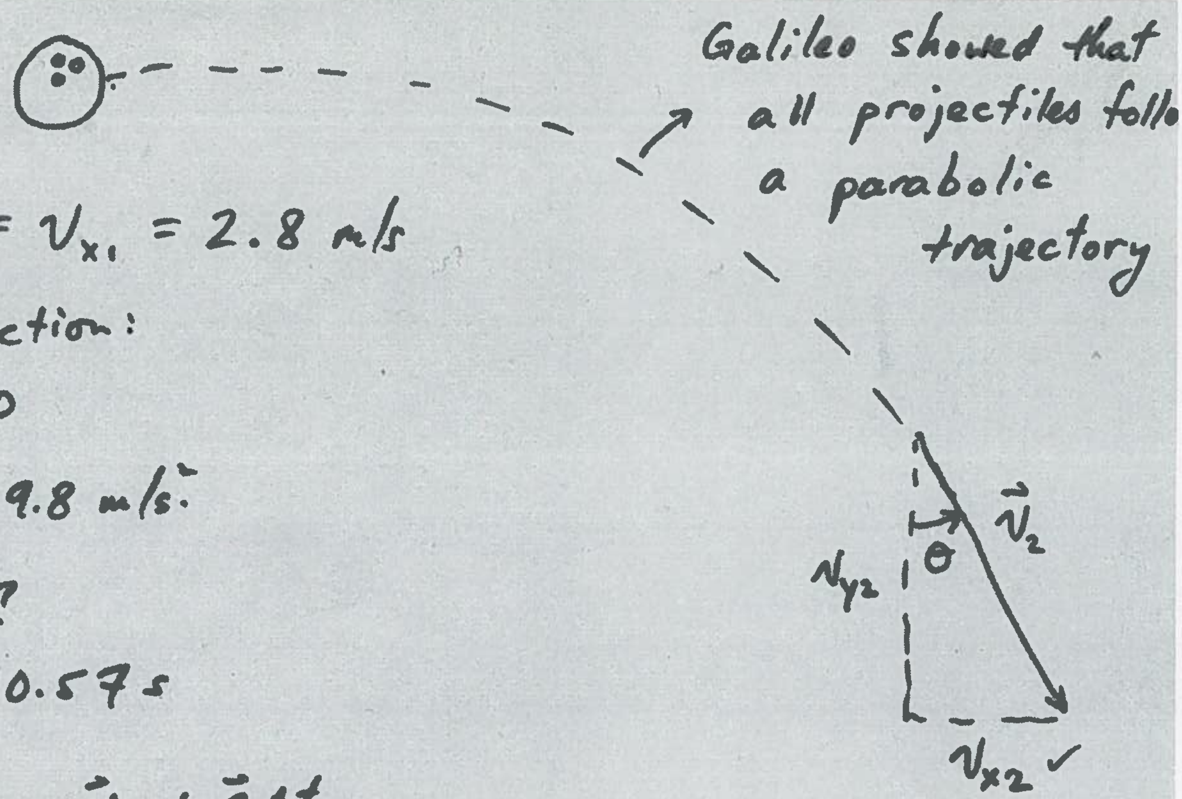
$\Delta t = ?$

$$\vec{\Delta d} = \vec{v}_1 \Delta t + \tfrac{1}{2}\vec{a}\Delta t^2$$

$$-1.6 = 0 + \tfrac{1}{2}(-9.8)\Delta t^2$$

$$\Delta t = 0.57 \text{ s}$$

(b)




$v_{x2} = v_{x1} = 2.8$ m/s

y-direction:

$v_{y1} = 0$

$a_y = -9.8$ m/s²

$v_{y2} = ?$

$\Delta t = 0.57$ s

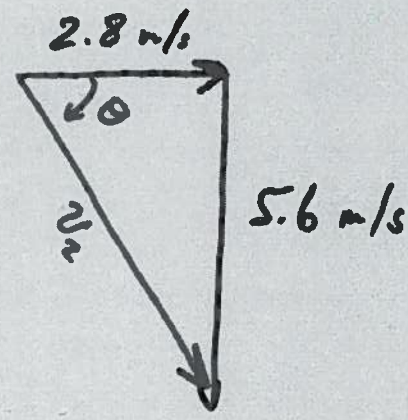
$$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$$

$$= 0 + (-9.8)(0.57)$$

$$= -5.6 \text{ m/s}$$

$$\vec{v}_2^{\,2} = (2.8)^2 + (5.6)^2$$

$$v_2 = 6.3 \text{ m/s}$$




$$\boxed{\vec{v}_2 = 6.3 \text{ m/s } [E\ 63.4°\ S]}$$

$$\tan\theta = \frac{5.6}{2.8}$$

$$\theta = 63.4°$$

## Projectile Motion (Non-Horizontal Projection)

The following applies to situations in which a projectile returns to its launch height.

(I call these “level field” problems)

Such an object has a vertical displacement of zero, so in the y-direction:

$$\overrightarrow{\Delta d} = 0$$

$$\overrightarrow{\Delta d} = \vec{v}_1 \Delta t + \frac{1}{2} \vec{a} \Delta t^2$$

$$0 = v_1 \sin\theta \, \Delta t + \frac{1}{2}(-g)\Delta t^2$$

$$\Delta t = \frac{2 v_1 \sin\theta}{g}$$

This is called the ***"time of flight"*** for the projectile, the time taken to return to launch height.

To find the horizontal distance the projectile travels, called the ***"range"***,

$$\overrightarrow{\Delta d}_x = \vec{v}_x \Delta t$$

(Since acceleration is zero in the x-direction)

$$\Delta d_x = v_1 \cos\theta \, \Delta t$$

$$\Delta d_x = v_1 \cos\theta \left( \frac{2 v_1 \sin\theta}{g} \right)$$

$$\Delta d_x = \frac{2 v_1^2 \sin\theta \cos\theta}{g}$$

$$\Delta d_x = \frac{v_1^2 \sin 2\theta}{g}$$

So to maximize the range of the projectile, we must maximize

$$\sin 2\theta$$

Thus the launch angle must be $45^{\circ}$ to maximize range.

1. Iggy punts a rugby ball with a launch speed of 22 m/s at an angle of $38^{\circ}$ above the horizontal. Determine the

a) “Hang time” of the ball.
b) the range of the kick.

(ignore the height of the ball when kicked) a)

$$\Delta t = \frac{2 v_1 \sin\theta}{g}$$

$$\Delta t = \frac{2(22)\sin 38^o}{9.8}$$

$$\Delta t = 2.76\, s$$

b)

$$\Delta d_x = \frac{v_1^2 \sin 2\theta}{g}$$

$$\Delta d_x = \frac{(22)^2 \sin 2(38^o)}{9.8}$$

$$\Delta d_x = 48\,m$$

2. Ringo the human cannonball is fired from a 32 m high cliff with a launch speed of 28 m/s at an angle of 48º above the horizontal. Determine

a) his flight time.
b) the velocity with which he hits the water below.

Name: ______________________ Class: ________________ Date: _________ ID: A

# Fundamental Motion SPH4U

## Problem

1. An object is pushed along a rough horizontal surface and released. It slides for 10.0 s before coming to rest and travels a distance of 20.0 cm during the last 1.0 s of its slide. Assuming the acceleration to be uniform throughout
(a) How fast was the object travelling upon release?
(b) How fast was the object travelling when it reached the halfway position in its slide?

2. An arrow is shot vertically upward with an initial speed of 25 m/s. When it's exactly halfway to the top of its flight, a second arrow is launched vertically upward from the same spot. The second arrow reaches the first arrow just as the first arrow reaches its highest point.
(a) What is the launch speed of the second arrow?
(b) What maximum height does the second arrow reach?

3. A truck travels at a constant speed of 28.0 m/s in the fast lane of a two-lane highway. It approaches a stationary car stopped at the side of the road. When the truck is still $1.2 \times 10^2$ m behind the car, the car pulls out into the slow lane with an acceleration of 2.6 $m/s^2$.
(a) How long will it take the truck to pass the car?
(b) How far will the car have travelled when the truck passes it?
(c) If the car were to maintain this acceleration, how fast would it be travelling when it overtakes the truck?

4. A car leaves point A and drives at 80.0 km/h [E] for 1.50 h. It then heads north at 60.0 km/h for 1.00 h and finally [30.0° W of N] at 100.0 km/h for 0.50 h, arriving at point B.
(a) Determine the displacement of point B from point A.
(b) A plane flies directly from point A to point B, leaving 2.00 h after the car has departed from point A. It arrives at point B at the same time the car arrives. There is a wind blowing at 60.0 km/h due south for the entire trip. What is the airplane's airspeed?
(c ) What direction must the plane head in order to arrive at point B?
(d) How long would the plane's trip be if there was no wind?

5. A shell is fired from a cliff that is 36 m above a horizontal plane. The muzzle speed of the shell is 80.0 m/s and it is fired at an elevation of 25° above the horizontal.
(a) Determine the horizontal range of the shell.
(b) Determine the velocity of the shell as it strikes the ground.

6. A baseball is hit by a bat and given a velocity of 40.0 m/s at an angle of 30.0° above the horizontal. The height of the ball above the ground upon impact with the bat is 1.0 m.
(a) What maximum height above the ground does the ball reach?
(b) A fielder is 110.0 m from home plate when the ball is hit and the ball's trajectory is directly at him. If he begins running at the moment the ball is hit and catches the ball when it is still 3.0 m above the ground, how long does he run before catching the ball?
(c) How fast (average speed) does he have to run in order to catch the ball?

# Fundamental Motion SPH4U
## Answer Section

**PROBLEM**

1. ANS:
(a)
The object's acceleration during the last 1.0 s: $\Delta t = 1.0$ s $v_1 = 40$ cm/s $v_2 = 0.0$ cm/s
$a = ?$ This is also the acceleration for the entire trip.

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{0.0 \text{ cm/s} - 40 \text{ cm/s}}{1.0 \text{ s}}$$

$$a = -40 \text{ cm/s}^2$$

The speed upon release: **The object was travelling at 4.0 m/s upon release.**

$$v_1 = v_2 - a\Delta t$$

$$= 0.0 \text{ m/s} - (-40 \text{ cm/s}^2)(10 \text{ s})$$

$$= 4.0 \times 10^2 \text{ cm/s}$$

$$v_1 = 4.0 \text{ m/s}$$

(b) The distance travelled: $\Delta t = 10.0$ s $v_2 = 0.0$ cm/s $a = -40$ cm/s² $\Delta d = ?$

$$\Delta d = v_2\Delta t - \frac{1}{2}a(\Delta t)^2$$

$$= 0.0 \text{ cm/s}(10.0 \text{ s}) - \frac{1}{2}(-40 \text{ cm/s}^2)(10.0 \text{ s})^2$$

$$\Delta d = 2.0 \times 10^3 \text{ cm}$$

At the halfway position:
$\Delta d = 1.0 \times 10^3$ cm $v_2 = 0.0$ cm/s $a = -40$ cm/s²
$v_1 = ?$

$$\Delta d = \frac{v_2^2 - v_1^2}{2a}$$

$$v_1 = \sqrt{v_2^2 - 2a\Delta d}$$

$$= \sqrt{(0.0 \text{ cm/s})^2 - 2(-40 \text{ cm/s}^2)(1.0 \times 10^3 \text{ cm})}$$

$$v_1 = 2.8 \times 10^2 \text{ cm/s}$$

**The object is travelling at 2.8 m/s at the halfway position in its slide.**

2. ANS:

(a)

Using the sign convention that "up" is (–) and "down" is (+):

$v_1 = -25$ m/s $\quad v_2 = 0.0$ m/s $\quad a = 9.8$ m/s² $\quad \Delta d = ?$

$$\Delta d = \frac{v_2^2 - v_1^2}{2a}$$

$$= \frac{(0.0\text{ m/s})^2 - (-25\text{ m/s})^2}{2(9.8\text{ m/s}^2)}$$

$$\Delta d = -31.9\text{ m}$$

The arrow travels 31.9 m upward to its highest point. The halfway position is 15.9 m.

The time to travel the last half of its flight:

$\Delta d = -15.9$ m $\quad v_2 = 0.0$ m/s $\quad a = 9.8$ m/s² $\quad \Delta t = ?$

$$\Delta d = v_2 \Delta t - \frac{1}{2}a(\Delta t)^2$$

$$\Delta t = \sqrt{\frac{-2\Delta d}{a}}$$

$$= \sqrt{\frac{-2(-15.9\text{ m})}{9.8\text{ m/s}^2}}$$

$$\Delta t = 1.80\text{ s}$$

For the second arrow: $\Delta d = -31.9$ m $\quad a = 9.8$ m/s² $\quad \Delta t = 1.80$ s $\quad v_1 = ?$

$$\Delta d = v_1 \Delta t + \frac{1}{2}a(\Delta t)^2$$

$$v_1 = \frac{\Delta d}{\Delta t} - \frac{1}{2}a\Delta t$$

$$= \frac{-31.9\text{ m}}{1.80\text{ s}} - \frac{1}{2}(9.8\text{ m/s}^2)(1.80\text{ s})$$

$$v_1 = -26.5\text{ m/s}$$

**The speed of the second arrow at launch is 27 m/s [upward].**

(b) Finding the maximum height of the second arrow:

$v_1 = -26.5$ m/s $\quad v_2 = 0.0$ m/s $\quad a = 9.8$ m/s² $\quad \Delta d = ?$

$$\Delta d = \frac{v_2^2 - v_1^2}{2a}$$

$$= \frac{(0.0\text{ m/s})^2 - (-26.5\text{ m/s})^2}{2(9.8\text{ m/s}^2)}$$

$$\Delta d = 35.9\text{ m}$$

**The second arrow reaches a maximum height of 36 m [upward].**

3. ANS:

(a)

Car: $v_{1C} = 0.0$ m/s, $a_C = 2.6$ m/s$^2$

Truck: $v_T = 28.0$ m/s

Car: $\Delta d_C = v_{1C}\Delta t + \frac{1}{2}a_C(\Delta t)^2$

$\Delta d_C = 1.3(\Delta t)^2$

Truck: $\Delta d_T = v_T\Delta t$

$\Delta d_T = 28.0\ \Delta t$

$\Delta d_T = \Delta d_C + 1.2 \times 10^2$ m

$28.0\ \Delta t = 1.3(\Delta t)^2 + 1.2 \times 10^2$

solving the quadratic: $\Delta t = 5.9$ s, 16 s

**The truck passes the car after 5.9 s.**

(b)

$v_{1C} = 0.0$ m/s

$a_C = 2.6$ m/s$^2$

$\Delta t = 5.9$ s

$\Delta d_C = ?$

$$\Delta d_C = v_{1C}\Delta t + \frac{1}{2}a_C(\Delta t)^2$$

$$= 1.3(5.9\text{s})^2$$

$$\Delta d_C = 45\text{ m}$$

**The car travels 45 m by the time the truck passes it.**

(c)

$v_{1C} = 0.0$ m/s

$a_C = 2.6$ m/s$^2$

$\Delta t = 15.6$ s (the other root of the quadratic)

$$v_{2C} = v_{1C} + a_C\Delta t$$

$$= 2.6\text{ m/s}^2(15.6\text{ s})$$

$$v_{2C} = 41\text{ m/s}$$

**The car will be travelling at 41 m/s when it passes the truck if it maintains its acceleration.**

4. ANS:

(a)

The car drives the following displacements: $\Delta\vec{d} = \vec{v}\Delta t$

$\Delta\vec{d}$ = 80.0 km/h [E](1.50 h) = 120 km [E]

$\Delta\vec{d}$ = 60.0 km/h [N](1.00 h) = 60.0 km [N]

$\Delta\vec{d}$ = 100.0 km/h [30°W of N](0.50 h) = 50 km [30°W of N]

Using the component method for the displacement of A to B:
north-south components: 60 km [N] + 50 km(cos 30°) [N] = 103.3 km [N]
east-west components: 120 km [E] + 50 km(sin 30°) [W] = 95 km [E]
Using Pythagoras Theorem, the magnitude of the displacement is 140 km
Using trigonometry, the direction is: [43° E of N]
**The displacement of point B from point A is 1.4 × 10² km [43°E of N].**

(b)

A vector diagram showing the relationship among the vectors is drawn:
$v_{PG}$ = velocity of plane with respect to the ground
$v_{PA}$ = velocity of plane with respect to the air
$v_{AG}$ = velocity of the air with respect to the ground

$\vec{v}_{PG} = \vec{v}_{PA} + \vec{v}_{AG}$

Since the car takes a total of 3.00 h to reach point B and the plane leaves 2.00 h later but arrives at the same time, the time it takes the plane to make the flight is 1.00 h.

$$v_{PG} = \frac{140 \text{ km}[43° \text{ E of N}]}{1.00 \text{ h}} = 1.4 \times 10^2 \text{ km/h } [43° \text{ E of N}]$$

Using cosine law:

$$\left|\vec{v}_{PA}\right| = \sqrt{(60)^2 + (140)^2 - 2(60)(140)\cos 137°}$$

$$\left|\vec{v}_{PA}\right| = 188 \text{ km/h}$$

**The plane's speed is 1.9 × 10² km/h.**

(c)

Using sine law:

$$\frac{60}{\sin\theta} = \frac{188}{\sin 137°},\ \theta = 13°$$

**The plane must head in a direction of [30°E of N]. (90° – 13° – 47°)**

(d)

If there is no wind: $\Delta t = \dfrac{\Delta d}{v} = \dfrac{140 \text{ km}}{188 \text{ km/h}} = 0.74 \text{ h}$

**The plane would take 0.74 h to fly from A to B if there was no wind.**

5. ANS:
(a)
Time of flight: let "up" be (–) and "down" be (+)
$v_1 = -80.0$ m/s(sin 25°) = –33.8 m/s
$a = 9.8$ m/s$^2$
$\Delta d = 36$ m
$\Delta t = ?$

$$\Delta d = v_1 \Delta t + \frac{1}{2} a(\Delta t)^2$$

$$36 = (-33.8)\Delta t + 4.9(\Delta t)^2$$

Solving the quadratic: $\Delta t = 7.84$ s

Horizontal range: $\Delta d = v\Delta t = 80.0$ m/s(cos 25°)(7.84 s) = 5.7 × 10$^2$ m
**The horizontal range of the shell is 5.7 × 10$^2$ m.**

(b) Horizontal component of final velocity: 80.0 m/s(cos 25°) = 72.5 m/s
Vertical component of final velocity: $v_2 = v_1 + a\Delta t = -33.8$ m/s + 9.8 m/s$^2$(7.84 s)
$v_2 = 43.0$ m/s

Using Pythagoras: $|\vec{v}| = \sqrt{(43.0)^2 + (72.5)^2}$

$|\vec{v}| = 84$ m/s

$$\theta = \tan^{-1}\left(\frac{43.0}{72.5}\right) = 31°$$

**The shell lands with a velocity of 84 m/s at an angle of 31° below the horizontal.**

6. ANS:
(a)
At maximum height: vertical component of velocity is zero:
let "up" be (–) and "down" be (+)
$v_1 = -40.0$ m/s(sin 30.0°) = –20.0 m/s
$a = 9.8$ m/s²
$v_2 = 0.0$ m/s
$\Delta d = ?$

$$\Delta d = \frac{v_2^2 - v_1^2}{2a}$$

$$= \frac{(0.0\text{ m/s})^2 - (-20.0\text{ m/s})^2}{2(9.8\text{ m/s}^2)}$$

$$\Delta d = -20\text{ m}$$

**The ball reaches a maximum height of 21 m above the ground. (hit from 1.0 m above the ground)**

(b)
Time of flight:
$v_1 = -40.0$ m/s(sin 30.0°) = –20.0 m/s
$a = 9.8$ m/s²
$\Delta d = -2.0$ m
$\Delta t = ?$

$$\Delta d = v_1\Delta t + \tfrac{1}{2}a(\Delta t)^2$$

$$-2.0 = (-20.0)\Delta t + 4.9(\Delta t)^2$$

Solving the quadratic: $\Delta t = 0.10$ s (way up) and 3.98 s (way down)
**The fielder must run for 4.0 s in order to catch the ball.**

(c)
Horizontal range: $\Delta d = v\Delta t$ = 40.0 m/s(cos 30°)(3.98 s) = 138 m
The fielder must run a distance of: 138 m – 110.0 m = 28 m.

The speed of the fielder: $v = \dfrac{\Delta d}{\Delta t}$

$$= \frac{28\text{ m}}{3.98\text{ s}}$$

$$v = 7.0\text{ m/s}$$

**The fielder must run with an average speed of 7.0 m/s.**