Momentum and Energy

Multiple Choice

1. What is the minimum work done when a 65 kg student climbs an 8.0 m-high stairway in 12 s?

   A. 420 J
   B. 520 J
   C. 5 100 J
   D. 6 200 J

2. Which of the following is equal to impulse?

   A. Energy
   B. Momentum
   C. Change in energy
   D. Change in momentum

3. A 1.50×10^3 kg car travelling at 11.0 m/s collides with a wall as shown.

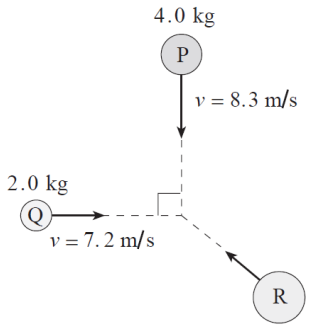
   The car rebounds off the wall with a speed of 1.3 m/s. If the collision lasts for 1.7 s, what force does the wall apply to the car during the collision?

   A. 8.6×10^3 N
   B. 1.1×10^4 N
   C. 1.5×10^4 N
   D. 1.8×10^4 N

4. A 1 500 kg car travelling at 25 m/s collides with a 2 500 kg van stopped at a traffic light. As a result of the collision the two vehicles become entangled. With what initial speed will the entangled mass move off, and is the collision elastic or inelastic?

	SPEED	TYPE OF COLLISION
A.	9.4 m/s	Elastic
B.	9.4 m/s	Inelastic
C.	15 m/s	Elastic
D.	15 m/s	Inelastic

5. Three objects travel as shown.



   What is the magnitude of the momentum of object R so that the combined masses remain stationary after they collide?

   A. 19 kg · m/s
   B. 30 kg · m/s
   C. 36 kg · m/s
   D. 48 kg · m/s

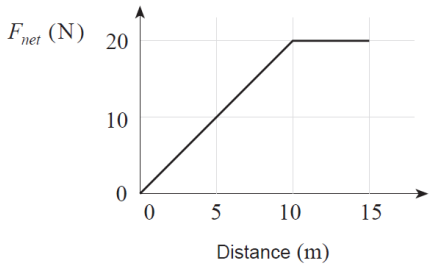
6. A change in kinetic energy is equivalent to

   A. work.
   B. power.
   C. impulse.
   D. momentum.

7. A 16 kg object is dropped from a height of 25 m and strikes the ground with a speed of 18 m/s. How much heat energy was produced during the fall?

A. 0 J
B. 1 300 J
C. 2 600 J
D. 3 900 J

8. A force is applied to an 8.0 kg object initially at rest. The magnitude of the net force varies with distance as shown.



What is the speed of the object after moving 15 m?

A. 5.0 m/s
B. 6.1 m/s
C. 7.1 m/s
D. 8.7 m/s

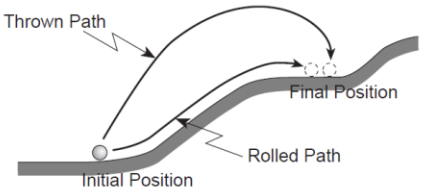
9. A machine rated at 1 500 W lifts a 100 kg object 36 m vertically in 45 s. What is the efficiency of this machine?

A. 0.053
B. 0.48
C. 0.52
D. 0.65

10. Two cars collide head-on and come to a complete stop immediately after the collision. Which of the following is correct?

	TOTAL MOMENTUM	TOTAL ENERGY
A.	is conserved	is conserved
B.	is conserved	is not conserved
C.	is not conserved	is conserved
D.	is not conserved	is not conserved

11. A child rolls a ball up a hill as shown. The same child then throws an identical ball up the hill.



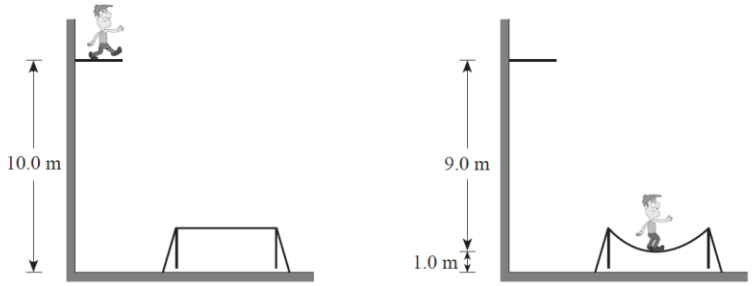
When both balls end up in the same location on the hill, which of the following correctly describes the potential energy change for each ball?

A. Both balls have the same potential energy change.
B. There is no potential energy change for either ball.
C. The thrown ball has a greater potential energy change than the rolled ball.
D. The thrown ball has a smaller potential energy change than the rolled ball.

12. A 950 kg elevator ascends a vertical height of 410 m with an average speed of 9.1 m/s. What average power must the lifting motor supply?

A. 8.6×10^{3} W
B. 8.5×10^{4} W
C. 4.2×10^{5} W
D. 3.8×10^{6} W

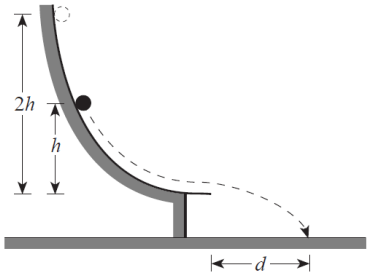
13. A 55.0 kg athlete steps off a 10.0 m high platform and drops onto a trampoline. As the trampoline stretches, it brings him to a stop 1.00 m above the ground.



How much energy must have been momentarily stored in the trampoline when he came to rest?

A. 0 J
B. 539 J
C. 4 850 J
D. 5 390 J

14. An object starts from rest and slides down a frictionless track as shown. It leaves the track horizontally, striking the ground at a distance d as shown.



The same object is now released from twice the height, $2h$. How far away will it land?

A. d
B. $\sqrt{2}\,d$
C. $2d$
D. $4d$

15. A crane lifts a 3 900 kg shipping container through a vertical height of 45 m in 8.0 s. What is the minimum average power that the crane motor must supply?

A. 2.7×10^{3} W
B. 7.7×10^{3} W
C. 2.1×10^{5} W
D. 1.7×10^{6} W

16. Identify momentum and kinetic energy as scalar or vector quantities.

	MOMENTUM	KINETIC ENERGY
A.	scalar	scalar
B.	scalar	vector
C.	vector	scalar
D.	vector	vector

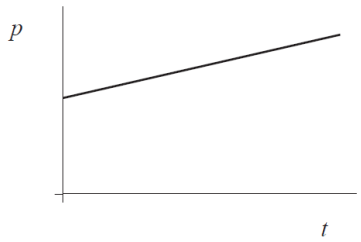
17. A 1.0 kg cart moves to the right at 6.0 m/s and strikes a stationary 2.0 kg cart. After the head-on collision, the 1.0 kg cart moves back to the left at 2.0 m/s and the 2.0 kg cart moves to the right at 4.0 m/s. In this collision

A. only momentum is conserved.
B. only kinetic energy is conserved.
C. both momentum and kinetic energy are conserved.
D. neither momentum nor kinetic energy is conserved.

18. A 12.0 kg shopping cart rolls due south at 1.50 m/s. After striking the bumper of a car, it travels at 0.80 m/s, 30° E of S. What is the magnitude of the change in momentum sustained by the shopping cart?

A. 8.4 kg · m/s
B. 9.7 kg · m/s
C. 11 kg · m/s
D. 27 kg · m/s

19. The graph below shows momentum, p, versus time, t, for a spacecraft while it is firing its rocket engines in space.



What does the slope of this graph represent?

A. the mass of the spacecraft
B. the velocity of the spacecraft
C. the net force on the spacecraft
D. the work done on the spacecraft

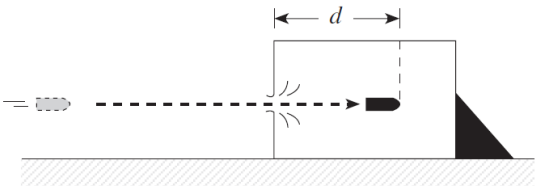
20. In order to use the joule as a unit of energy in an experiment, measurements must be converted to

A. cm, g and s
B. m, kg and s
C. cm, N and s
D. m, g and min

21. Which of the following best represents the work done by an adult in ascending a typical flight of stairs in a home?

A. 10^0 J
B. 10^1 J
C. 10^2 J
D. 10^3 J

22. A 0.055 kg bullet was fired at 250 m/s into a block of wood as shown in the diagram below.



Assuming an average force of 9 500 N brings the bullet to rest in the wood, what distance d did the bullet penetrate the block?

A. 1.4×10^{-3} m
B. 1.4×10^{-2} m
C. 1.8×10^{-1} m
D. 3.6×10^{-1} m

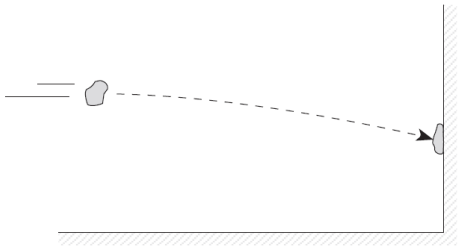
23. A 0.40 kg ball rolls at 8.5 m/s towards a player. The player kicks the ball so that it then travels at 15.2 m/s in the opposite direction. What is the magnitude of the impulse that the ball sustained?

A. 1.3 N · s
B. 2.7 N · s
C. 4.7 N · s
D. 9.5 N · s

24. Which of the following best represents efficiency?

A. Final time compared to initial time
B. Work output compared to work input
C. Final velocity compared to initial velocity
D. Momentum after compared to momentum before

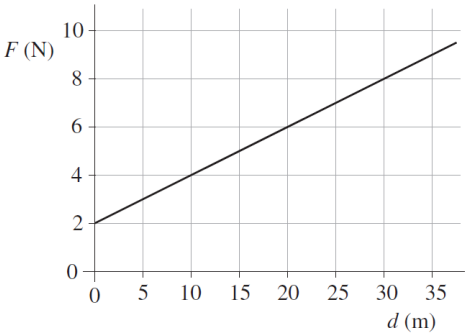
25. A wad of putty is thrown against a wall as shown. The wad of putty sticks against the wall.



Which of the following statements best applies the application of the law of conservation of energy to this collision?

A. All energy has been lost.
B. Kinetic energy is converted to heat.
C. Kinetic energy is converted to momentum.
D. Kinetic energy is converted to potential energy.

26. The graph below shows how the force applied to an object varies with distance.

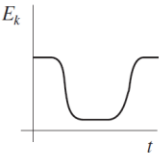


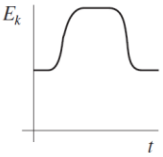
What is the work done to move the object from 10 m to 30 m?

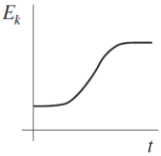
A. 40 J
B. 80 J
C. 120 J
D. 240 J

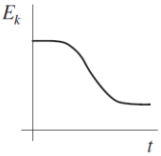
27. A projectile is fired through a fixed block of wood. The diagram shows the projectile above point P just before it enters the block and again above point Q just after leaving the block.

Which of the graphs best illustrates how the kinetic energy of the projectile varies over the time it takes to travel from P to Q?

A. 

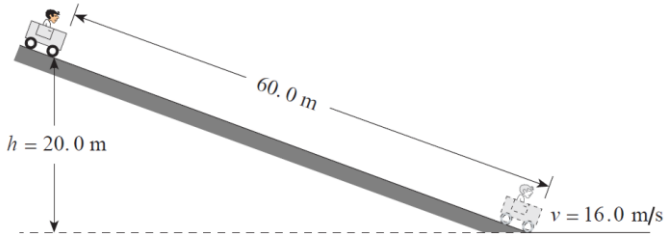
B. 

C. 

D. 

Written Response

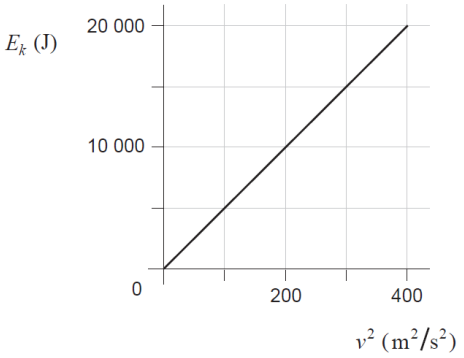
1. A 170 kg cart and rider start from rest on a 20.0 m high incline.



a) How much energy is transformed to heat? **(5 marks)**

b) What is the average force of friction acting on the cart? **(2 marks)**

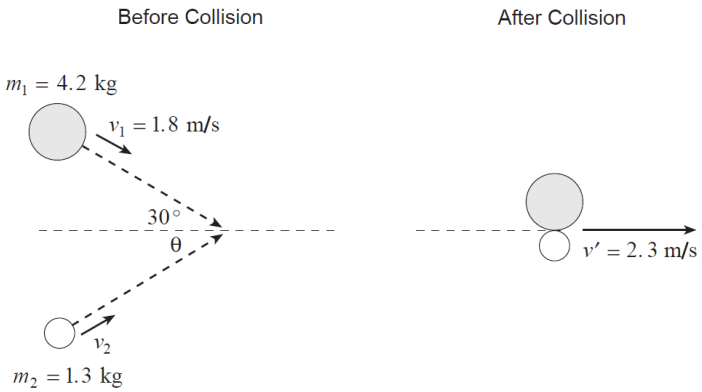
2. A student plots the graph below, showing the kinetic energy E_k of a motorbike versus the square of its velocity v^2.



a) What is the slope of this graph? **(2 marks)**

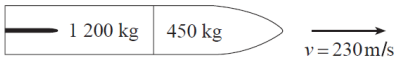
b) What does the slope represent? **(2 marks)**

3. Two steel pucks are moving as shown in the diagram. They collide inelastically.

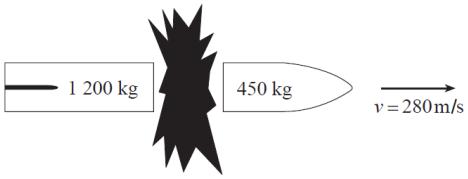


Determine the speed and direction (angle θ) of the 1.3 kg puck before the collision. **(7 marks)**

4. A space vehicle made up of two parts is travelling at 230 m/s as shown.



An explosion causes the 450 kg part to separate and travel with a final velocity of 280 m/s as shown.



a) What was the momentum of the space vehicle before the explosion? **(2 marks)**

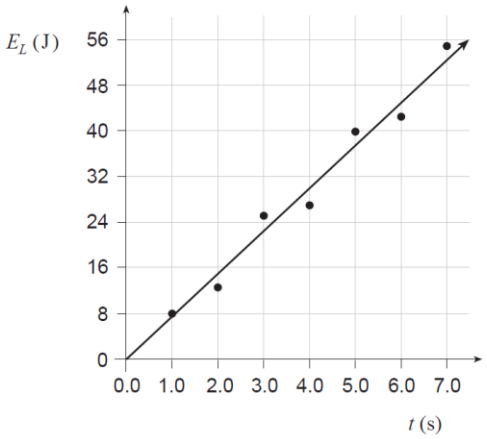
b) What was the magnitude of the impulse on the 1 200 kg part during the separation? **(3 marks)**

c) Using principles of physics, explain what changes occur, if any, to the

i) momentum of the system as a result of the explosion. **(2 marks)**

ii) kinetic energy of the system as a result of the explosion. **(2 marks)**

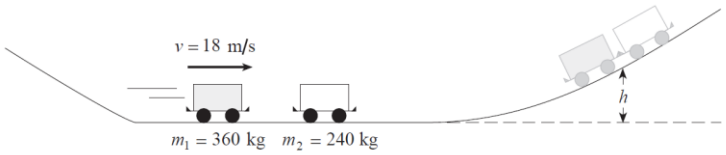
5. The graph shows the light energy E_L emitted by a bulb versus time t.



a) Find the power output of the bulb. **(2 marks)**

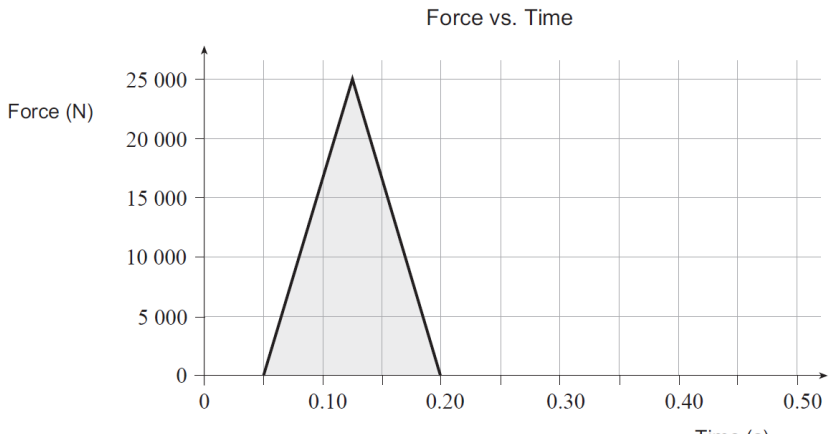
b) If this bulb is 20% efficient, find the power delivered to the bulb. **(3 marks)**

6. A 360 kg roller coaster car travelling at 18 m/s collides inelastically with a stationary 240 kg car on a section of horizontal track as shown in the diagram below.



To what maximum height, h, do the combined cars travel before rolling back down the hill? (Assume no friction.) **(7 marks)**

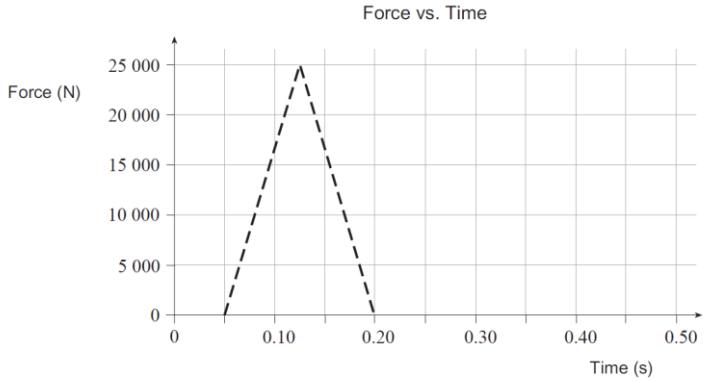
7. During a motor vehicle accident an unbelted passenger experienced a force which varied with time as shown on the graph.



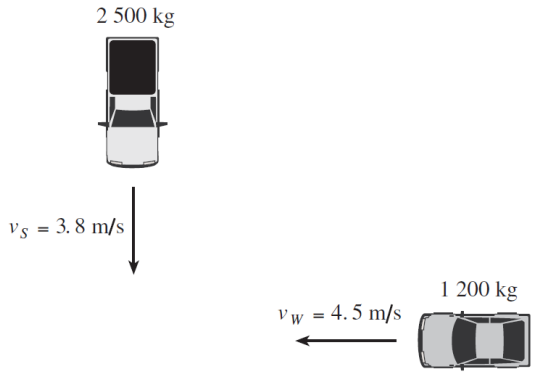
a) Calculate the area of the shaded region in the graph. **(1 mark)**

b) What does this area represent? **(2 marks)**

c) If the passenger was wearing a seatbelt properly, the maximum force would have been one third the force experienced without the seatbelt. Sketch on the graph below how the force on the belted passenger might have varied with time. **(2 marks)**



8. Sally is driving south in her 2 500 kg pickup truck at 3.8 m/s when she collides with Willy driving west in his 1 200 kg car at 4.5 m/s.



The two vehicles lock together and slide over the wet parking lot. Find the speed and direction of the damaged vehicles immediately after the collision. **(7 marks)**

9. A rocket motor, capable of generating a 24 N·s impulse, is attached to a stationary frictionless 3.0 kg cart. The rocket motor is ignited.

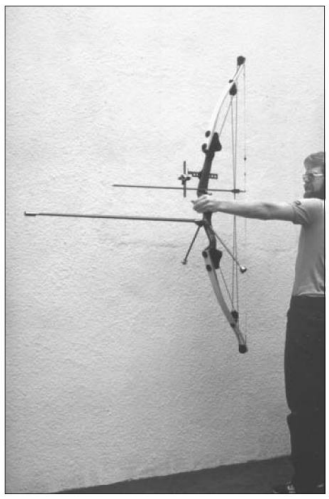
a) What will the velocity of the cart be immediately after the rocket motor burns out? **(3 marks)**

b) What is the resulting kinetic energy of the cart? **(2 marks)**

c) A frictionless cart of larger mass will end up with less kinetic energy when powered by an identical rocket motor. Using principles of physics, explain this result. **(4 marks)**

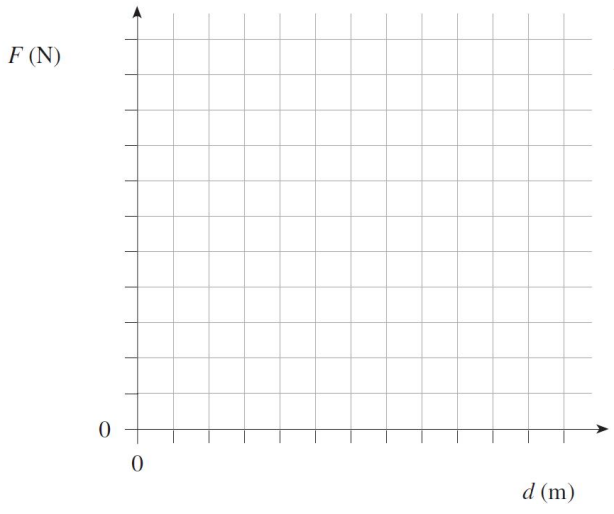
10.

As a compound bow was drawn back, the applied forces and displacements were recorded.



F (N)	0	31	65	84	122	160	186	180	175	184	180
d (m)	0	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50

a) Plot a force vs. displacement graph below. **(2 marks)**



b) How much energy was stored in this compound bow?

Answers

MC

1. C
2. D
3. B
4. B
5. C
6. A
7. B
8. C
9. C
10. A
11. A
12. B
13. C
14. B
15. C
16. C
17. C
18. C
19. C
20. B
21. D
22. C
23. D
24. B
25. B
26. C
27. D

WR

1. How much energy is transformed to heat? **(5 marks)**

$$\Delta E = 0$$

$$Ep = E_k + Heat \quad \leftarrow \textbf{2 marks}$$

$$mgh = \tfrac{1}{2}mv^2 + Heat \quad \leftarrow \textbf{1 mark}$$

$$170(9.8)20.0 = \tfrac{1}{2}(170)16.0^2 + E_h \quad \leftarrow \textbf{1 mark}$$

$$33\,320 = 21\,760 + E_h$$

$$1.16\times10^4 \text{ J} = E_h \quad \leftarrow \textbf{1 mark}$$

b) What is the average force of friction acting on the cart? **(2 marks)**

E_h = work done by friction

$$11560 = F_f \cdot d$$

$$\therefore F_f = \frac{11\,560}{60.0}$$

$$F_f = 193 \text{ N}$$

$F_f = 190$ N ← **2 marks**

2. a) What is the slope of this graph? **(2 marks)**

$$slope = \frac{\Delta E_k}{\Delta v^2}$$

$$= \frac{20\,000 \text{ J}}{400 \text{ m}^2/\text{s}^2}$$

$$= 50 \text{ J}/\text{m}^2/\text{s}^2 \quad \leftarrow \textbf{2 marks}$$

or 50 kg

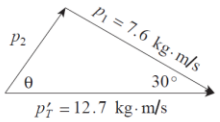
b) What does the slope represent? **(2 marks)**

From the graph: $E_k = kv^2$, $\therefore \left(E_k = 50\,v^2\right)$ ← **1 mark**

But $E_k = \tfrac{1}{2}mv^2$, **therefore the slope represents one half the mass of the motorbike.** ← **1 mark**

3.

Determine the speed and direction (angle θ) of the 1.3 kg puck before the collision. **(7 marks)**



$$p_1 = m_1 v_1$$
$$= 4.2 \times 1.8$$
$$= 7.6 \text{ kg·m/s}$$
$$p'_T = m_T v'_1$$
$$= 5.5 \times 2.3$$
$$= 12.7 \text{ kg·m/s}$$
← **1 mark**

Method 1:

Cosine Law:

$$p_2^2 = (p'_T)^2 + p_1^2 - 2p'_T p_1 \cos 30°$$
$$= 12.7^2 + 7.6^2 - 2 \times 12.7 \times 7.6 \times \cos 30°$$
$$p_2^2 = 51.9$$
$$p_2 = \sqrt{51.9} = 7.20 \text{ kg m/s}$$ ← **3 marks**
$$v_2 = \frac{p_2}{m_2} = \frac{7.20 \text{ kg m/s}}{1.3 \text{ kg}} = 5.5 \text{ m/s}$$ ← **1 mark**

Sine Law:

$$\frac{\sin\theta}{7.6} = \frac{\sin 30°}{7.2}$$
$$\sin\theta = \frac{7.6 \times \sin 30°}{7.2}$$
$$\sin\theta = 0.528$$
$$\theta = 32°$$
← **2 marks**

$$v_2 = 5.5 \text{ m/s at } 32°$$

Method 2: **(one variation)**

$$m_1 v_1 \cos 30° + m_2 v_2 \cos\theta = m_T v'$$ ← **1 mark**
$$4.2(1.8)\cos 30° + 1.3(v_2)\cos\theta = (4.2 + 1.3)(2.3)$$ ← **1 mark**
$$v_2 = \frac{4.69}{\cos\theta}$$ ← **1 mark**
$$m_1 v_1 \sin 30° + m_2 v_2 \sin\theta = 0$$ ← **1 mark**
$$4.2(1.8)\sin 30° + 1.3(v_2)\sin\theta = 0$$ ← **1 mark**
$$v_2 = \frac{2.91}{\sin\theta}$$
$$\frac{4.69}{\cos\theta} = \frac{2.91}{\sin\theta}$$
$$\frac{\sin\theta}{\cos\theta} = \frac{2.91}{4.69}$$
$$\tan\theta = 0.618$$
$$\theta = 32°$$
← **1 mark**

$$v_2 = \frac{4.69}{\cos 31.8}$$
$$v_2 = 5.5 \text{ m/s}$$
← **1 mark**

4.

a) What was the momentum of the space vehicle before the explosion? **(2 marks)**

$$p = mv$$
$$= (1\,200 + 450)230$$
$$= 3.8 \times 10^5 \text{ kg m/s}$$ ← **2 marks**

b) What was the magnitude of the impulse on the 1 200 kg part during the separation? **(3 marks)**

$$Impulse = \Delta p$$
$$= P_b - P_a$$ ← **1 mark**
$$= (450 \times 280) - (450 \times 230)$$ ← **1 mark**
$$= 2.3 \times 10^4 \text{ N·s}$$ ← **1 mark**

c) Using principles of physics, explain what changes occur, if any, to the
i) momentum of the system as a result of the explosion. **(2 marks)**

In an explosion, momentum must be conserved.

ii) kinetic energy of the system as a result of the explosion. **(2 marks)**

Since the explosion adds energy to the system, the system will gain kinetic energy.

5.

a) Find the power output of the bulb. **(2 marks)**

$P = \frac{\Delta E}{\Delta t}$ ← **1 mark**

$\cong 7.6$ W ← **1 mark**

b) If this bulb is 20% efficient, find the power delivered to the bulb. **(3 marks)**

$\frac{P_{out}}{P_{in}} = 0.20$

$\frac{7.6}{P_{in}} = 0.20$

$P_{in} \cong 38$ W ← **3 marks**

6.

$V_{combined} = \frac{m_1 v_1}{m_1 + m_2}$

$= \frac{360 \cdot 18}{360 + 240}$

$= 10.8$ m/s ← **3 marks**

$E_{k\,combined} = \frac{1}{2} m v^2$

By conservation of energy:

$mgh = \frac{1}{2} m v^2$ ← **2 marks**

$\therefore h = \frac{v^2}{2g}$

$= \frac{(10.8)^2}{2 \cdot 9.8}$

$= 5.95$ m

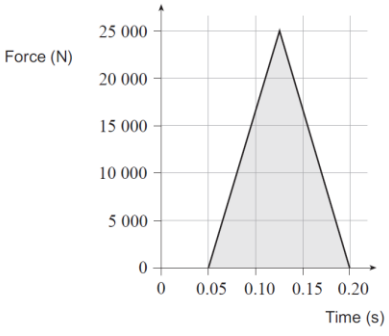
$= 6.0$ m ← **2 marks**

7.

a) Calculate the area of the shaded region in the graph. **(1 mark)**

two triangles: $(0.075 \times 25\,000) = 1\,875$ N·s

$= 1\,900$ N·s ← **1 mark**



b) What does this area represent?

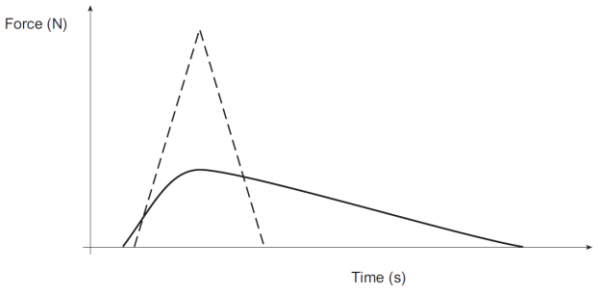
Impulse or change in momentum

c) If the passenger was wearing a seatbelt properly, the maximum force would have been one third the force experienced without the seatbelt. Sketch on the graph below how the force on the belted passenger might have varied with time. **(2 marks)**

peak $\approx \frac{1}{3}(25\,000) \approx 8\,000$ N ← **1 mark**

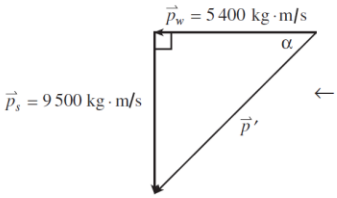
(but for a longer period of time)

area should be (about) the same ← **1 mark**



8.

The two vehicles lock together and slide over the wet parking lot. Find the speed and direction of the damaged vehicles immediately after the collision. **(7 marks)**



← **1 mark for momentums**

$(p')^2 = 5\,400^2 + 9\,500^2$ ← **1 mark for addition**

$p' = 10\,900$ kg·m/s ← **2 marks for pythagorus**

$v' = \dfrac{10\,900}{(2\,500 + 1\,200)} = 3.0$ m/s ← **1 mark for dividing by 3700**

$\tan\alpha = \dfrac{9\,500}{5\,400}$

$\alpha = 60°$ ← **1 mark**

$v' = 3.0$ m/s, 60° S of W ← **1 mark**

9.

a) What will the velocity of the cart be immediately after the rocket motor burns out? **(3 marks)**

$Impulse = m\Delta v$ ← **1 mark**

$24 = 3.0\Delta v \qquad \therefore \Delta v = 8.0$ m/s

The final velocity of the 3.0 kg cart is 8.0 m/s. ← **2 marks**

b) What is the resulting kinetic energy of the cart?

$E_k = \frac{1}{2}mv^2$

$= \frac{1}{2}\cdot 3.0\cdot(8.0)^2$ ← **1 mark**

$= 96$ J ← **1 mark**

c) A frictionless cart of larger mass will end up with less kinetic energy when powered by an identical rocket motor. Using principles of physics, explain this result. **(4 marks)**

2 marks → Work is done on both carts. However, the lighter cart is travelling faster while the force is being applied

2 marks → and therefore more work is being done on it while it travels the greater distance.

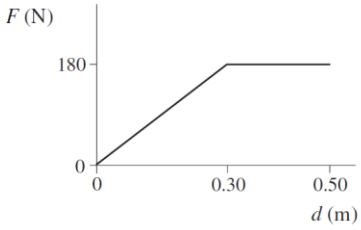
OR

2 marks → The velocity change of each cart is inversely related to its mass. The heavier cart therefore has a smaller velocity change.

2 marks → The v^2 term will therefore dominate in the final kinetic energy.

10.

a) Plot a force vs. displacement graph below. **(2 marks)**



b) How much energy was stored in this compound bow? **(3 marks)**

$Energy = W = area$

$27 + 36 \approx 63$ J