Phys116A - Fall 2008
Regular Solutions

MC ________ 11 ________ 12 ________ Raw Score ________ Final Percentage ________%

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. Write your answer at the right. (2 points each)

1) Which of the following is a FALSE statement? 1) B

A) In a transverse wave the particle motion is perpendicular to the velocity vector of the wave.
B) Waves transport energy and matter from one region to another.
C) A wave in which particles move back and forth in the same direction as the wave is moving is called a longitudinal wave.
D) Not all waves are mechanical in nature.
E) The speed of a wave and the speed of the vibrating particles that constitute the wave are different entities.

The particles in a wave oscillate back and forth, but their average displacement is zero. Therefore, waves cannot transport matter.

2) A 910-kg object is released from rest at an altitude of 1200 km above the north pole of the earth. Ignore atmospheric friction. The speed of the object as it strikes the surface of the earth, in km/s, is closest to: 2) A

A) 4.4 B) 3.2 C) 2.7 D) 4.8 E) 2.2

$r_E = 6.38\times10^{6}\,m$

$r_0 = r_E + 1200\times10^{3}\,m = 7.58\times10^{6}\,m$

$U = \frac{Gm_1m_2}{r}$

$\Delta U = Gm_Em_2\left(\frac{1}{r_E} - \frac{1}{r_0}\right)$

$= (6.67\times10^{-11}\,\frac{Nm^2}{kg^2})(5.97\times10^{24}\,kg)(910\,kg)\left(\frac{1}{6.38\times10^{6}\,m} - \frac{1}{7.58\times10^{6}\,m}\right)$

$= 8.99\times10^{9}\,J$

$\frac{1}{2}mv^2 = \Delta U$

$v = \sqrt{\frac{2\Delta U}{m}} = \sqrt{\frac{2(8.99\times10^{9}\,J)}{910\,kg}} = 4.4\,km/s$

3) A violinist is trying to tune his string to 440 Hz. If his string is currently vibrating at a frequency of 448.4 Hz, and has a tension of 200 N, what should he make the tension in order to bring the string into tune? 3) B

A) 204 N B) 193 N C) 196 N D) 202 N E) 198 N

$v = f\lambda = \sqrt{\frac{T}{\mu}}$

$T = \mu f^2 \lambda^2$

$T_1 = \mu f_1^2 \lambda^2$

$T_2 = \mu f_2^2 \lambda^2$

$\frac{T_1}{T_2} = \frac{f_1^2}{f_2^2}$

$T_2 = \frac{T_1 f_2^2}{f_1^2} = 200N \left(\frac{440 Hz}{448.4 Hz}\right)^2$

$= 193 N$

4) If both the mass of a simple pendulum and its length are doubled, the period will 4) D

A) increase by a factor of 2.
B) be unchanged.
C) increase by a factor of 4.
D) increase by a factor of 1.4
E) increase by a factor of 0.71.

For a simple pendulum

$T = \frac{1}{2\pi}\sqrt{\frac{l}{g}}$

doesn't depend on mass

$T' = \frac{1}{2\pi}\sqrt{\frac{2l}{g}}$

$= \frac{1}{2\pi}\sqrt{2}\sqrt{\frac{l}{g}}$

$= T\sqrt{2}$

5) A satellite in a circular orbit of radius R around planet X has an orbital period T. If Planet X had one-fourth as much mass, the orbital period of this satellite in an orbit of the same radius would be: 5) D

A) $T/4$ B) $T\sqrt{2}$ C) $4T$ D) $2T$ E) $T/2$

To derive the relationship between period and mass

$F = \frac{G m_x \cancel{m_s}}{r^2} = \frac{\cancel{m_s} v^2}{\cancel{r}}$

$v = \sqrt{\frac{G m_x}{r}}$

$T = \frac{d}{v} = 2\pi r \sqrt{\frac{r}{G m_x}}$

$= \frac{2\pi r^{3/2}}{\sqrt{G m_x}}$

$T' = \frac{2\pi r^{3/2}}{\sqrt{\frac{1}{4} G m_x}}$

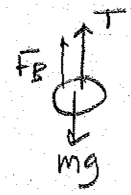
$= \frac{\sqrt{4}\, 2\pi r^{3/2}}{\sqrt{G m_x}}$

$= 2\left(\frac{2\pi r^{3/2}}{\sqrt{G m_x}}\right)$

$= 2T$

6) A 7.5-kg solid sphere, made of metal whose density is 2400 kg/m^3, is suspended by a cord. When the sphere is immersed in a liquid of unknown density, the tension in the cord is 18 N. The density of the liquid is closest to: 6) C

A) 1300 kg/m^3
B) 1700 kg/m^3
C) 1800 kg/m^3
D) 1400 kg/m^3
E) 1600 kg/m^3



$$T + F_B = mg$$

$$T + \rho_{liq} g V = mg$$

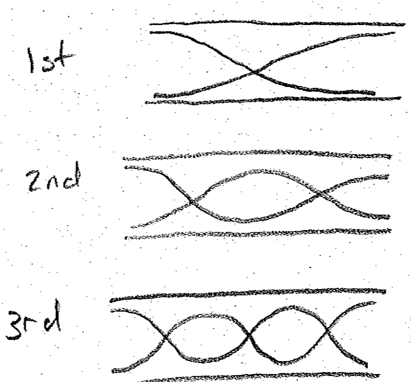
$$\rho_\ell = \frac{mg - T}{gV}$$

$$V = \frac{m_s}{\rho_s}$$

$$\rho_\ell = \frac{(7.5\,\text{kg})(9.8\,\text{m/s}^2) - 18\,\text{N}}{(9.8\,\text{m/s}^2)(7.5\,\text{kg})/(2400\,\text{kg/m}^3)} = 1812\,\text{kg/m}^3$$

7) A pipe open on bth ends, 0.64 m long, vibrates in the second overtone (i.e., third longest wavelength) with a frequency of 848 Hz. In this situation, the speed of sound in air, in SI units, is closest to: 7) B

A) 368 B) 362 C) 344 D) 350 E) 356



$L = \frac{\lambda}{2}$

$L = \lambda$

$L = \frac{3}{2}\lambda \rightarrow \lambda = \frac{2L}{3}$

$$v = f\lambda = \frac{2fL}{3} = \frac{2}{3}(848\,\text{Hz})(0.64\,\text{m}) = 361.8\,\text{m/s}$$

8) Three tuning forks are available. Fork *A* produces a 440 Hz tone. The other forks are marked X and Y. 8) A

The frequency of fork X is less than the frequency of fork Y.
When forks *A* and X are sounded together, a beat frequency of 4 Hz is heard.
For forks *A* and Y, the beat frequency is 7 Hz.
For forks X and Y, the beat frequency is 3 Hz.

The frequencies of forks X and Y, respectively, in SI units, are closest to:

A) 444 and 447
~~B) 444 and 433~~
~~C) 436 and 447~~
~~D) 447 and 444~~
~~E) 436 and 433~~

$X < Y$
$|440 - X| = 4$
$|440 - Y| = 7$
$|X - Y| = 3$

use these for conditions to eliminate answer choices

9) For an object undergoing simple harmonic motion, 9) D

A) the maximum potential energy is larger than the maximum kinetic energy.
B) the total energy oscillates at frequency $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$.
C) the displacement is greatest when the speed is greatest.
D) the acceleration is greatest when the displacement is greatest.
E) the acceleration is greatest when the speed is greatest.

A) No, $P_{max} = K_{max} = E_{tot}$

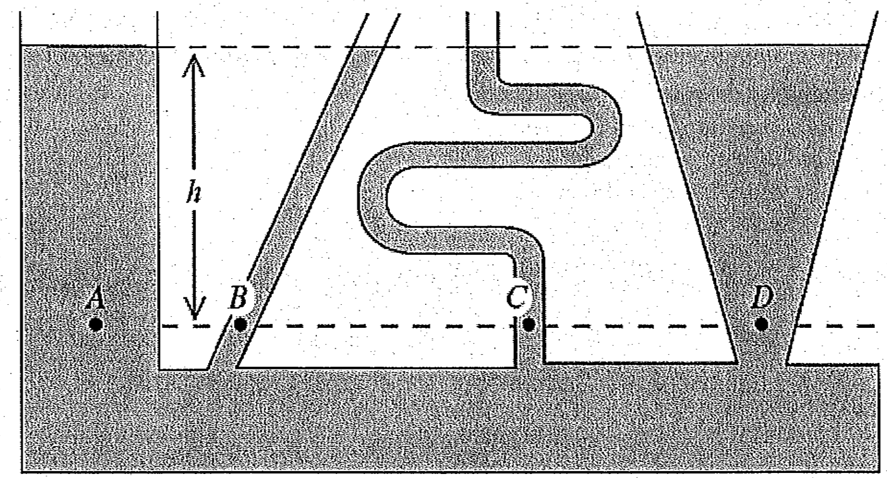
B) No, K and P oscillate but the total energy is constant

C) No, when the displacement is greatest the speed is zero
ex: $x = \sin(\omega t)$, $v = \omega\cos(\omega t)$

D) Yes, ex: $x = \sin(\omega t)$ $a = \frac{d^2x}{dt} = -\omega^2\sin(\omega t)$

E) No, compare C and D

Figure 14.5



10) In Fig. 14.5, fluid fills the container shown here. At which of the indicated points is the pressure greatest? 10) E

A) A
B) B
C) C
D) D
E) The pressure is the same at each of the labeled points.

The pressure below a column of fluid depends only on the height of the fluid.

FREE RESPONCE. Write your answer in the space provided. Show your work for partial credit, but make sure your final answer is clear. (10 points each)

11) An object of mass 6.8 kg is attached to a spring of force constant 1780 N/m. The object is set into simple harmonic motion, with an initial velocity of $v_0 = 3.2$ m/s and an initial displacement of $x_0 = 0.14$ m.
   (a) What is the total energy of the mass–spring system?
   (b) What is the maximum displacement of the mass?
   (c) What is the maximum velocity of the mass?
   (d) What is the maximum acceleration of the mass?

(a) $E = K + U = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}(6.8kg)(3.2\,m/s)^2 + \frac{1}{2}(1780\,\frac{N}{m})(0.14m)^2$

$= \boxed{52.3\,J}$

(b) At maximum displacement, all energy is potential

$E = \frac{1}{2}kx_{max}^2$

$x_{max} = \sqrt{\frac{2E}{k}} = \sqrt{\frac{2(52.3J)}{1780\,N/m}} = \boxed{0.24m}$

(c) At maximum velocity, all energy is kinetic

$E = \frac{1}{2}mv_{max}^2$

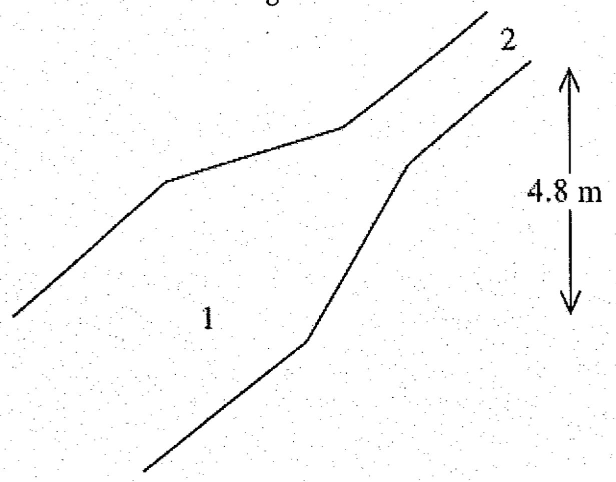
$v_{max} = \sqrt{\frac{2E}{m}} = \sqrt{\frac{2(52.3J)}{6.8kg}} = \boxed{3.92\,m/s}$

(d) $F_{max} = |kx_{max}|$

$= (1780\,N/m)(0.24m) = 427\,N$

$a_{max} = \frac{F_{max}}{m} = \frac{427N}{6.8kg} = \boxed{63\,m/s^2}$

Figure 14.7



12) In Fig. 14.7, water (density 1000 kg/m^3) is flowing in a pipeline. At point 1 the water velocity is 4.7 m/s. Point 2 is 6.8 m above point 1. The cross-sectional area of the pipe is $0.06\ m^2$ at point 1 and $0.020\ m^2$ at point 2.
(a) What is the velocity of the water at point 2?
(b) What is the pressure difference $p_1 - p_2$ between points 1 and 2?

(a) $A_1 v_1 = A_2 v_2$

$$v_2 = v_1 \frac{A_1}{A_2} = (4.7\,m/s)\left(\frac{.06\,m^2}{.02\,m^2}\right) = \boxed{14.1\,m/s}$$

(b) $$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

$$p_1 - p_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) + \rho g(h_2 - h_1)$$

$$= \frac{1}{2}\left(1000\,\frac{kg}{m^3}\right)\left[\left(14.1\,\frac{m}{s}\right)^2 - \left(4.7\,\frac{m}{s}\right)^2\right] + \left(1000\,\frac{kg}{m^3}\right)\left(9.8\,\frac{m}{s^2}\right)(4.8\,m)$$

$$= 135{,}400\,Pa$$

$$= \boxed{135\,kPa}$$

Phys 116A - Fall 2008

Alternate Solutions

MC ________ 11 ________ 12 ________ Raw Score ________ Final Percentage ________%

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. Write your answer at the right. (2 points each)

1) A satellite of mass m has an orbital period T when it is in a circular orbit of radius R around the Earth. If the satellite instead had mass $4m$, its orbital period would be: 1) A

A) T B) $4T$ C) $T/4$ D) $2T$ E) $T/2$

You could derive the expression for orbital period

$$F = \frac{G m_E \cancel{m_s}}{r^2} = \frac{\cancel{m_s} v^2}{r}$$

but since the mass of the satellite cancels, you can stop here.

2) At a given point above the surface of the earth, the gravitational acceleration is equal to 6.4 m/s^2. The altitude of this point, above the surface of the earth, in km, is closest to: 2) D

A) 2800 B) 4700 C) 1900 D) 1500 E) 3900

$$\cancel{m}a = \frac{G m_E \cancel{m}}{r^2}$$

$$r = \sqrt{\frac{G m_E}{a}} = \sqrt{\frac{(6.67\times10^{-11}\,Nm^2/kg^2)(5.97\times10^{24}\,kg)}{6.4\,m/s^2}} = 7.9\times10^6\,km$$

→ above surface $= (7.9\times10^6\,km) - (6.38\times10^6\,m) = 1500\,km$

3) A mass at the end of an ideal spring vibrates with period T. If you double the mass, by what factor must you change the force constant of the spring so that the period of vibration will now be $2T$? 3) A

A) Decrease it by a factor of 2.

B) Increase it by a factor of 2.

C) Decrease it by a factor of 4.

D) Increase it by a factor of $\sqrt{2}$.

E) Decrease it by a factor of $\sqrt{2}$.

$$T = \frac{1}{2\pi}\sqrt{\frac{m}{k}}$$

$$T' = \frac{1}{2\cancel{\pi}}\sqrt{\frac{2m}{k'}} = 2T = \frac{1}{\cancel{\pi}}\sqrt{\frac{m}{k}}$$

$$\frac{1}{2}\sqrt{\frac{2\cancel{m}}{k'}} = \sqrt{\frac{\cancel{m}}{k}}$$

$$\frac{2}{4}\frac{1}{k'} = \frac{1}{k}$$

$$k' = \frac{1}{2}k$$

4) For an object undergoing simple harmonic motion,

A) the displacement is greatest when the speed is greatest.

B) the acceleration is greatest when the displacement is greatest.

C) the maximum potential energy is larger than the maximum kinetic energy.

D) the total energy oscillates at frequency $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$.

E) the acceleration is greatest when the speed is greatest.

4) B

Remember that the total energy is constant

5) The Bernoulli effect is described by the equation

$p_1 + 1/2\rho v^2{}_1 + \rho g h_1 = p_2 + 1/2\rho v^2{}_2 + \rho g h_2$

The origin of this relation is that it is a statement of

A) the conservation of energy for a moving fluid.

B) the continuity principle for fluids.

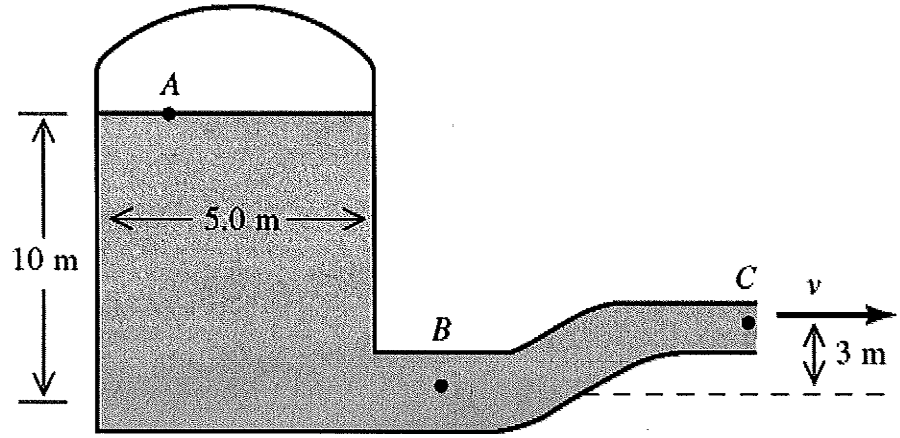
C) Newton's Third Law, i.e equal action and reaction.

D) the conservation of linear momentum.

E) $F = ma$ as applied to a fluid.

5) A

Figure 14.3



6) A pressurized cylindrical tank, 5.0 m in diameter, contains water which emerges from the pipe at point C, with a velocity of 34 m/s. The atmospheric pressure at point C is 101kPa. Point *A* is 10 m above point *B* and point C is 3 m above point *B*. The area of the pipe at point *B* is 0.06 m^2 and the pipe narrows to an area of 0.01 m^2 at point C. Assume the water is an ideal fluid in laminar flow. The density of water is 1000 kg/m^3. In Fig. 14.3, the air pressure (absolute) in the tank above the water, in kPa, is closest to: 6) C

A) 760 B) 560 C) 620 D) 790 E) 690

Don't worry about point B

$V_1 A_1 = V_2 A_2$

$V_1 = (34 m/s) \frac{0.01 m^2}{\pi (2.5 m)^2} = 0.017 m/s$

you can neglect this

$P_A + \frac{1}{2}\rho v_A^2 + \rho g h_A = P_B + \frac{1}{2}\rho v_B^2 + \rho g h_B$

$P_A = P_B + \frac{1}{2}\rho(v_B^2 - v_A^2) + \rho g(h_B - h_A)$

$= (101 \times 10^3 Pa) + \frac{1}{2}(1000 kg/m^3)(34 m/s)^2 + (100 kg/m^3)(9.8 m/s^2)(-7m$

$= 610 kPA$

7) Which of the following is a FALSE statement? 7) E

A) The speed of a wave and the speed of the vibrating particles that constitute the wave are different entities.

B) In a transverse wave the particle motion is perpendicular to the velocity vector of the wave.

C) Not all waves are mechanical in nature.

D) A wave in which particles move back and forth in the same direction as the wave is moving is called a longitudinal wave.

E) Waves transport energy and matter from one region to another.

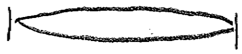
Particles in a wave oscillate back and forth, ie, they have no net displacement.

8) What is the frequency of the fundamental mode of vibration of a steel piano wire stretched to a tension of 440 N? The wire is 0.600 m long and has a mass of 5.60 grams. 8) E

A) 234 Hz B) 312 Hz C) 517 Hz D) 366 Hz E) 181 Hz

$V = \sqrt{\frac{T}{\mu}} = f\lambda$

$f = \frac{1}{2L}\sqrt{\frac{T}{m/L}} = \frac{1}{2(.6m)}\sqrt{\frac{440N}{(.00560kg)/(.6m)}} = 181\,Hz$



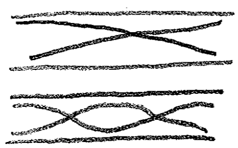
$\lambda = 2L$

9) A pipe open at both ends, 0.46 m long, vibrates in the second overtone (i.e., third longest wavelength) with a frequency of 1200 Hz. In this situation, the distance from the center of the pipe to the nearest displacement antinode, in cm, is closest to: 9) B

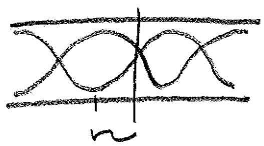
A) 15 B) 7.7 C) 3.8 D) 12 E) zero

1st

2nd



3rd



$\sim \frac{L}{6}$

$\frac{46cm}{6} = 7.7cm$

Displacement waves

10) Three tuning forks are available. Fork *A* produces a 440 Hz tone. The other forks are marked *X* and *Y*. The frequency of fork *Y* is less than the frequency of fork *X*. When forks *A* and *X* are sounded together, a beat frequency of 4 Hz is heard. For forks *A* and *Y*, the beat frequency is 7 Hz. For forks *X* and *Y*, the beat frequency is 3 Hz. The frequencies of forks *X* and *Y*, respectively, in SI units, are closest to: 10) B

~~A) 444 and 447~~
B) 436 and 433
~~C) 436 and 447~~
~~D) 444 and 433~~
~~E) 447 and 444~~

$Y < X$

$|440 - X| = 4$

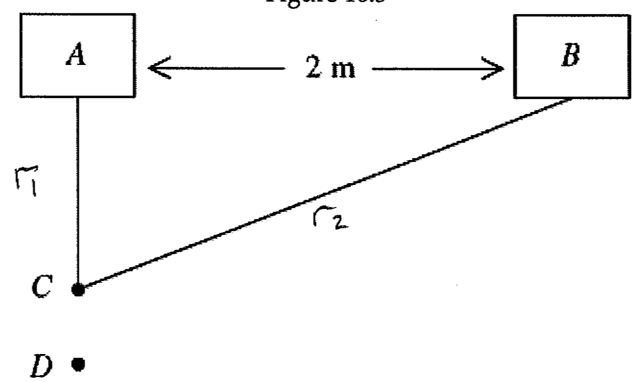
$|440 - Y| = 7$

$|X - Y| = 3$

use these conditions to eliminate answer choices

FREE RESPONSE. Write your answer in the space provided. Show your work for partial credit, but make sure your final answer is clear. (10 points each)

Figure 16.3



11) In Fig. 16.3, two identical loudspeakers, *A* and *B*, driven by the same amplifier, are separated by 2.00 m and produce sound waves of the same frequency. Point *C* is 3.00 m from speaker *A* along the line perpendicular to the line connecting the two speakers. Point D is 4.50 m from speaker A, along the same line as point C. The speed of sound is 344 m/s.

(a) Find the lowest frequency at which destructive interference occurs at Point C.
(b) Find the lowest frequency at which constructive interference occurs at Point D.
(c) Find the lowest frequency at which constructive interference occurs at both points.

(a) Destructive interference occurs when the paths differ by $(n+\frac{1}{2})$ wavelengths

$r_2 = \sqrt{(2m)^2 + (3m)^2} = 3.61m$

$r_1 = 3m$

$\Delta r_C = 0.606m$

For lowest frequency $n = 1$

$\Delta r_C = \frac{\lambda}{2} \Rightarrow \lambda = 2\Delta r_C = 1.21m$

$f = \frac{v}{\lambda} = \frac{344m/s}{1.21m} = \boxed{284\,Hz}$

(b) Constructive interference occurs when the paths differ by n wavelengths

$r_2 = \sqrt{(2m)^2 + (4.5m)^2} = 4.92$

$r_1 = 4.5m$

$\Delta r_D = 0.424m = \lambda$

$f = \frac{v}{\lambda} = \frac{344m/s}{0.424m} = \boxed{810\,Hz}$

Constructive interference at both points means

$\Delta r_C = n\lambda$ where n and m are integers
and
$\Delta r_D = m\lambda$

$\frac{\Delta r_C}{\Delta r_D} = \frac{n}{m}$ unfortunately, there are no integer values for n and m that satisfy this exactly.

12) An 75 kg astronaut is standing on the surface of the moon that has a radius $R = 1.74 \times 10^6$ m and a mass $m = 7.35 \times 10^{22}$ kg. An experiment is planned where a projectile needs to be launched straight up from the surface.

(a) What is the weight of the astronaut?

(b) What does the initial speed of the projectile need to be for it to reach a height of 2.55×10^6 m above the moon's surface?

(c) What does the initial speed of the projectile need to be for it to escape the moon's gravitational pull entirely?

(a) weight is the force of gravity at the surface

$$F_G = \frac{G m_1 m_2}{r^2} = \frac{(6.67\times10^{-11} N \frac{m^2}{kg^2})(7.35\times10^{22} kg)(75 kg)}{(1.74\times10^6 m)^2} = \boxed{121 N}$$

by comparison, weight on Earth would be

$$w = mg = (75 kg)(9.8 m/s^2) = 735 N$$

(b) Initial kinetic energy = change in potential energy

$$\frac{1}{2} m v^2 = U_{final} - U_{initial}, \quad r_{final} = (2.55\times10^6 m) + (1.74\times10^6 m) = 4.29\times10^6 m$$

$$\frac{1}{2} \cancel{m} v^2 = -G m_{moon} \cancel{m} \left(\frac{1}{r_{final}} - \frac{1}{r_{initial}}\right)$$

$$\frac{1}{2} v^2 = -G m_{moon} \left(\frac{1}{4.29\times10^6 m} - \frac{1}{1.74\times10^6 m}\right)$$

$$v = \boxed{1830 \text{ m/s}}$$

(c) same thing, but $r_{final} \to \infty$ (ie, escape velocity)

$$\frac{1}{2} v^2 = -G m_{moon} \left(0 - \frac{1}{r_{initial}}\right)$$

$$v = \sqrt{\frac{2 G m_{moon}}{r_{initial}}} = \boxed{2370 \text{ m/s}}$$